# Appendix H

# SACFEM2013 Manual

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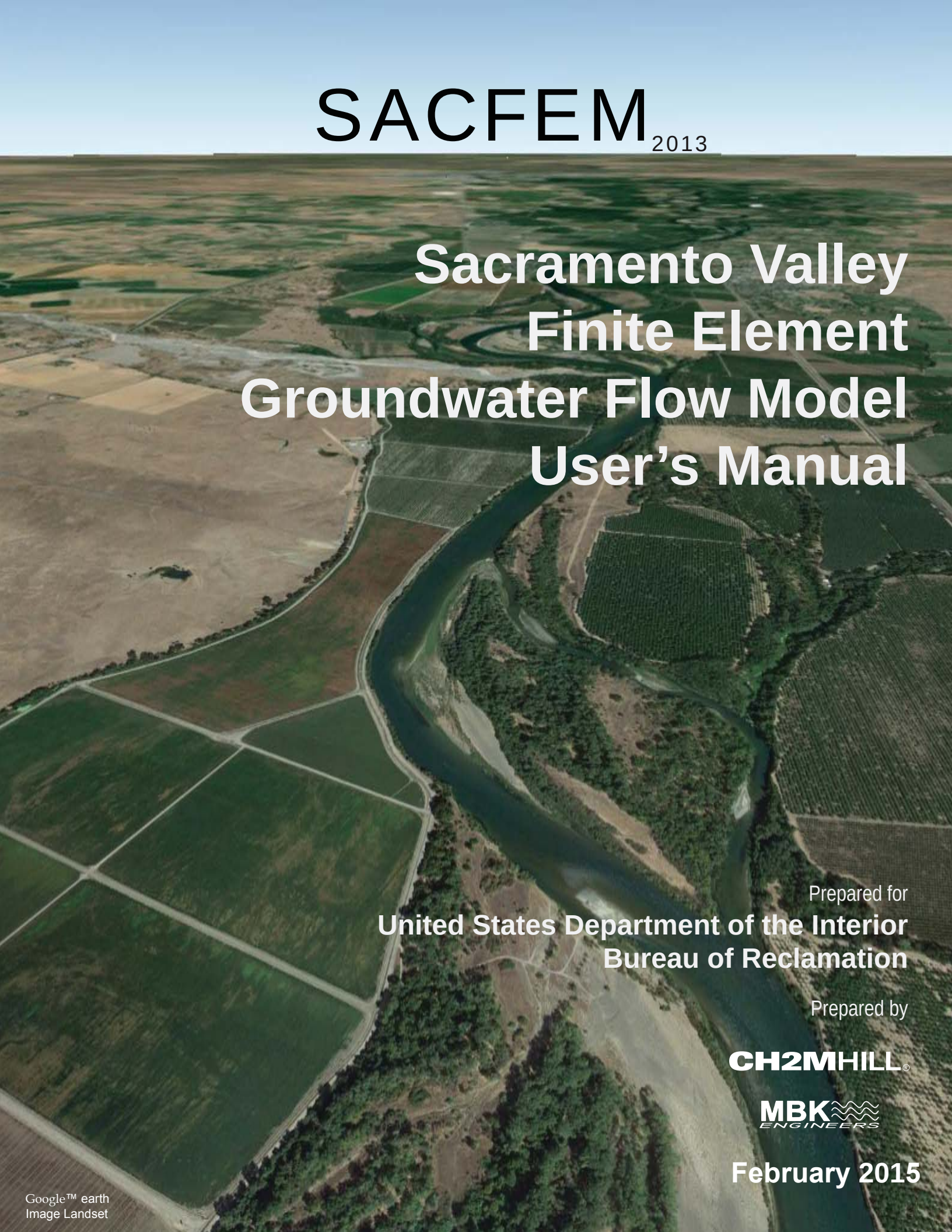
# SACFEM2013

# Sacramento Valley Finite Element Groundwater Flow Model User's Manual



Prepared for

**United States Department of the Interior**
**Bureau of Reclamation**

Prepared by

CH2MHILL®

MBK ENGINEERS

**February 2015**

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# SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model User's Manual

Prepared for

United States Department of the Interior
Bureau of Reclamation

Prepared by

CH2M HILL and MBK Engineers, Inc.

February 2015

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# Acronyms and Abbreviations

| | |
|---|---|
| *.fem file | MicroFEM Base-model |
| *.fpr | SACFEM2013 project file |
| 40-30-30 | Sacramento Valley Water Year Type |
| ac-ft/month | acre-feet per month |
| AVI | audio video interleave |
| AWD | applied water demand |
| bgs | below ground surface |
| CSM | conceptual site model |
| DEM | digital elevation model |
| DWR | Department of Water Resources |
| ET | evapotranspiration |
| GIS | geographic information system |
| gpm | gallons per minute |
| h1 | upper aquifer |
| IDC | Integrated Water Flow Model Demand Calculator |
| Kh | horizontal hydraulic conductivity |
| m | meters |
| MAF | million acre-feet |
| ME | Mean error |
| $R^2$ | Coefficient of determination |
| RMSE | Root mean squared error |
| RMSE/Range | RMSE divided by the range of target head values |
| SACFEM | Sacramento Valley Finite Element Groundwater Flow Model |
| SVGB | Sacramento Valley Groundwater Basin |
| USGS | U.S. Geological Survey |
| WBAs | water budget areas |
| wh1 | user-specified stream stage |
| wl1 | critical depth |
| WSE | water surface elevation |
| WY | water year |

SECTION 1

# Introduction

Implementation of conjunctive water management within the Sacramento Valley is one strategy being used to enhance the reliability of the existing water supply, as well as potentially improve water quality, within the San Francisco Bay-Delta. However, operating conjunctive water management, or groundwater substitution projects, can result in adverse impacts on water resources within the Valley. The two most critical potential impacts of additional groundwater production are depression of local groundwater levels, with associated impacts on well yields from nearby water supply wells, and changes in the hydraulic relationship between the surface water and groundwater systems in the area. To support the evaluation of these potential impacts, a high-resolution, numerical groundwater modeling tool was developed to estimate the impacts of potential future conjunctive water management projects on surface water and groundwater resources within the Sacramento Valley. This model, known as the Sacramento Valley Finite Element Groundwater Flow Model (SACFEM2013), is described herein.

SECTION 2

# Sacramento Valley Groundwater Basin Conceptual Site Model Overview

The following briefly summarizes the geology and hydrology of the Sacramento Valley Groundwater Basin (SVGB). The groundwater conceptual site model (CSM) is a theoretical construct that represents primary features of the physical system beneath the Sacramento Valley (Figure 1). The CSM is the primary basis for developing SACFEM2013.

## 2.1 Geologic Setting

The Sacramento Valley is located in the northern portion of the Great Valley physiographic region of California. The Great Valley is bounded by the Coast Ranges to the west, the Sierra Nevada to the East, and the Klamath Mountains and Cascade Range to the north. The Sacramento Valley is a north-northwestern trending asymmetrical trough filled with as much as 10 miles of both marine and continental rocks and sediment (Page, 1986). On the eastern side, the basin overlies basement bedrock that rises relatively gently to form the Sierra Nevada; on the western side, the underlying basement bedrock rises more steeply to form the Coast Ranges. Marine sandstone, shale, and conglomerate rocks that generally contain brackish or saline water overlie the basement bedrock. The more recent continental deposits, overlying the marine sediments, contain fresh water. These continental deposits are generally 2,000 to 3,000 feet thick (Page, 1986). The depth (below ground surface) to the base of fresh water typically ranges from 1,000 to 3,000 feet (Bertoldi et al., 1991). Three areas of bedrock outcrop are present within the interior of the Sacramento Valley; these include the Sutter Buttes, Black Butte, and the Dunnigan Hills. Descriptions of the major geologic units within the Sacramento Valley are listed in Table 1 (Page, 1986; California Department of Water Resources [DWR], 1978). Figure 2 presents a conceptual geologic section of the Central Valley.

## 2.2 Hydrogeology

The Sacramento Valley is part of the Sacramento River Hydrologic Region, which covers approximately 27,200 square miles in northern California (Figure 3) (DWR, 2003a). As shown on Figure 3, the Sacramento Valley includes the Redding Groundwater Basin (in the northern portion of the Valley) and the SVGB (in the southern portion of the Valley). The SVGB has been divided into 18 subbasins by DWR, as shown on Figure 3, based on groundwater characteristics, surface water features, and political boundaries (DWR, 2003a). However, from a hydrologic standpoint, these individual groundwater subbasins have a high degree of hydraulic interconnection because the rivers do not always act as barriers to groundwater flow. Therefore, the SVGB functions primarily as a single laterally extensive alluvial aquifer, rather than numerous discrete, smaller groundwater subbasins.

Fresh water in the SVGB is found within the continental deposits described in Section 2.1. Hydrostratigraphic units containing fresh water along the eastern portion of the basin (derived from the Sierra Nevada) are primarily the Tuscan and Mehrten Formations. In the southeastern portion of the SVGB, the Laguna, Riverbank, and Modesto Formations are important sources of fresh water. The primary hydrostratigraphic unit in the western portion of the SVGB is the Tehama Formation, which was derived from the Coast Ranges. As described above, these deeper hydrogeologic units are overlain by younger alluvial and floodplain deposits over the majority of the SVGB.

In the SVGB, surface water and groundwater systems are strongly connected and are highly variable spatially and temporally. Generally, the major trunk streams of the Valley (the Sacramento and Feather Rivers) act as drains and are recharged by groundwater throughout most of the year. The exceptions are areas of depressed groundwater elevations attributable to groundwater pumping (inducing leakage from the rivers) and localized recharge to the groundwater system. In contrast, the upper reaches of tributary streams

flowing into the Sacramento River from upland areas are almost all losing streams (they recharge the groundwater system). Some of these transition to gaining streams (they receive groundwater) farther downstream, closer to their confluences with the Sacramento River. Estimates of these surface water/ groundwater exchange rates have been developed for specific reaches on a limited number of streams in the SVGB (U.S. Geological Survey [USGS], 1985), but a comprehensive Valley-wide accounting has not been performed to date.

Figure 4 presents a conceptual diagram of groundwater flow in the SVGB. Under current conditions, groundwater generally flows from the mountains toward the SVGB and then toward the Sacramento River in a southerly direction parallel to the river. Depth to groundwater throughout most of the SVGB averages about 30 feet below ground surface (bgs), with shallower depths along the Sacramento River and greater depths along the basin margins. Seasonal fluctuations in groundwater levels occur due to the recharge from precipitation and snowmelt runoff, associated fluctuations in river stages, and the pumping of groundwater to supply agricultural and municipal demands.

Groundwater level fluctuations reflect changes in the amount of groundwater stored in the aquifer system, which is driven by variability in the magnitude and timing of aquifer recharge and discharge. The primary components of groundwater inflow to the SVGB include the following:

- Groundwater recharge from precipitation
- Groundwater recharge from applied irrigation water
- Groundwater recharge from river, bypass, or lake leakage
- Groundwater recharge along the margin of the basin (mountain front recharge)

The primary components of groundwater outflow from the SVGB include the following:

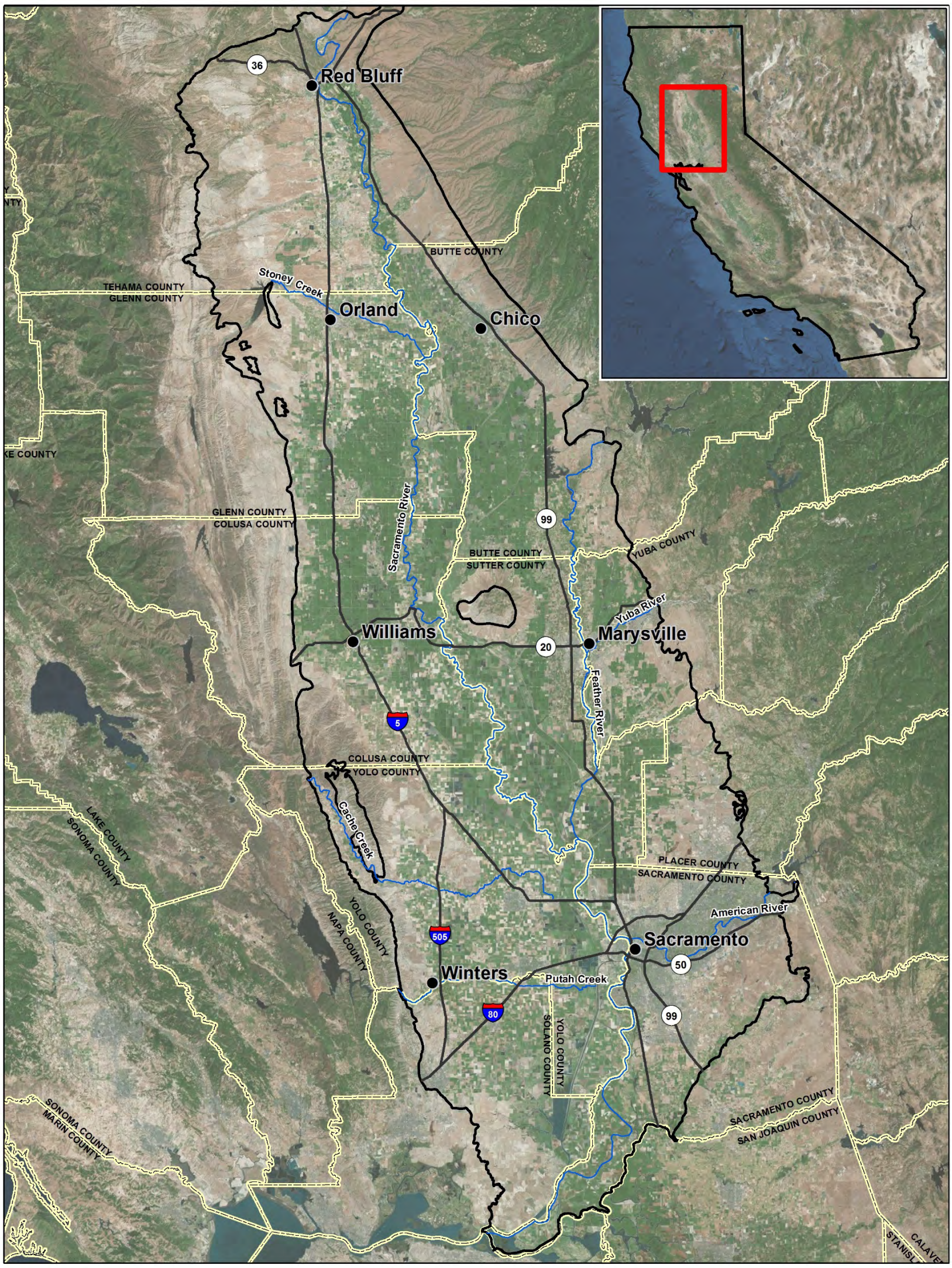
- Groundwater discharge to land surface (including evapotranspiration, discharge to low-lying stream riparian areas, and discharge to low-lying areas such as the Butte Sinks in the Sutter Basin)
- Groundwater discharge to rivers
- Groundwater discharge to wells

In dry years, groundwater levels gradually decline in many areas because more water is extracted than recharged. During wet years, groundwater levels in the SVGB typically recover because more water is recharged than extracted (DWR, 2003b).-

Except during drought periods, groundwater levels recover to pre-irrigation-season levels each spring. In other words, no extensive areas of depressed groundwater levels exist in the basin except for localized conditions as described below. Historical groundwater level hydrographs suggest that even after extended droughts, groundwater levels in this basin recovered to pre-drought levels within 1 or 2 years after the return of normal rainfall.

As agricultural land use and water demands have intensified over time, groundwater levels in some areas have declined because increases in pumping have exceeded the quantity of local recharge to the groundwater system. This imbalance between pumping and recharge in portions of the Valley has been the motivating force developing supplemental surface water supplies in several areas during the past 30 to 40 years. Examples include Yolo County's construction of Indian Valley Dam on the North Fork of Cache Creek, South Sutter Water District's construction of Camp Far West Reservoir on the Bear River, and Yuba County's construction of New Bullards Bar Dam and Reservoir on the North Yuba River.

Currently, groundwater levels are generally in balance Valley-wide, with pumping matched by recharge from the various sources annually. Some locales show the early signs of persistent declines in groundwater level, including northern Sacramento County, areas near Chico, and on the far west side of the Valley in Glenn County, where water demands are met primarily, and in some locales exclusively, by groundwater.




**LEGEND**

- City
- Major Road
- Major Stream
- County Boundary
- Sacramento Valley Groundwater Basin

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 1**
**Location Map**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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TABLE 1
**Major Lithologic Units of the Sacramento Valley**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

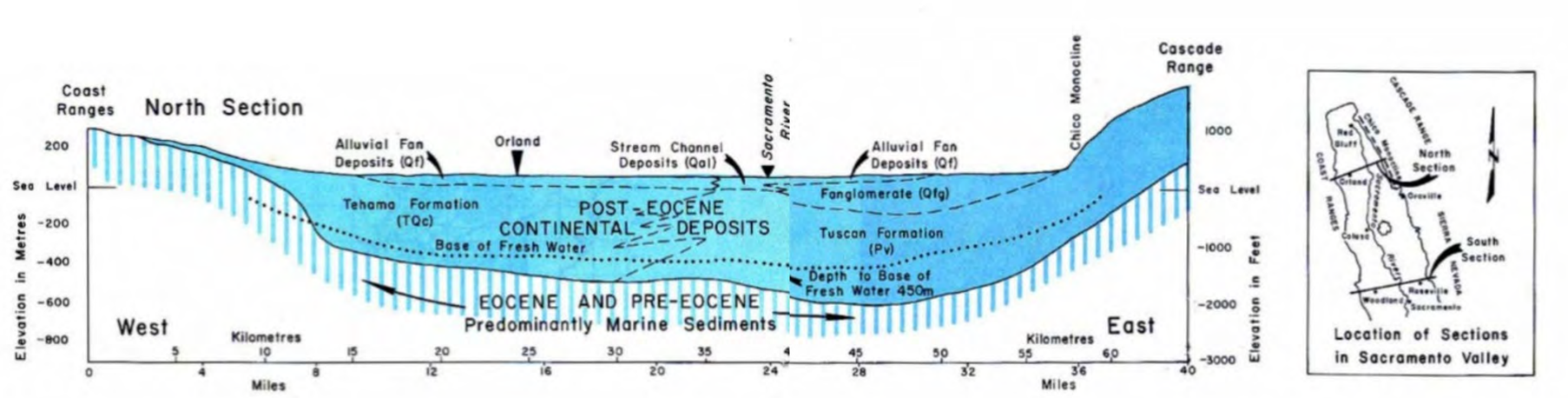
| Geologic Unit | Geologic Age | Description | Water-Bearing Properties |
|---|---|---|---|
| Alluvium | Quaternary (Holocene) | Alluvial deposits not included as fans or flood basin deposits are found throughout the Sacramento Valley and consist of stream channel, natural levee, and floodplain deposits. Alluvium consists primarily of sands and gravel with minor amounts of silt and clay. Large, coarse-grained deposits are associated with larger streams in the Valley. | Stream channel deposits have high yields. |
| Flood Basin Deposits | Quaternary (Holocene) | Flood basin deposits are found in five distinct basins along the Sacramento River. During flood conditions, silts, clays, and fine sands were deposited in low-lying areas between the natural levees of streams and the alluvial plains on the Valley sides. | Insufficient data, but yields expected to be low given the fine-grained nature of the deposits. |
| Alluvial Fan Deposits | Quaternary (Pleistocene-Holocene) | Alluvial fan deposits are found along the western side of the Sacramento Valley from Stony Creek southward. Alluvial fans along the eastern side of the Valley are limited to the Chico area. Coalescing fans comprise materials ranging from clay to gravel. Alluvial fans in the Stony Creek and Chico areas contain a high proportion of coarse-grained materials. | Coarse-grained alluvial fans (Stony Creek) have reported yields up to 4,000 gpm. Alluvial fans dominated by finer-grained materials have lower yields. |
| Victor Formation | Quaternary (Pleistocene) | The Victor Formation is present on the eastern side of the Sacramento Valley where it forms a broad plain. The unit was deposited on a plain of aggradation by shifting streams draining the Sierra Nevada. The Victor Formation consists of stream channel sand and gravel deposits that grade laterally and vertically to silts and clays with a thickness up to 100 feet. | Important water-bearing unit for domestic and shallow irrigation wells. Limited data are available for wells completed entirely in the Victor Formation; yields up to 1,900 gpm are estimated for channel deposits of sand and gravel. |
| Arroyo Seco Gravel<br>South Fork Gravels<br>Red Bluff Formation | Quaternary (Pleistocene) | Small gravel deposits that form caps to the low hills and dissected uplands along the eastern and western sides of the Sacramento Valley. Gravel deposits are associated with glaciation of the Sierra Nevada and Coast Ranges and are generally either cemented or contain hardpan soils. | Not important water-bearing units, generally found above the regional water table, where units are saturated; well yields are generally low. |
| Fanglomerate | Quaternary (Pleistocene) | This unnamed geologic unit is restricted to the northeastern portion of the Sacramento Valley (north of Chico). The unit consists of coalescing alluvial fans derived from erosion of outcrops of the Tuscan Formation. The fanglomerates consist predominantly of cemented sand and gravel with large amounts of clay. | Estimated to have low to moderate yields. |
| Laguna Formation<br>Fair Oaks Formation | Tertiary-Quaternary (Pliocene to middle-Pleistocene) | The Laguna Formation outcrops along the eastern margin of the basin and consists of westward-thickening deposits of silt, clay, and sand with gravel lenses. The Laguna Formation was deposited by streams draining the Sierra Nevada, with primarily granitic and metamorphic mineralogy (little/no volcanics). In portions of Sacramento County, deposits are referred to as the Fair Oaks Formation. | Finer-grained portions of the formation have low well yields. Well sorted sand units have reported well yields up to 1,750 gpm. |
| Tehama Formation | Tertiary-Quaternary (Pliocene to middle-Pleistocene) | The Tehama Formation occupies entire western portion of the Sacramento Valley and consists of predominantly fine-grained materials (silts and clays) with thin/ discontinuous lenses of sand and gravel derived from erosion of the Coast Ranges and the Klamath Mountains. The relative proportion of coarse-grained materials varies | The Tehama Formation is a principal water-bearing unit in the Sacramento Valley with reported well yields up to 4,000 gpm. |

TABLE 1
**Major Lithologic Units of the Sacramento Valley**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Geologic Unit | Geologic Age | Description | Water-Bearing Properties |
|---|---|---|---|
| Tehama Formation (cont'd) | | spatially within the unit. The Tehama Formation extends eastward from the Valley margin and interfingers with the Tuscan and Laguna Formations at depth beneath the central portion of the Valley. The average thickness of the unit beneath the western half of the Sacramento Valley is approximately 2,000 feet. | |
| Mehrten Formation Tuscan Formation | Tertiary (Pliocene) | The Mehrten Formation is a volcanic unit that outcrops primarily along the southeastern margin of the Sacramento Valley. The formation is divided into two units: an upper fluvatile unit of interbedded black sands and blue to brown clay and a lower unit consisting of dense tuff-breccia. The formation dips and thic kens to the southwest.<br>The Tuscan Formation outcrops in the east/northeastern portion of the Sacramento Valley and dips westward. The formation underlies approximately 900 square miles of the Valley. The Tuscan Formation is a wedge-shaped unit that thins from approximately 1,000 to 1,600 feet in the eastern outcrop areas to approximately 300 feet beneath the Valley center where it interfingers with the Tehama Formation. The unit consists of stream-deposited black volcanic sands, tuffaceous clay, and gravel. | The black sands of the Valley Springs Formation yield large quantities of fresh water to wells.<br>The Tuscan Formation is an important water bearing unit in the Sacramento Valley, with reported well yields up to 3,000 gpm. |
| Valley Springs Formation | Tertiary (Miocene) | The Valley Springs Formation outcrops primarily along the southeastern margin of the Sacramento Valley. The unit consists of southwestward-dipping sequence of rhyolitic ash, clay, sand, and gravel deposited by streams with thickness up to approximately 200 feet. | Fresh water-bearing unit; low yields due to presence of fine-grained materials. |
| Marine and Continental Deposits (Includes Ione Formation) | Tertiary (Eocene) | Mixed marine and continental sediments deposited in a semi-isolated basin during and following uplift of the Coast Range. With transgression and regression of seas, some deposits contain both marine and sedimentary materials.<br>Ione formation was deposited in a marsh-like environment in the east/southeastern portion of the Sacramento Valley and in fluvatile to marine environments in other portions of the Central Valley. The unit outcrops along the eastern margin of the Sacramento Valley and dips southwestward. The Ione Formation consists of clay, sand, sandstone, and conglomerate up to 400 feet thick. | Largely non-water bearing or saline.<br>Where deposited in near-shore environment, the Ione Formation yields small quantities of fresh water to wells (up to 50 gpm). |
| Volcanics (Includes Sutter Buttes) | Tertiary | Andesitic and rhyolitic volcanics within interior of the Sacramento Valley. | Primarily non-water-bearing. |
| Marine Rocks (Includes Chico Formation) | Cretaceous | Outcrop primarily along the western side of the Sacramento Valley. Sedimentary rocks consisting primarily of eastward-dipping (and thickening) sandstones and shales. | Generally contain connate water or yield small volumes. |
| Basement Rocks | Pre-Tertiary | Igneous and metamorphic rocks that underlie the sedimentary deposits. Outcrops are limited to the eastern portion of the Valley, in the Sierra Nevada, and slope southwest. Igneous rocks include granitics with some mafic intrusions. Metamorphic rocks include metasedimentary, metavolcanic, and undifferentiated metamorphics. | Primarily impermeable boundary at base of groundwater basin; fractures and joints yield small quantities of water. |

Notes:

Lithologic descriptions from DWR (1978) and Page (1986)
gpm = gallons per minute







Note:
Figure reproduced from DWR (1978).

**Figure 2**
**Generalized Geologic Section of the Sacramento Valley**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

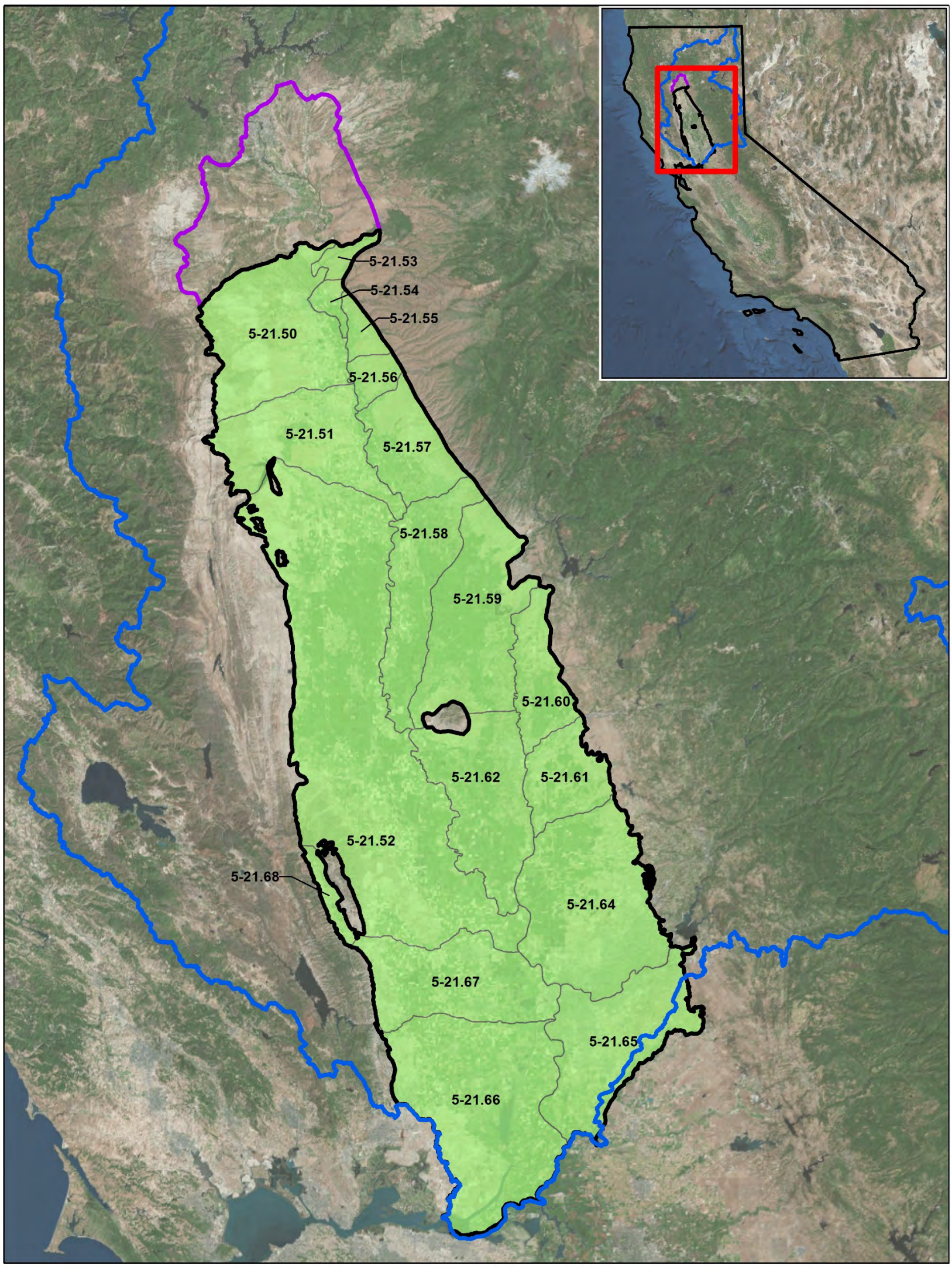



**Figure 3**
**Sacramento Valley Groundwater Basin**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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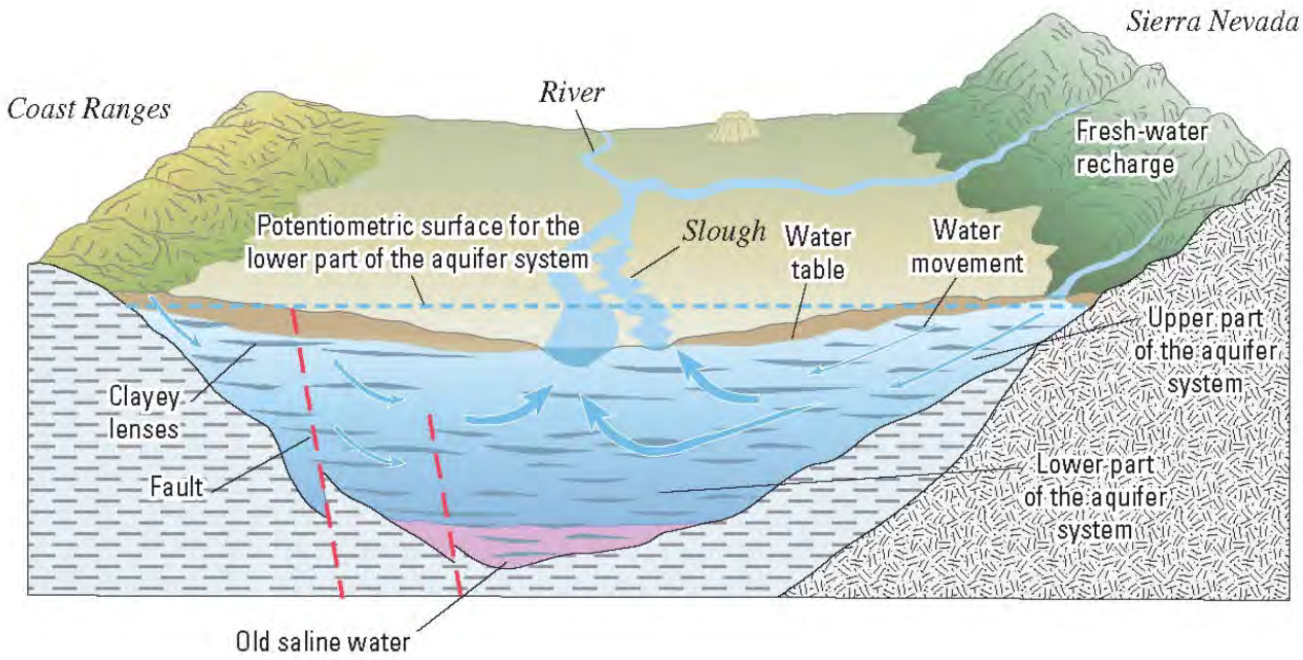


**Figure 4**
**Conceptual Diagram of Groundwater Flow in the Sacramento Valley Groundwater Basin**

Note:
Figure reproduced from USGS (2009).

## 2.3 Regional Hydrology

The SVGB is an area of approximately 3.6 million acres on the Valley floor (Figure 3). The Sacramento River is the main surface water feature in the SVGB. It has several major tributaries draining the Sierra Nevada, including the Feather, Yuba, and American Rivers. Stony, Cache, and Putah Creeks drain the Coast Range and are the main westside tributaries to the Sacramento River. The westside tributaries contribute significantly less stream flow than those on the eastside. The Sacramento River flows south through the center of the Valley before heading west to flow to Suisun Bay.

The Sacramento River and its major tributaries are the main water supply source for much of the area and provide water for urban, agricultural, and environmental uses. The flow of the major rivers and tributaries is managed by reservoir operations of the Central Valley Project, State Water Project, and locally operated projects. Groundwater pumping has been developed in much of the Valley to supplement surface water sources, and in some areas, it is the only source of water. Stream flow data for streams throughout the SVGB are collected at gaging stations operated by California DWR[1] and USGS[2].

The SVGB experiences a Mediterranean climate characterized by cool, wet winters and warm, dry summers. The average annual precipitation on the Valley floor is approximately 22 inches and varies considerably. The majority of the precipitation comes in the winter months from November through March with typically only minimal amounts from June through September. Figure 5 presents a plot of the Sacramento Valley water year[3] (WY) index between WY1970 and WY2010. The WY index is a function of the unimpaired runoff in the hydrologic region and is used to illustrate climatic variability. As shown on Figure 5, the SVGB has experienced prolonged droughts (such as WY1976-WY1977 and WY1987-WY1992) and extremely wet periods (such as WY1982-WY1984 and WY1995-WY1999).

[1] http://cdec.water.ca.gov/

[2] http://waterdata.usgs.gov/nwis

[3] A water year runs from October 1 of the previous calendar year through September 30 of the current calendar year (for example, water year 1970 includes the period of October 1, 1969, through September 30, 1970).

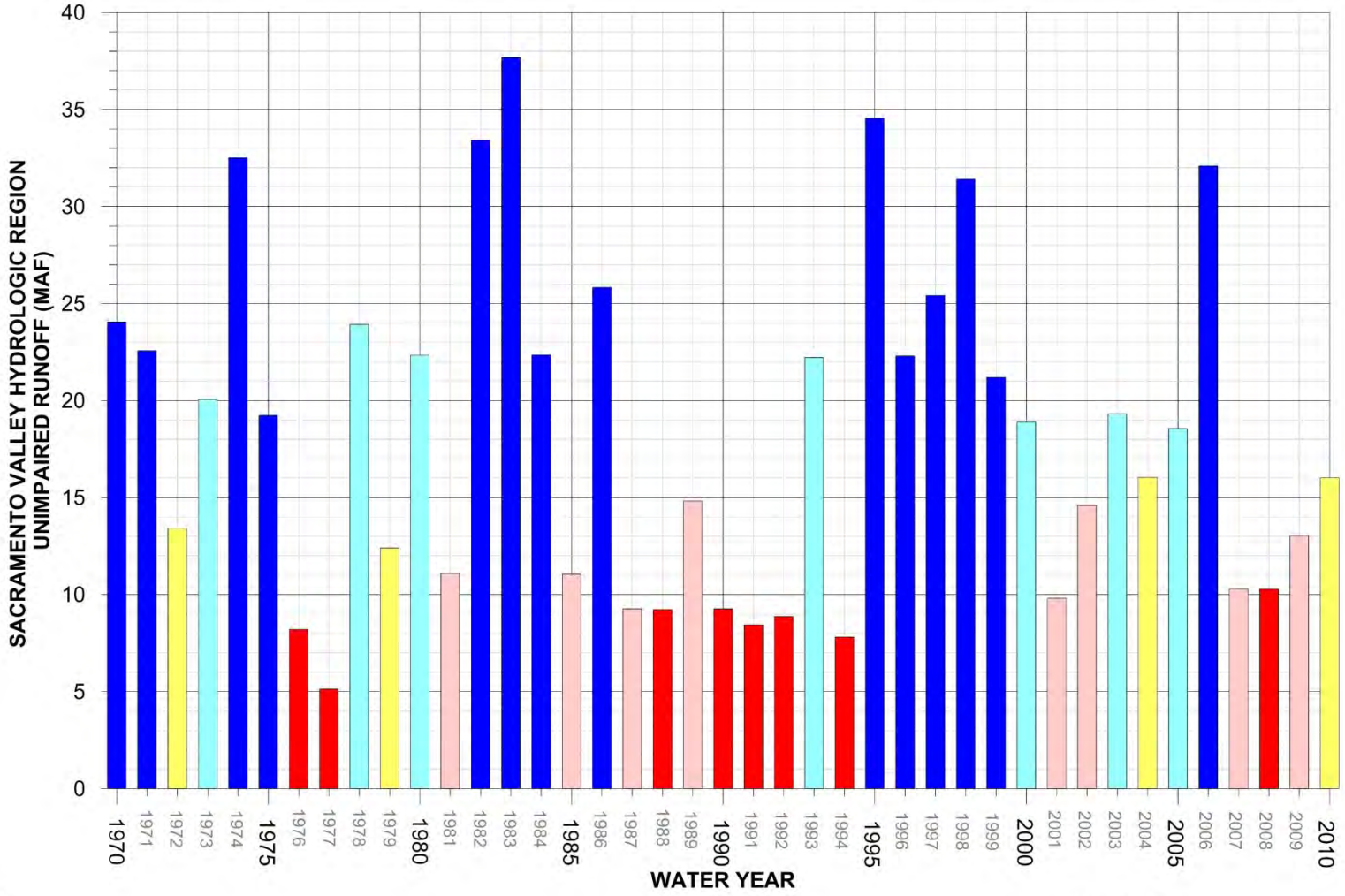


**Figure 5**
**Sacramento Valley**
**Water Year Classification**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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SECTION 3

# Groundwater Flow Model Construction

## 3.1 Model Code Description

MicroFEM (Hemker, 1997), a finite-element based, three-dimensional, integrated groundwater modeling package developed in The Netherlands, was chosen to simulate the groundwater flow systems in the SVGB. The current version of the program (4.10) has the ability to simulate up to 25 layers and 250,000 surface nodes. MicroFEM is capable of modeling saturated, single-density groundwater flow in layered systems. Horizontal flow is assumed in each layer, as is vertical flow between adjacent layers.

MicroFEM was the chosen modeling platform for the following reasons:

- The finite-element scheme allowed the construction of a model grid covering large geographic areas (more than 5,960 square miles in the SVGB) with coarse node spacing outside of the simulated project areas and finer node spacing in areas of interest (e.g., near potential project areas). The finer node spacing near simulated production wells provides greater resolution of simulated groundwater levels and stream impacts.
- The graphical interface allows rapid assignment of aquifer parameters and proofing of these values by graphical means.
- The flexible post-processing tools allow for rapid evaluation of transient water budgets for model simulations and identification of changes to stream discharges and other water fluxes across the model domain.

### 3.1.1 Numerical Assumptions

MicroFEM, as applied to the development of SACFEM2013, is conceptualized mathematically into a single-density subsurface groundwater flow regime. The subsurface flow regime includes the hydraulic properties that control groundwater movement and rates. All model layers are treated as vertically integrated, leaky-confined layers to facilitate accurate simulation of the 3D groundwater flow conditions. The minimum inputs required by MicroFEM to execute a simulation for a given model grid include transmissivity, vertical resistance, and boundary conditions. SACFEM2013 is simulated under confined conditions in all model layers; therefore, the user-defined transmissivity values do not vary during the model simulation.

### 3.1.2 Scientific Bases

The theory and numerical techniques that are incorporated into MicroFEM have been scientifically tested. The governing equations for saturated subsurface flow are well established and have been solved by several modeling codes over the past few decades on a wide range of field problems. Thus, the scientific bases of the theory and the numerical techniques for solving these equations have been well established. MicroFEM has been developed using strict quality assurance/quality control guidelines and with various levels of testing, from simple analytical solutions to complex field problems.

### 3.1.3 Data Formats

MicroFEM input and output files use American Standard Code for Information Interchange (ASCII) data formats and can be read and edited outside the program by a text editor.

### 3.1.4 Limitations

Mathematical models 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. CH2M HILL incorporated as many details of the physical system into the numerical model as possible. SACFEM2013 is a powerful tool that, when used carefully, can

provide useful insight into processes of the physical system. Section 4.3 discusses potential sources of input and output error.

# 3.2 Model Construction

The mathematical model design is the result of translating the CSM into a form that is suitable for numerical modeling. The following steps were included in the development of the mathematical model design:

1. Establishing study area boundaries (that is, model domain) and developing a model grid
2. Spatially distributing land surface elevation values
3. Spatially distributing subsurface hydraulic parameter values
4. Selecting a time discretization approach appropriate for evaluating the field problem and fulfilling the modeling objectives
5. Establishing boundary conditions for flow (that is, water budget terms through time)

The following subsections describe the results of these design steps.

## 3.2.1 Model Domain

In the real world, space is continuous, but a numerical model must use discrete space to represent the hydrologic system. The simplest way to discretize space is to subdivide the study area into many subregions (that is, model elements) of variable size. This was the approach taken for development of the SACFEM2013 grid.

### 3.2.1.1 Areal Characteristics of Model Grid

The current version of the SACFEM2013 grid consists of 153,812 nodes and 306,813 elements (see Figure 6). The current grid was configured to support evaluation of potential conjunctive water management projects associated with the Long-Term Water Transfer Program; however, SACFEM2013 was designed to be grid independent, and geographic information system (GIS)-based tools have been developed to build a similar model of the Valley on any grid developed to support a particular application. The nodal spacing of the current grid varies from as large as approximately 3,300 feet (1,000 meters) near the model boundary and in areas where long-term water transfer projects are not being evaluated, to as small as 410 feet (125 meters) in areas where long-term water transfer groundwater production is being evaluated. Nodal spacing of approximately 1,640 feet (500 meters) is included along streams and flood bypasses included in SACFEM2013. The finer node spacing near proposed project areas allows for more refined estimates of the effects of groundwater pumping on groundwater levels and groundwater/surface water interaction in the potential project areas. The model domain boundary coincides with the lateral extent of the freshwater aquifer within the SVGB.

*Note: The horizontal datum for SACFEM2013 is Universal Transverse Mercator, North American Datum of 1983, Zone 10 North, meters. The vertical datum for SACFEM2013 is North American Vertical Datum of 1988, meters.*

### 3.2.1.2 Vertical Characteristics of Model Grid

As previously discussed, MicroFEM uses the user-defined aquifer transmissivity when executing calculations under confined conditions. When constructing the SACFEM2013 model, aquifer transmissivity was divided into the two components: saturated aquifer thickness and horizontal hydraulic conductivity (transmissivity is equal to saturated thickness multiplied by horizontal hydraulic conductivity). The following section describes the conceptualization of the saturated aquifer thickness.

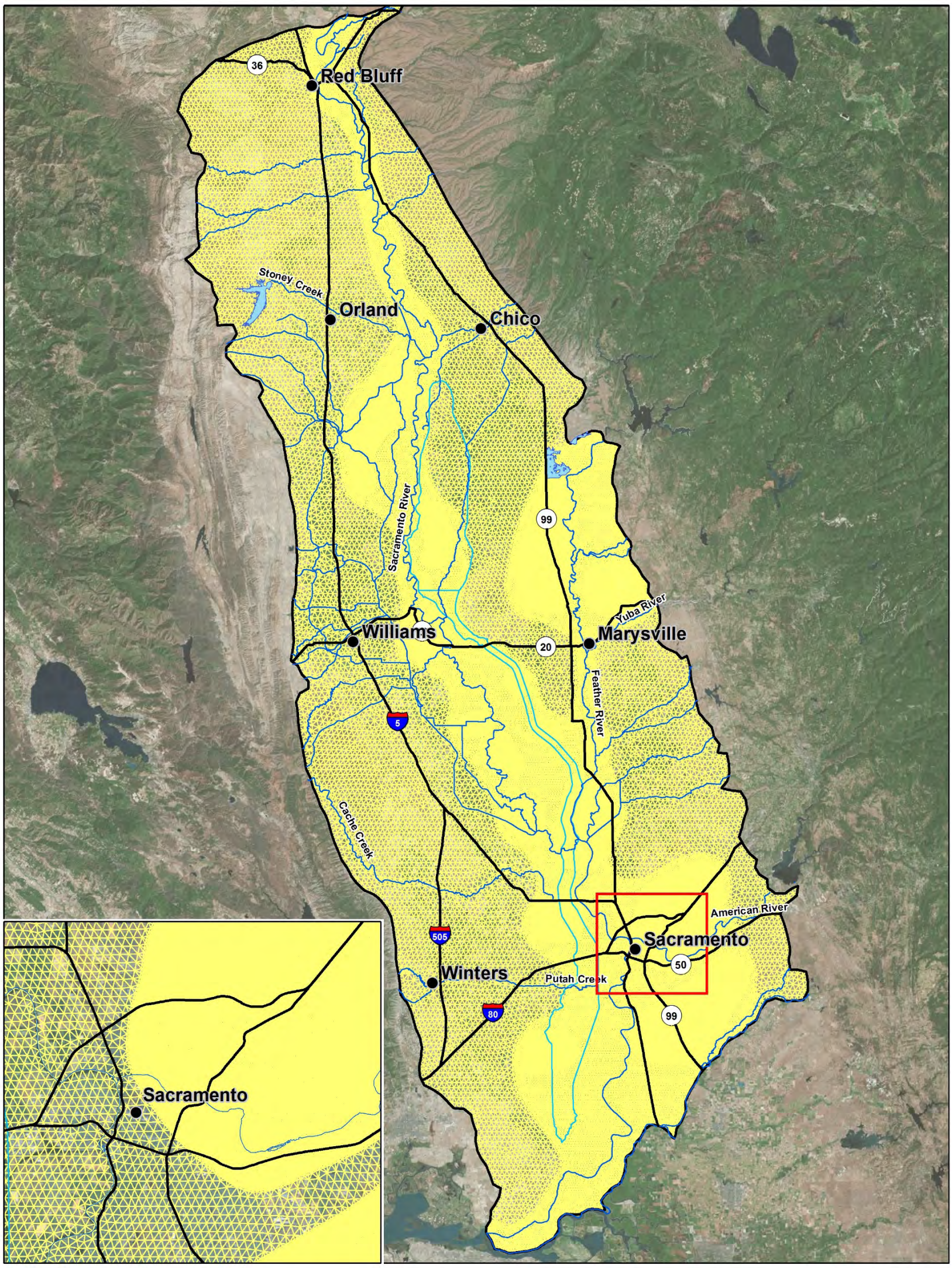


**Figure 6**
**SACFEM2013 Model Grid**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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The total model thickness is defined by the thickness of the freshwater aquifer (less than 3,000 micromhos per centimeter), as defined by Berkstresser (1973) and subsequently refined in the northern portion of the Valley by DWR (2002, 2005). For the southern portion of the model area, elevation contour lines of the base of fresh water, defined by Berkstresser data, along with information from boring locations (point measurements of the elevation of the base of fresh water) were digitized and used to generate a 3D surface defining the elevation of the base of fresh groundwater. For the northern portion of the model area, the locations of geologic cross sections developed by DWR Northern District staff were plotted, along with the estimated base of freshwater elevations obtained from the cross section information, and a base-of-freshwater elevation contour map was constructed. These data sets were then merged to yield a single interpretation of the structural contour map of the base of freshwater across the SVGB (see Figure 7).

**Total Aquifer Thickness.** Because SACFEM 2013 is simulated under confined conditions, the uppermost boundary of SACFEM2013 is defined at the water table. To develop a total saturated aquifer thickness distribution and, therefore, a total model thickness distribution, it was necessary to construct a groundwater elevation contour map and then subtract the depth to the base of freshwater from that groundwater elevation contour map. Average calendar year 2000 groundwater elevation measurements were obtained from the DWR Water Data Library. These measurements were primarily collected biannually, during the spring and fall periods; and these values were averaged at each well location to compute an average water level for each location. These values were then contoured, considering streambed elevations for the gaining reaches of the major streams included in the model, to develop a target groundwater elevation contour map for the year 2000. As described above, the distribution of the elevation of the base of freshwater was subtracted from this groundwater elevation contour map to provide an estimate of the distribution of the total saturated aquifer thickness across the model domain (see Figure 8).

**Model Layer Thickness.** The strategy used to develop the overall layering of the SACFEM2013 model was to develop a tool that provides a sufficient number of layers to assess the effects of groundwater pumping on shallow features such as wetlands and streams. The model also was developed to provide sufficient vertical resolution to allow assignment of pumping stresses to appropriate depths within the aquifer that reflect the major producing zones within the aquifer system. Additionally, to facilitate investigation of potential future conjunctive water management projects using the Lower Tuscan aquifer, the layering strategy also provided for two layers explicitly representing this deep aquifer system.

Layer 1 of the SACFEM2013 model was assigned a maximum thickness of approximately 65 feet (20 meters). The thickness of this layer was limited to provide more accurate shallow groundwater elevations with which to support evaluations of the effects of changing groundwater levels on surface streams and wetland/ riparian areas. Layers 2 through 5 represent the more regional groundwater-producing zones within the Valley. The thicknesses of these layers were assigned using a specified percentage of the available aquifer thickness at a given location, to provide multiple-depth zones within which to assign regional pumping. The assumed layer thicknesses for Layers 2 through 5 were also selected to reflect typical screened intervals of production wells in the SVGB. The thicknesses of Layers 2 through 4 each represent approximately 10 percent of the total aquifer thickness (1 to 107 meters, 3 to 350 feet), and the thickness of Layer 5 represents approximately 15 percent of the total aquifer thickness on average (1 to 193 meters, 3 feet to 633 feet).

Where the Lower Tuscan aquifer is present (the northeastern and central portions of the Valley), the elevation of the top of Layer 6 was defined by the structural contour surface of the top of the Lower Tuscan aquifer (Figure 9). Two layers were assigned to represent this unit because, in many areas of the model, the depth to the base of fresh water (the base of the model) is as much as 900 feet below the upper surface of the Lower Tuscan. Groundwater production wells drilled into the Lower Tuscan would almost certainly be screened over a much smaller depth interval. To represent this condition in the model, Layer 6 was assigned a thickness of between 250 to 360 feet (75 to 110 meters) in the central portion of the northern SVGB. The total range in Layer 6 thickness is approximately 3 to 580 feet (1 to 177 meters). The remaining Lower Tuscan thickness not apportioned to Layer 6 was assigned to Layer 7. The exception to this convention is in

the northeastern portion of the model near the City of Chico. The Lower Tuscan outcrops in the foothills above Chico; thus, in these areas, all layers of the model represent the Lower Tuscan aquifer. Moving west from Chico, a transition zone exists where a decreasing number of layers represents the Lower Tuscan until it is limited to Layers 6 and 7, as discussed above. In areas where the Lower Tuscan is not present, the thicknesses of Layers 6 and 7 represent 18 and 27 percent of the total aquifer thickness, respectively. A contour map of the total saturated aquifer thickness is presented on Figure 8, and cross sections illustrating SACFEM2013 model layers are presented on Figures 10 and 11 (these oversized figures are presented at the end of this report).

## 3.2.2 Subsurface Hydraulic Parameters

The hydraulic parameters in the SACFEM2013 were initially assigned using available and relevant field data from previous investigations. Subsurface hydraulic properties required by MicroFEM include the horizontal hydraulic conductivity (Kh) and the vertical resistance.

### 3.2.2.1 Horizontal Hydraulic Conductivity

The distribution of aquifer properties across the SVGB is poorly understood. In certain areas with significant levels of groundwater production, the collection of aquifer test data and the measurement of historical groundwater-level trends in response to known groundwater production rates have provided valuable information on aquifer properties. However, in the majority of the Valley, these data are not available.

To estimate the spatial distribution of aquifer properties across the model domain for this numerical modeling effort, a database of well productivity information was used. In consultation with DWR staff, a database was obtained that included all of the specific capacity yield data that were available from well log records. These data were compiled along with well construction information for each production well to yield a representative data set of well productivity across the Valley. Wells that did not have available construction data were omitted from further consideration. To protect owner privacy, the exact location of each well was modified by DWR staff to reflect the center of the section in which each well was located. This modification in well location did not adversely affect the use of the data to estimate the spatial distribution of aquifer properties, given the extremely large area encompassed by the model domain. Approximately 1,000 wells in the database within the model domain were used in this analysis.

The intent of the modeling analysis described herein is to simulate the effects of operating high-productivity irrigation wells screened within the major producing zones in the Valley to support conjunctive water management projects. Therefore, the aquifer properties that are of primary interest are those of the major aquifer zones tapped by large-diameter irrigation wells. The well database described above was filtered to remove data obtained from tests on low-yield and shallow, domestic-type wells. All test data from wells that reported a well yield below 100 gpm were eliminated from consideration, as were the test data from wells with a total depth of less than 100 feet. The only exception to this second consideration was for wells that were located along the basin margins – where aquifers are thin – that reported what appeared to be valid test results. Data from these wells were considered because they were often the only data available in the basin margin areas.

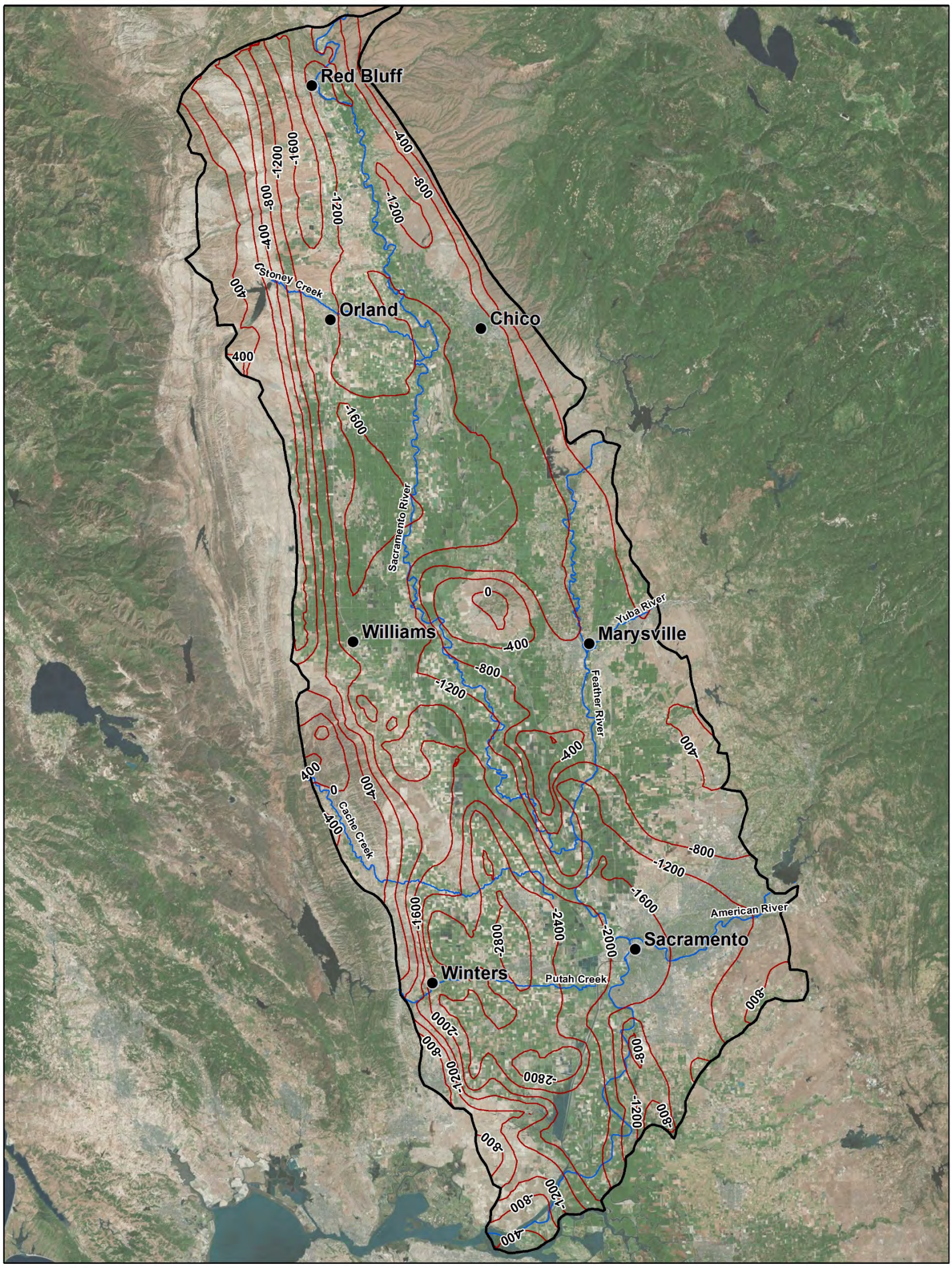
After the data set for consideration was finalized, the reported specific capacity data for each well were used to estimate an aquifer transmissivity for that location. The relationship used to estimate aquifer transmissivity was the following form of a simplified version of the Jacob non-equilibrium equation:

$$S_c = \frac{T}{2000} \quad (1)$$

Where:

$S_c$ = specific capacity of an operating production well (gallons per minute per foot of drawdown)

T = aquifer transmissivity (gallons per day per foot)




**LEGEND**

- City
- Major Stream
- SACFEM2013 Model Boundary
- Simulated Base of Fresh Groundwater (feet NAVD88)

Note:
NAVD88 = North American Vertical Datum of 1988

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 7**
**Base of Fresh Groundwater**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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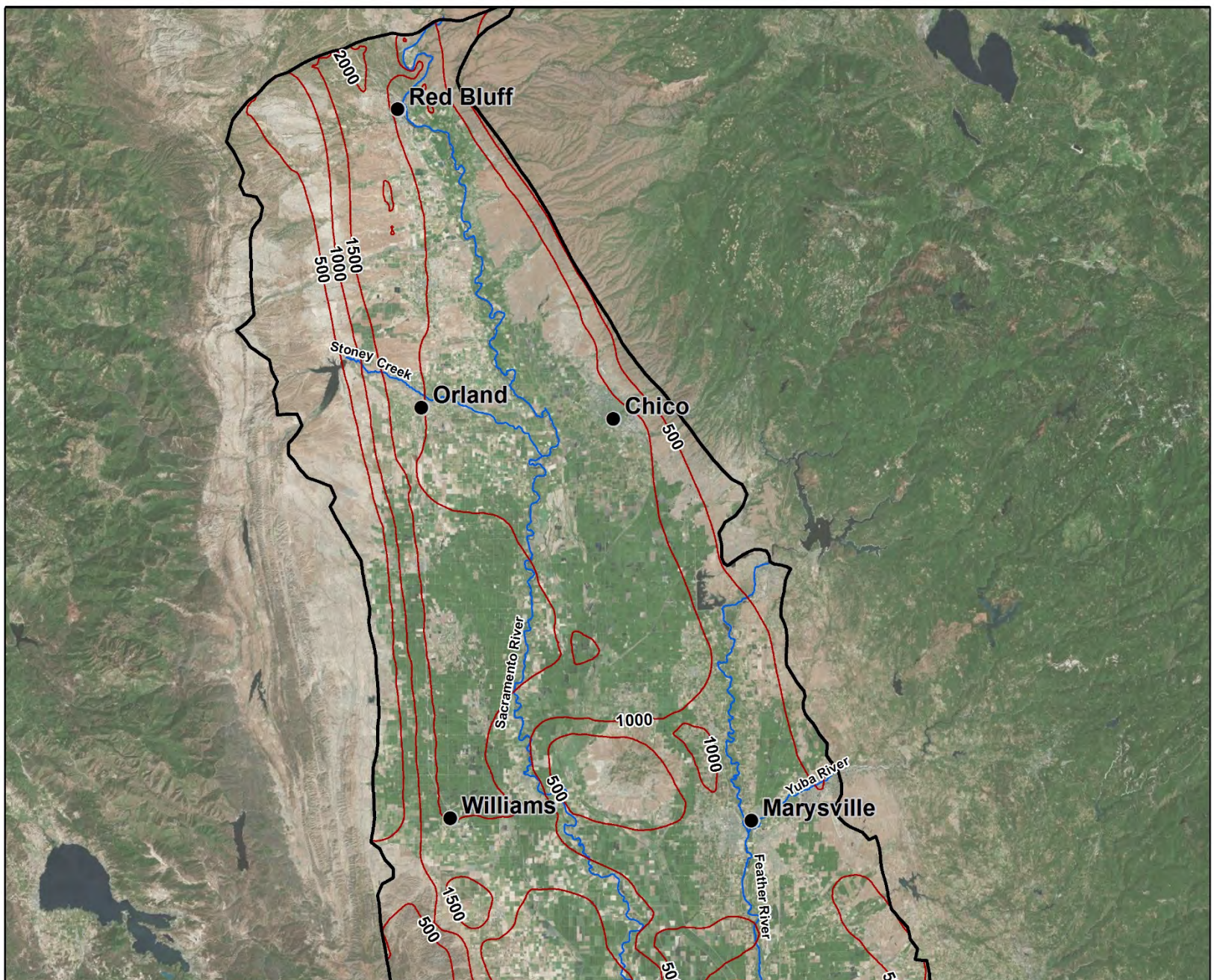


**LEGEND**

- City
- Major Stream
- SACFEM2013 Model Boundary
- Contour of Equal Saturated Aquifer Thickness (feet)

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 8**
**Total Saturated Aquifer Thickness**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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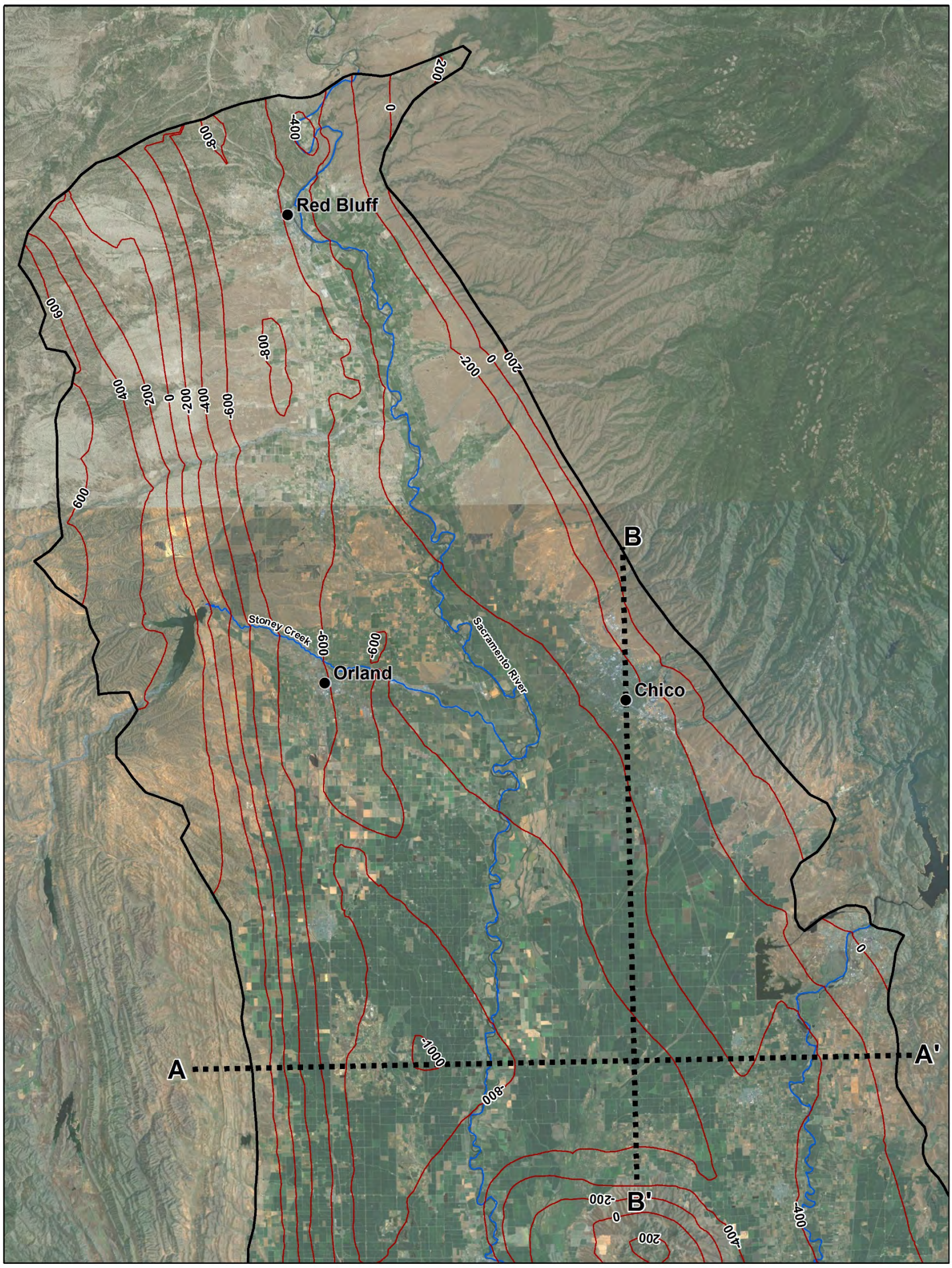


**Figure 9**
**Elevation of the Top of Model Layer 6**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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After a transmissivity estimate was computed for each location, the transmissivity value was then divided by the screen length of the production well to yield an estimate of the aquifer Kh. The final step in the process was to smooth the Kh field to provide regional-scale information. Individual well tests produce aquifer productivity estimates that are local in nature, and might reflect small-scale aquifer heterogeneity that is not necessarily representative of the basin as a whole. To average these smaller-scale variations present in the data set, a FORTRAN program was developed that evaluated each independent Kh estimate in terms of the available surrounding estimates. When this program is executed, each Kh value is considered in conjunction with all others present within a user-specified critical radius, and the geometric mean of the available Kh values is calculated. This geometric mean value is then assigned as the representative regional hydraulic conductivity value for that location. The critical radius used in this analysis was approximately 6 miles (10,000 meters). The point values obtained by this process were then gridded to develop a Kh distribution across the model domain. The aquifer transmissivity at each model node within each model layer was then computed using the geometric mean Kh values at that node times the thickness of the model layer. Insufficient data were available to attempt to subdivide the data set into depth-varying Kh distributions, and it was, therefore, assumed that the computed mean Kh values were representative of the major aquifer units in all model layers.

The distribution of Kh was used as a calibration parameter for SACFEM2013, and minor adjustments were made during the calibration process. Figures 12 and 13 present the final Kh distributions for model Layers 1 through 5 and model Layers 6 and 7. The final distribution of Kh in model Layer 1 is slightly lower than model Layers 2 through 5 east of Dunnigan Hills; however, this is not readily apparent given the 20-foot contour interval on Figure 12. Further, bedrock areas within the interior of the SVGB were assigned Kh values of 1 foot per day in all model layers.

### 3.2.2.2 Vertical Resistance

MicroFEM computes vertical flow between adjacent model layers based on the simulated head difference between adjacent model layers and the vertical resistance term. The vertical resistance term in MicroFEM is calculated as follows:

$$c = \left(AF \times \frac{mt_i^2 \div 2}{t_i}\right) + \left(AF \times \frac{mt_{i+1}^2 \div 2}{t_{i+1}}\right) \quad (2)$$

Where:

c = Vertical resistance to flow between an upper model layer (i) and adjacent lower model layer (i+1) ($days^{-1}$)
AF = Anisotropy factor (ratio of horizontal to vertical hydraulic conductivity [Kh:Kv])
Kv = Vertical hydraulic conductivity
$mt_i$ = Saturated thickness of model layer i (length [L])
$mt_{i+1}$ = Saturated thickness of model layer i+1 (L)
$t_i$ = Transmissivity of model layer i ($L^2$/time [T])
$t_i$+1 = Transmissivity of model layer i ($L^2$/T)

The Kh:Kv values were assumed to be 500:1 in Layers 2 through 7 and 50:1 in Layer 1 at all model nodes except those representing bedrock areas. The Kh:Kv in areas of bedrock outcrop (such as the Sutter Buttes, Black Butte, and Dunnigan Hills) was assumed to be 1:1 in all model layers.

### 3.2.2.3 Aquifer Storage

The specific yield of model Layer 1 was assumed to be 12 percent throughout the SACFEM2013 model domain. The aquifer storativity of model Layers 2 through 7 is $6.5 \times 10^{-5}$ multiplied by model layer thickness throughout the majority of the model domain, with variations along small portions of the model boundary.

## 3.2.3 Model Time Discretization

Time is continuous in the physical system, but a numerical model must describe the field problem at discrete time intervals. SACFEM2013 was set up to simulate transient flow conditions between WY1970 and WY2010. The period WY1970 through WY2010 was used because it includes very wet periods such as the winter of WY1983, as well as dry periods such as the WY1976 to WY1977 and WY1988 through WY1992 droughts. Using a climatic period of this type allows for assessing model accuracy and the water budgeting process and replicating observed conditions during periods of extreme hydrologic conditions, as well as the more average conditions that persisted throughout the remainder of the calibration period. The 41-year simulation was discretized with monthly stress periods. As such, model stresses (such as stream stage, groundwater pumping, deep percolation) and model output are assigned/evaluated monthly.

## 3.2.4 Boundary Conditions

Boundary conditions are mathematical statements describing either the head or the groundwater flux within a model domain (Anderson and Woessner, 1992). Correct selection of boundary conditions is a critical step in model construction because boundaries largely determine the flow pattern in steady-state models. Boundary conditions can represent either physical boundaries, such as impermeable rock, or hydraulic boundaries, such as groundwater divides or streamlines. The following types of boundary conditions are used with the SACFEM2013:

- **Head-dependent flux:** The flux across the boundary is calculated as a function of a defined head and a resistance term (which regulates seepage) by using an appropriate governing flow equation.
- **Specified-flux:** A prescribed groundwater flux is defined along the boundary or within the model domain.

### 3.2.4.1 Head-dependent Flux Boundaries

**Groundwater-Surface Water Interaction.** A head-dependent boundary condition was chosen to simulate the major streams, flood bypasses, and reservoirs within the SVGB. The MicroFEM wadi system was used to implement streams within the model domain. MicroFEM's wadi package is a two-way, head-dependent boundary condition (that is, it can act as a source of groundwater recharge or as a groundwater sink) that calculates the magnitude and direction of nodal fluxes by using the relative values of the user-specified stream stage (wh1) and the calculated head in the upper aquifer (h1), but is limited by a critical depth (wl1). When calculated groundwater elevations fall below this critical depth, it is assumed that the water table de-couples from the river system, and the leakage rate from the river to the aquifer becomes constant. The equations that govern operation of the wadi package are as follows:

Groundwater discharge to a stream is simulated if h1 > wh1:

$$Q_{outflow} = a * (h1 - wh1) / wc1 \quad (3)$$

In coupled streams (groundwater elevation is above the stream bottom elevation), groundwater recharge from a stream is simulated if h1 < wh1:

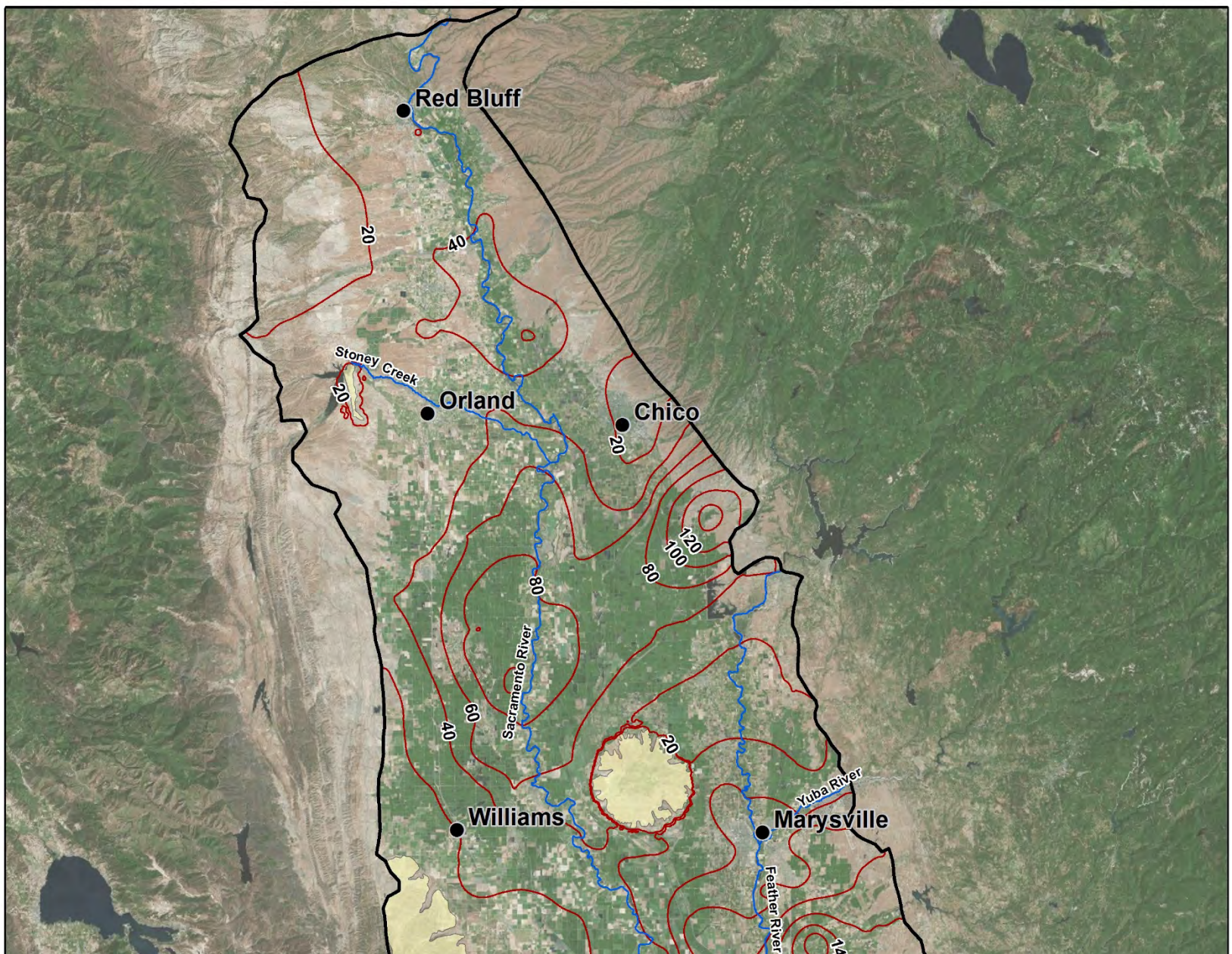
$$Q_{inflow} = a * (wh1 - h1) / wc1 \quad (4)$$

In de-coupled streams (groundwater elevation is below the stream bottom elevation), groundwater recharge from a stream is simulated if:

$$Q_{inflow} = a * (wh1 - wl1) / wc1 \quad (5)$$

Where:

Q = volumetric flux ($L^3/T$)
a = nodal area ($L^2$)
h1 = simulated groundwater elevation in layer 1 (L)
wh1 = simulated stream stage (L)
wl1 = stream bottom elevation (L)
wc1 = resistance across the streambed ($T^{-1}$)




**LEGEND**

- City
- Major Stream
- SACFEM2013 Model Boundary
- SACFEM2013 Bedrock Outcrop Areas
- Contour of Equal Horizontal Hydraulic Conductivity (feet per day)

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 12**
**Distribution of Horizontal Hydraulic Conductivity Model Layers 1 through 5**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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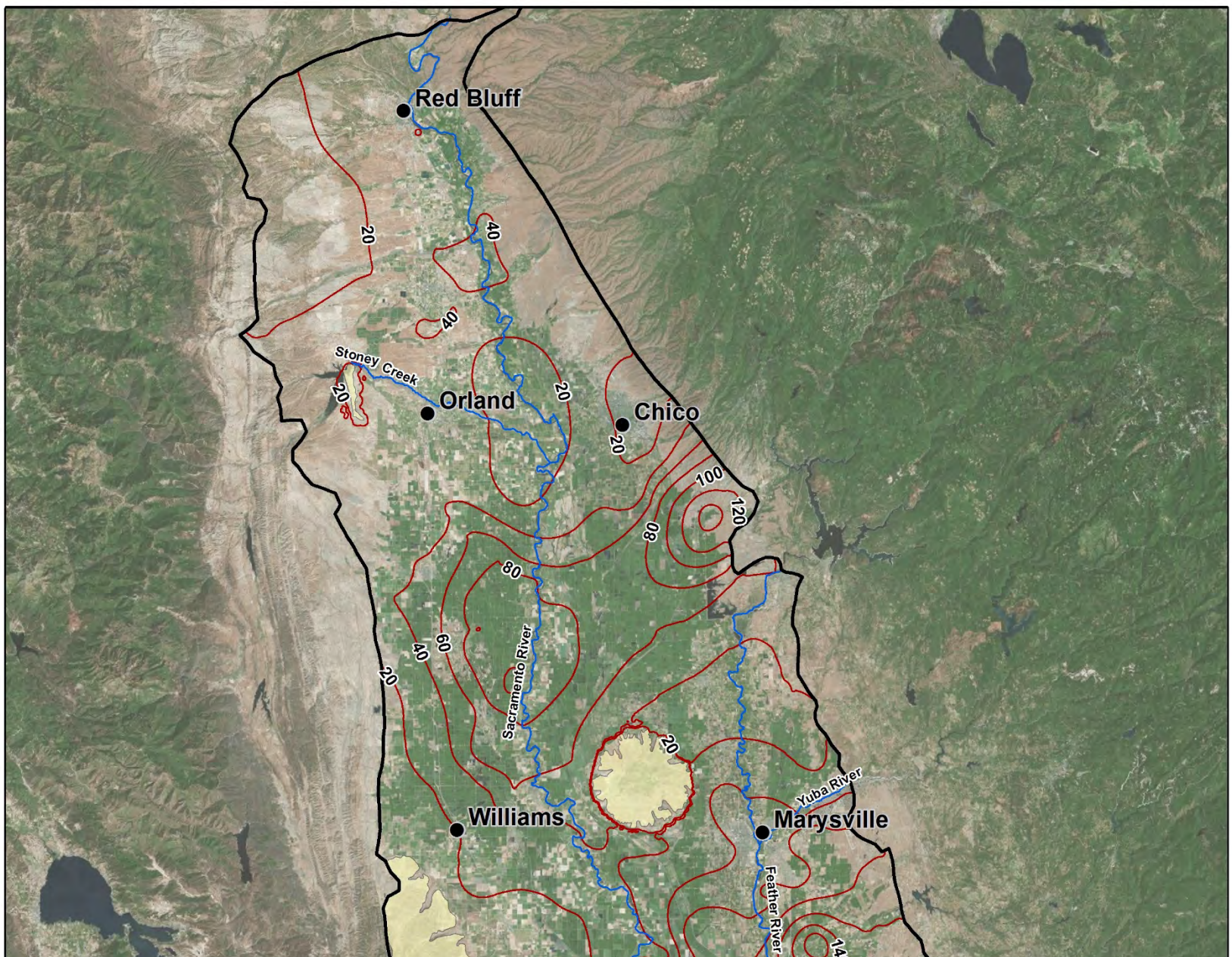


**LEGEND**

- City
- Major Stream
- SACFEM2013 Model Boundary
- SACFEM2013 Bedrock Outcrop Areas
- Contour of Equal Horizontal Hydraulic Conductivity (feet per day)

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 13**
**Distribution of Horizontal Hydraulic Conductivity Model Layers 6 and 7**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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Nodal area is a grid-dependent parameter that can be automatically calculated within MicroFEM. In general, the nodal area around a node that represents a discrete reach of a stream is greater than the surface area of that stream along the reach in the field. The effective resistance term (wc1) incorporates an areal correction factor to account for this discrepancy; the wadi resistance term (wc1) is a measure of the resistivity of the streambed sediments. The resistances are calculated as follows:

$$wc1 = Dr/Kv * (a/LW) \quad (6)$$

Where:

Dr = thickness of streambed sediments (L)
Kv = vertical hydraulic conductivity of streambed sediments (L/T)
L = stream length represented by the model node (L)
W = field width of the wetted river channel within the stream reach represented by L (L)

Fifty individual streams are simulated with MicroFEM's wadi package in the current version of SACFEM2013. Stream locations were digitized from existing base maps and USGS topographic quad sheets and imported into the model domain. Figure 14 presents the locations of surface water features included in SACFEM2013. Stream length within a given node is a grid-dependent variable calculated by MicroFEM at each river node. The stream-length term is generally overestimated by MicroFEM at stream confluences. Manual corrections of this term were made where necessary. Streambed thickness was assumed to be 3.28 feet (1 meter) for all river nodes. Assumptions of streambed Kv were based on the type of streambed deposits expected given stream size. Further, the streambed Kv for individual streams was included as a calibration parameter for SACFEM2013. Figure 15 presents the final distribution of streambed Kv. These data are also included in Table 2. Streams draining the Sierra Nevada were generally assigned lower streambed Kv values, with all streams except the Bear River and Big Chico Creek having values of 6.6 ft/day (0.0023 centimeters per second [cm/s]) or less. Westside streams were assigned higher values, with most having assigned Kv values greater than or equal to 16.4 ft/day (0.0058 cm/sec).

Wetted stream width was calculated from aerial photographs at two locations along each stream. Table 3 presents the average wetted stream width included in SACFEM2013. Few streams showed greater variability in width to necessitate developing a continuously variable distribution along the stream length. This was accomplished by estimating wetted stream width at several points via examination of aerial photographs and fitting a polynomial to the data points to interpolate between the measured points. The ranges of wetted stream width are included in Table 3 for these streams.

***Representation of Streams.*** Previous versions of SACFEM included average stream stage elevations (wh1) in the model simulations that did not vary through time. SACFEM2013 incorporates transient stream stage elevations to improve the representation of stream-groundwater interaction under varying hydrologic conditions. Review of historical river stage data shows that stage along the Sacramento and Feather rivers can vary by up to approximately 20 feet between high winter flows and low summer flows. Figure 16 is a plot of historical stage data for the Sacramento and Feather Rivers that illustrates this variability.

A data set of transient stream stage (wh1) was developed for use in SACFEM2013. This involved multiple steps and several assumptions as described in the following sections. There are 55 rivers, streams, and surface water canals or drains and reservoirs explicitly represented in SACFEM2013 (see Figure 14). These 55 surface water features are represented by approximately 5,500 model nodes. As discussed in Section 2.1, SACFEM2013 simulates a 41-year period from WY1970 through WY2010 with 492 monthly time-steps. Therefore, transient stream stage inputs for SACFEM2013 number approximately 2.7 million separate inputs for the entire simulation period (i.e., 5,500 nodes multiplied by 492 time-steps).

***Estimating Streambed Elevations.*** The first step in developing transient stream stage inputs was to estimate the streambed elevation for each stream node. MicroFEM input for stream boundary conditions consists of a water surface elevation (WSE) for each node that must relate to the model streambed elevation for the

node. Streambed elevations must also relate to model ground surface elevation for surrounding nodes. Therefore, a consistent vertical datum must be used for ground surface, streambed, and WSE.

The ground surface in SACFEM2013 is based on 30-meter digital elevation model (DEM) data. Model ground surface was developed through a GIS analysis that intersected the SACFEM2013 grid with 30-meter DEM data and calculated statistics for areas that contribute to each SACFEM2013 node. Statistics include the maximum, minimum, and mean elevations for areas that contribute to each node. Ground surface elevation for each node was assumed to be equal to the mean DEM elevation. An initial streambed elevation was estimated as the minimum DEM elevation for the area that contributes to each stream node.

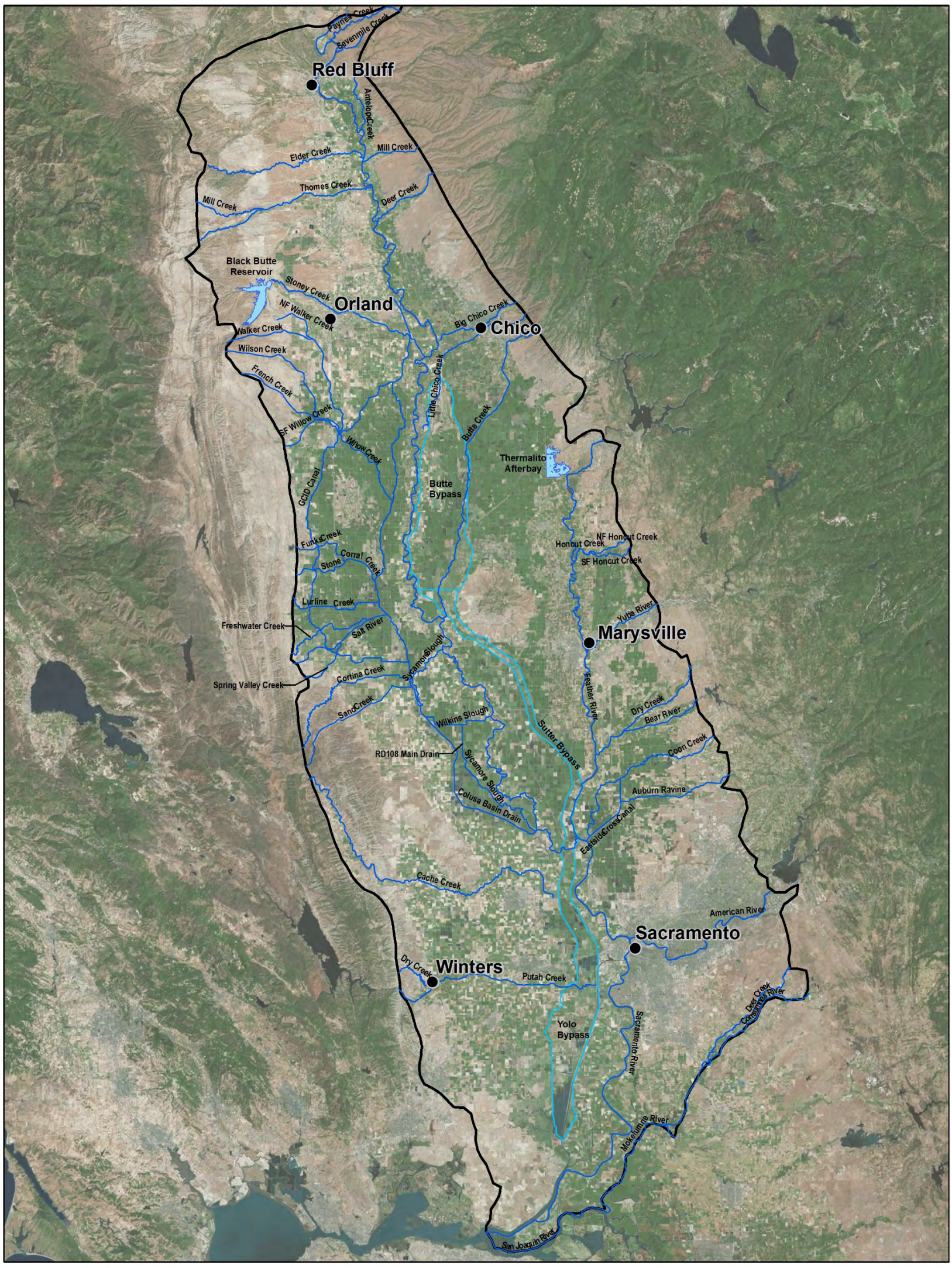
Minimum DEM elevations, or initial streambed elevations, for each stream were reviewed and plotted versus stream node distance from the confluence. These plots illustrate initial streambed elevation based on DEM data from downstream to upstream. Figure 17 is an example of the initial streambed elevation data for all Sacramento River stream nodes.

Review of initial streambed elevations for many streams showed unrealistic increases and decreases in streambed elevations between nodes. For the Sacramento River, minimum DEM elevations provided streambed elevations that are generally flat in the lower reaches of the Sacramento River in and near the Sacramento-San Joaquin River Delta, and a steeper streambed slope at the upstream end of the model. These are expected results based on the topography of the Sacramento Valley. However, there are also areas of significant variation in streambed elevation such as the reach between 75 and 100 miles upstream from the confluence with the San Joaquin River (see Figure 17). These variations illustrate limitations of using 30-meter DEM data and GIS analysis to estimate streambed elevation. Therefore, for each stream, a polynomial trend line was fit through the minimum DEM elevations to provide a more ordered set of streambed elevations. Figure 18 illustrates the trend line used to estimate streambed elevation along the Sacramento River. The trend line provides a set of well-ordered streambed elevations that decrease from upstream to downstream while generally following the topography of the basin.

***Stream Stage.*** A well-ordered estimate of streambed elevation is needed to best utilize available stage and flow data. SACFEM2013 stream stage inputs were developed to represent historical stage that occurred in each surface water feature. Therefore, historical stream stage and flow data were collected and analyzed. These data were collected from a variety of sources including USGS records, DWR gage records and publications, and available data from local water districts and agencies. Available stream stage data are frequently based on different vertical datums, including elevations for individual gages that cannot be related to a standard vertical datum such as North American Vertical Datum of 1988 (NAVD 88). Therefore, it is not possible to establish a consistent vertical datum for all available stage and flow data. Additionally, many gaged streams report only stream flow, not stage, and rating curves are not readily available for most of these streams, or if available, rating curves do not provide the vertical datum.

To utilize as much of the available gage data as possible while addressing the issue of multiple or unknown vertical datums, historical stage data were assumed to approximate stream depth above the streambed elevation. Historical stream depths were then added to estimated streambed elevations to determine water surface elevations for input into SACFEM2013.

There were multiple challenges to develop a complete and realistic dataset of water surface elevations for all surface water features in SACFEM2013. These challenges included estimates for ungaged streams or gaged streams with an incomplete record, estimates for stage along the entire length of the stream based on a single gage location, and methods to estimate water surface elevations at stream confluences.




**LEGEND**

- City
- SACFEM2013 Stream
- Flood Bypass
- SACFEM2013 Model Boundary

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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0 6 12 24 Miles

**Figure 14**
**SACFEM2013 Surface Water Features**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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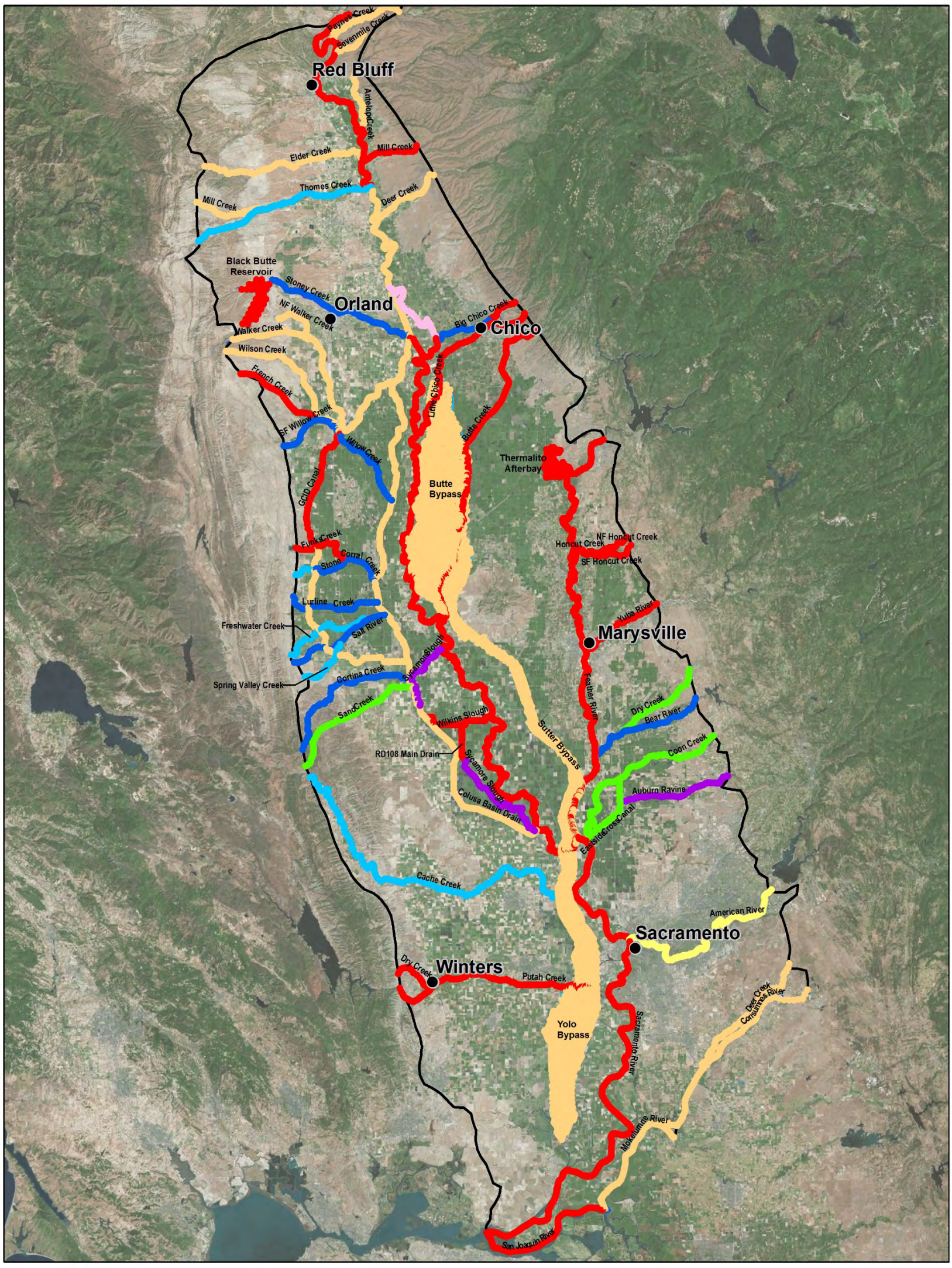


**LEGEND**

- City
- SACFEM2013 Model Boundary

**Streambed Vertical Hydraulic Conductivity (feet per day)**

| | |
|---|---|
| 0.1 | 3.3 |
| 0.3 | 6.6 |
| 0.6 | 16.4 |
| 1.6 | 32.8 |

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 15**
**Distribution of Vertical Hydraulic Conductivity, Surface Water Features**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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TABLE 2
**Assumed Streambed Vertical Hydraulic Conductivity**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Stream | Vertical Hydraulic Conductivity (foot/day) | Vertical Hydraulic Conductivity (centimeters/second) |
|---|---|---|
| American River | 0.1 | 3.47E-05 |
| Antelope Creek | 0.3 | 1.16E-04 |
| Auburn Ravine | 0.7 | 2.31E-04 |
| Bear River | 32.8 | 1.16E-02 |
| Big Chico Creek | 3.3 – 32.8 | 1.16E-03 – 1.16E-02 |
| Black Butte Reservoir | 3.3 | 1.16E-03 |
| Butte Bypass | 0.3 | 1.16E-04 |
| Butte Creek | 3.3 | 1.16E-03 |
| Cache Creek | 16.4 | 5.79E-03 |
| Colusa Basin Drain | 0.3 | 1.16E-04 |
| Consumnes River | 0.3 | 1.16E-04 |
| Coon Creek | 6.6 | 2.31E-03 |
| Cortina Creek | 32.8 | 1.16E-02 |
| Deer Creek (Tehama County) | 0.3 | 1.16E-04 |
| Deer Creek (Sacramento County) | 0.3 | 1.16E-04 |
| Dry Creek (Yolo County) | 3.3 | 1.16E-03 |
| Dry Creek (Yuba County) | 6.6 | 2.31E-03 |
| Eastside Cross Canal | 6.6 | 2.31E-03 |
| Elder Creek | 0.3 | 1.16E-04 |
| Feather River | 3.3 | 1.16E-03 |
| French Creek | 3.3 | 1.16E-03 |
| Freshwater Creek | 16.4 | 5.79E-03 |
| Funks Creek | 3.3 | 1.16E-03 |
| Glen Colusa Irrigation District Canal | 0.3 – 3.3 | 1.16E-04 – 1.16E-03 |
| Honcut Creek | 3.3 | 1.16E-03 |
| Little Chico Creek | 3.3 | 1.16E-03 |
| Lurline Creek | 32.8 | 1.16E-02 |
| Mill Creek (Eastern Tehama County) | 3.3 | 1.16E-03 |
| Mill Creek (Western Tehama County) | 0.3 | 1.16E-04 |
| Mokelumne River | 0.3 | 1.16E-04 |
| North Honcut Creek | 3.3 | 1.16E-03 |
| North Fork Walker Creek | 0.3 | 1.16E-04 |
| Paynes Creek | 0.3 | 1.16E-04 |
| Putah Creek | 3.3 | 1.16E-03 |
| RD108 Main Drain | 3.3 | 1.16E-03 |
| South Honcut Creek | 3.3 | 1.16E-03 |
| Sacramento River | 0.3 – 3.3 | 1.16E-04 – 1.16E-03 |

TABLE 2
**Assumed Streambed Vertical Hydraulic Conductivity**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Stream | Vertical Hydraulic Conductivity (foot/day) | Vertical Hydraulic Conductivity (centimeters/second) |
|---|---|---|
| Salt River | 32.8 | 1.16E-02 |
| San Joaquin River | 3.3 | 1.16E-03 |
| Sand Creek | 6.6 | 2.31E-03 |
| Seven Mile Creek | 0.3 | 1.16E-04 |
| South Fork Willow Creek | 32.8 | 1.16E-02 |
| Spring Valley Creek | 16.4 | 5.79E-03 |
| Stone Corral Creek | 16.4 – 32.8 | 5.79E-03 – 1.16E-02 |
| Stoney Creek | 3.3 – 32.8 | 1.16E-03 – 1.16E-02 |
| Sutter Bypass | 0.3 | 1.16E-04 |
| Lower Sycamore Slough | 0.7 | 2.31E-04 |
| Thermalito | 3.3 | 1.16E-03 |
| Thomes Creek | 16.4 | 5.79E-03 |
| Walker Creek | 0.3 | 1.16E-04 |
| Wilkins Slough Canal | 3.3 | 1.16E-03 |
| Willow Creek | 32.8 | 1.16E-02 |
| Wilson Creek | 0.3 | 1.16E-04 |
| Yolo Bypass | 0.3 | 1.16E-04 |
| Yuba River | 3.3 | 1.16E-03 |

TABLE 3
**Wetted Stream Width Values**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Stream Name | Wetted Stream Width (feet) |
|---|---|
| American River | 394 |
| Antelope Creek | 49 |
| Auburn Ravine | 33 |
| Bear River | 91 – 167 |
| Big Chico Creek | 49 |
| Butte Creek | 43 – 144 |
| Cache Creek | 39 – 108 |
| Colusa Basin Drain | 24 – 100 |
| | 98 |
| Coon Creek | 49 |
| Cortina Creek | 33 |
| Deer Creek (Tehama County) | 66 |
| Deer Creek (Sacramento County) | 49 |

Table 3
**Wetted Stream Width Values**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Stream Name | Wetted Stream Width (feet) |
|---|---|
| Dry Creek (Yuba County) | 49 |
| Dry Creek (Yolo County) | 49 |
| Eastside Cross Canal | 49 |
| Elder Creek | 13 – 79 |
| Feather River | 233 – 758 |
| French Creek | 16 |
| Freshwater Creek | 33 |
| Funks Creek | 33 |
| Glen Colusa Irrigation District Canal | 43 – 242 |
| Honcut Creek | 49 |
| Little Chico Creek | 20 – 144 |
| Lurline Creek | 33 |
| Mill Creek (Eastern Tehama County) | 49 |
| Mill Creek (Western Tehama County) | 33 |
| Mokelumne River | 312 |
| North Fork Walker Creek | 33 |
| North Honcut Creek | 66 |
| Paynes Creek | 33 |
| Putah Creek | 61 – 95 |
| RD108 Main Drain | 65 |
| Sacramento River | 230 – 4,433 |
| Salt River | 16 |
| San Joaquin River | 3,248 |
| Sand Creek | 33 |
| Sevenmile Creek | 33 |
| South Fork Willow Creek | 33 |
| South Honcut Creek | 49 |
| Spring Valley Creek | 16 |
| Stone Corral Creek | 33 |
| Stoney Creek | 56 – 131 |
| Sycamore Slough | 10 – 115 |
| Thomes Creek | 49 |
| Walker Creek | 49 |
| Wilkins Slough Canal | 49 |
| Willow Creek | 33 |
| Wilson Creek | 33 |
| Yuba River | 230 – 356 |

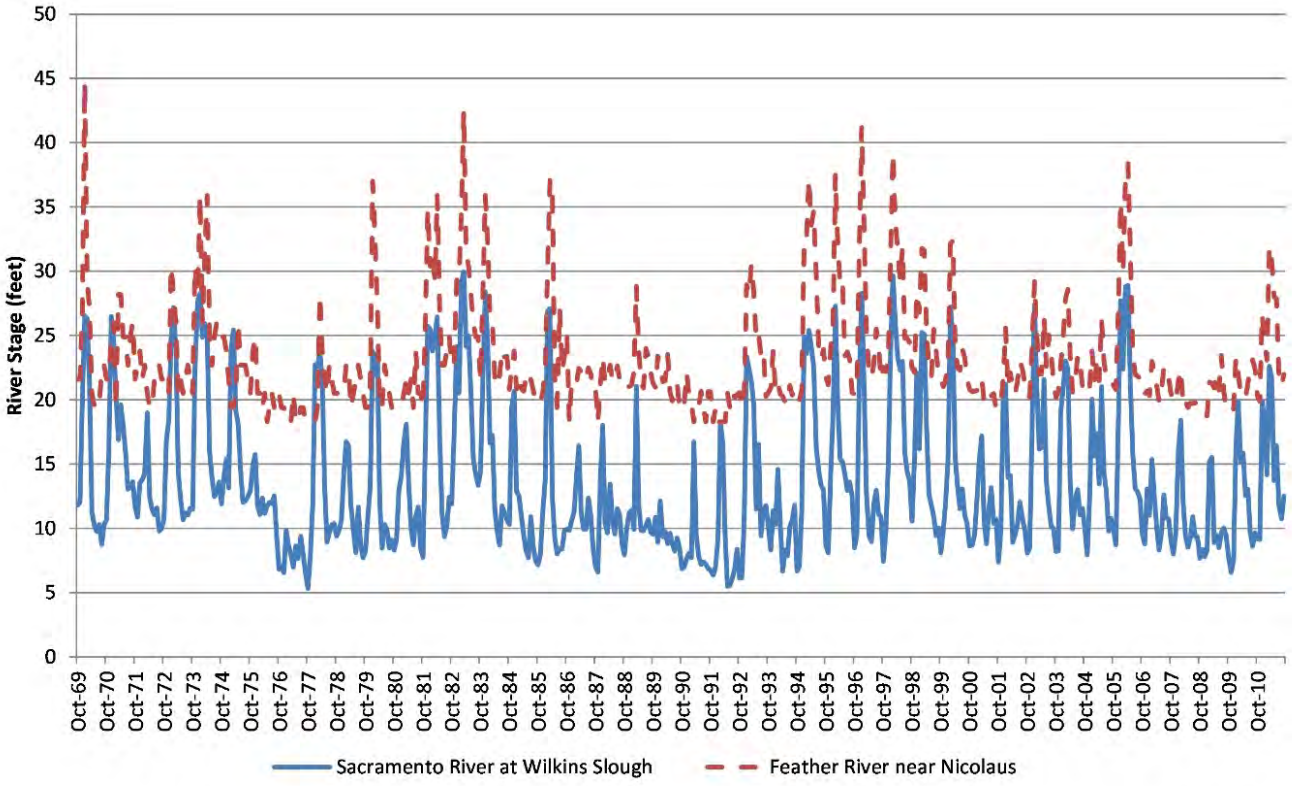


**Figure 16**
**Historical Sacramento and Feather River Stage**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

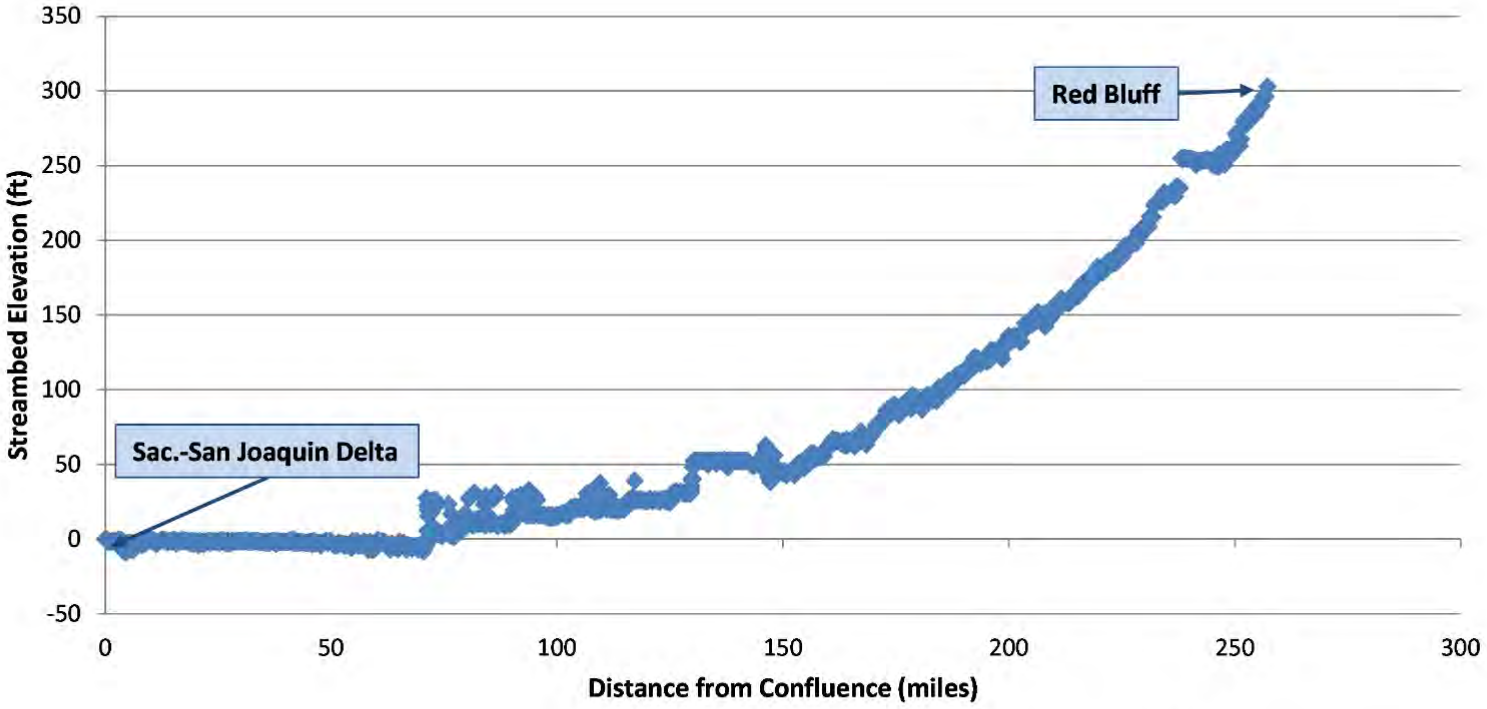


**Figure 17**
**Initial Sacramento River Streambed Elevation based on 30-meter Digital Elevation Model Data**

*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

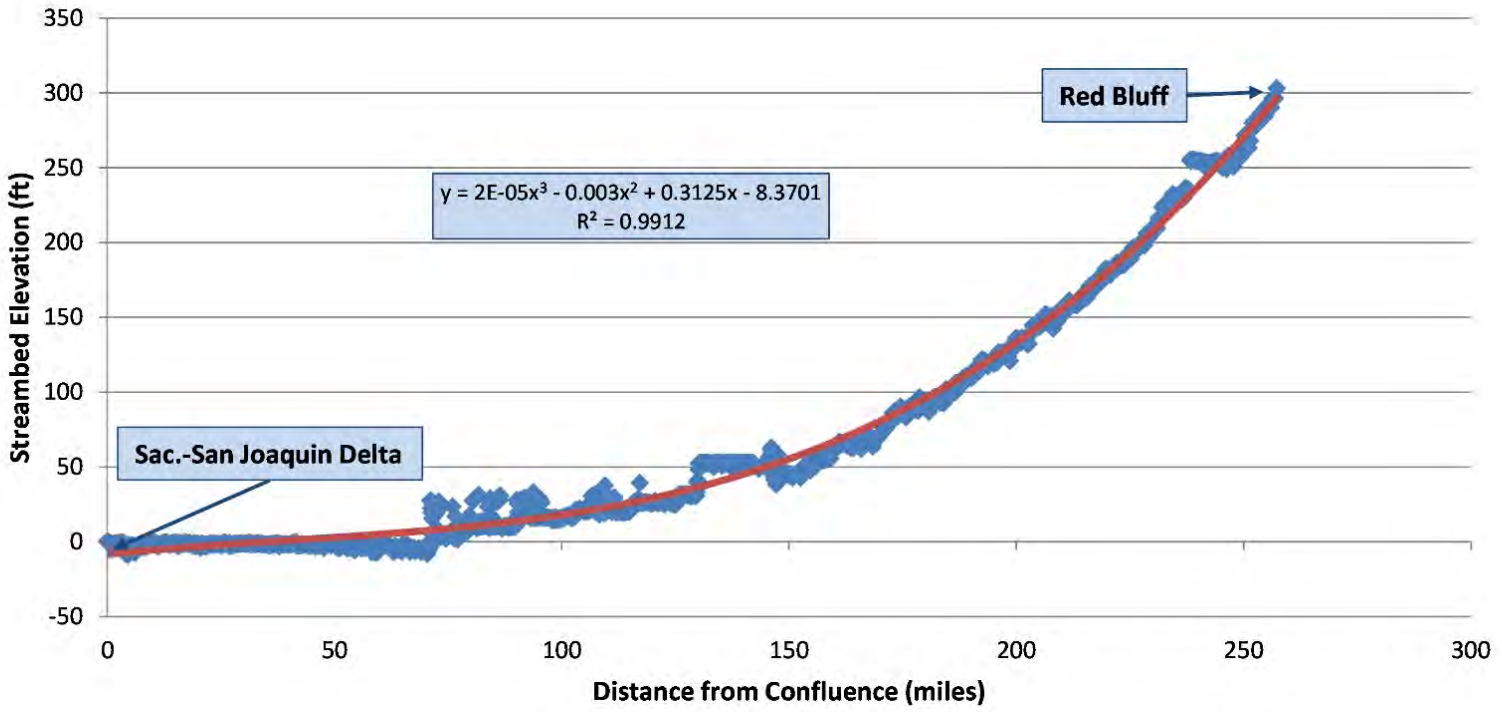


**Figure 18**
**Sacramento River Streambed Elevation based on Regression Trendline**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

***Ungaged Streams and Incomplete Records.*** Review of available stream stage and flow data identified available records for all or a part of the simulation period for 35 streams and canals explicitly represented in SACFEM2013. The remaining surface water features were estimated using data from nearby and similar gaged streams. The majority of ungaged streams are small streams on the west side of the Colusa Basin or small streams near the Bear River. Incomplete gage records were extended or missing periods filled by correlation with nearby and similar streams with complete records, when an adequate correlation could be developed. When an adequate correlation could not be developed, these streams were estimated based on nearby and similar gaged streams.

***Stage along Length of Streams.*** Most gaged streams are gaged at only one location along the entire length of the stream. This information provides one data point on stream stage that must then be extended along the entire length of the stream for all stream nodes. Absent any additional data, it was assumed that depth of water at the gage location is uniform along the length of the stream. Multiple factors can affect stream stage along the length of the stream including watershed area contributing to flow, diversions and return flows from the stream, channel geometry, and others. Attempting to research and account for all such factors for each stream would be a significant undertaking beyond the scope of this project. Exceptions to this assumption are the Sacramento and Feather Rivers. Multiple gages for flow or stage exist along these two rivers, and these gages were used to develop SACFEM2013 inputs. Table 4 shows the gage data used to estimate stream depth along each river.

TABLE 4
**Gage Locations Used to Estimate Sacramento and Feather River Stage**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Sacramento River Gages | Feather River Gages |
|---|---|
| Bend Bridge | Gridley |
| Colusa | Yuba City |
| Wilkins Slough | Nicolaus |
| Verona | |
| Freeport | |

Water depth at stream nodes nearest gage locations was set equal to the gage record. Water depth at stream nodes between each gage location was interpolated based on stream distance. Water depths at stream nodes upstream of the most upstream gage (i.e., Bend Bridge on the Sacramento River and Gridley on the Feather River) were assumed to equal depth at the gage. Water depths in the Sacramento River downstream of Freeport were assumed to equal water depth at Freeport. Water depths in the Feather River between Nicolaus and the confluence with the Sacramento River were determined based on gage data at Nicolaus and the estimate of Sacramento River water surface elevation at the confluence as described in the following section.

***Stream Confluences.*** An additional review was undertaken and adjustment was made where tributary streams join the Sacramento and Feather Rivers. In some streams and time-steps, WSE in tributary stream nodes at the downstream end of the stream was below the calculated WSE in the trunk stream where the tributary entered. For these tributary streams and time-steps, the WSE in the tributary stream nodes was set equal to the WSE in the trunk stream to represent a back-water effect at the confluence. This adjustment was made at each tributary stream node where the calculated WSE was less than that in the trunk stream for the given time-step.

***Review and Quality Assurance.*** WSE inputs were calculated for each of the approximately 5,500 stream and canal nodes simulated in SACFEM2013 for each of the 492 model time-steps. A spreadsheet was developed to plot streambed and water surface elevation for a given stream and time-step as a method to review and

check the input files. A plot for each time-step was created and saved for a given stream, and all plots were compiled into a single audio video interleave (AVI) file to illustrate stream WSE throughout the simulation period. AVI files were reviewed to ensure that input WSEs were reasonable and varied appropriately through time.

Figure 19 is an example of individual time-step plots for the American River WSE. Figure 19 illustrates WSE and the streambed in February 1986 during a large flood event, and August 1992 during a critical drought.

Figure 19 illustrates change in American River WSE for these two months. Figures such as these were developed for each time-step and reviewed to ensure WSE increased and decreased appropriately through time and relative to simulated streambed elevation. These figures also illustrate how WSE at the downstream end of the American River was adjusted based on the WSE in the Sacramento River in these time-steps. WSE at nodes in the downstream end of the American River is controlled by stage in the Sacramento River in both figures. WSE in these nodes was set equal to the WSE in the Sacramento River at the confluence with the American to represent back-water effects in the lower American River and avoid having adjacent stream nodes with significant differences in simulated WSE.

***Representation of Flood Bypasses.*** A similar process was used to estimate water surface elevation within flood bypass areas in the SVGB. These areas differ from stream nodes in that the majority of nodes within the flood bypass areas are typically dry. However, during wet periods some or all of these nodes are flooded and represent a source of aquifer recharge in SACFEM2013.

**Definition of Flood Bypass Areas**. The first step in calculating WSE inputs in flood bypass areas was to delineate areas within the three major flood bypasses of the Butte Basin, Sutter Bypass, and Yolo Bypass. Each of these three major areas was further divided into sub-areas based on locations of major inflows or outflows. Existing GIS data on locations of levees and bypasses were used to identify bypass areas. Figure 20 illustrates the flood levee locations and the polygons used to represent the flood bypass areas and where those areas were subdivided.

After flood bypass areas were identified in GIS, bypass areas were intersected with the SACFEM2013 model grid to identify model nodes within bypass areas. This process identified 15,742 model nodes within bypass areas. Model ground surface elevation for these nodes was also identified based on 30-meter DEM data statistics for the area contributing to each node. The minimum elevation from the GIS intersection with DEM data was used as ground surface for nodes within bypass areas.

The approach to calculate WSE within flood bypass areas differs from that used for streams and other surface water features. An actual WSE was calculated based on historical flow data and flow-stage relationships from existing hydraulic models of the Sacramento River flood control system. Historical flow data were compiled from a variety of sources including USGS gage records and DWR's Water Data Library and California Data Exchange Center. Flows within bypass areas are from streams such as Butte and Cache Creeks plus flows over the Moulton, Colusa, Tisdale, Fremont, and Sacramento weirs. Flow goes over these weirs and into the bypass areas when stage is high in the Sacramento and Feather Rivers.

Flow was estimated at each of the lines that separate the flood bypass sub-areas on Figure 20. These separating lines represent cross section locations in the hydraulic model. For example, flow was estimated at the horizontal line that separates the upper Butte Basin area (BB1 Upper) from the middle Butte Basin area (BB2 Middle). Streams that contribute to flow in the upper Butte Basin area include Big and Little Chico creeks and Butte Creek. These flows were summed to estimate flow at the cross section between the upper and middle Butte Basin areas. Estimates of flow at downstream cross sections were made by adding additional inflows to the estimated flow at the upstream cross section. For example, flow at the cross section that separates the middle and lower Butte Basin (BB3 Lower) area was estimated by adding spills over the Moulton Weir to flows at the upstream cross section.

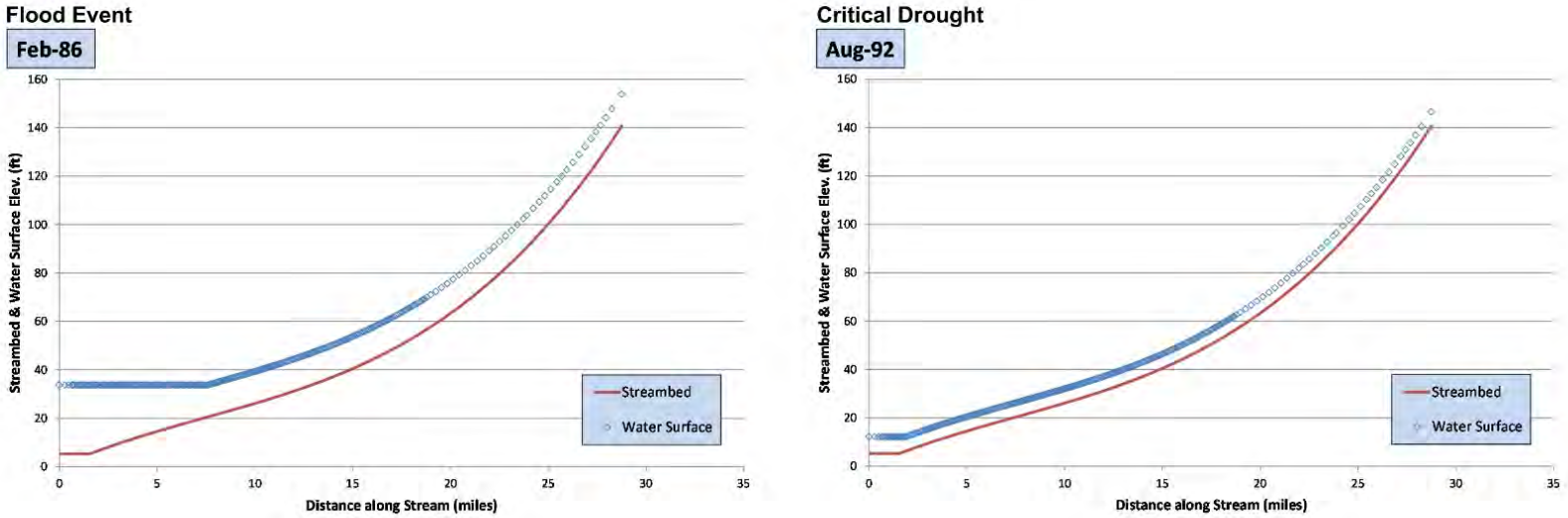


**Figure 19**
**American River Water Surface Elevation during Flood Event and Drought**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

Flows at each cross section were used to calculate a WSE at the cross section. Flow-stage relationships from hydraulic models were used to estimate WSE with the same vertical datum as the ground surface in SACFEM2013. It was assumed that WSE changed linearly from upstream to downstream, and WSE at nodes between cross sections was interpolated from WSE at the upstream and downstream cross sections based on distance. WSE in the most upstream section, upper Butte Basin area (BB1 Upper), and most downstream section, lower Yolo Bypass (YB4 Lower), was assumed to be constant. This assumption is reasonable for the lower Yolo Bypass where flow enters the Sacramento-San Joaquin Delta. This assumption was made for the upper Butte Basin because there is little data to estimate inundated areas.

Calculated WSE was compared to ground surface elevation for each node to determine if the node was flooded. Some nodes within flood bypass areas are at higher elevation and may not flood at the same time as lower elevation nodes. WSE is calculated only for nodes that are flooded during a given time-step. Nodes that are not flooded are identified with a WSE of "-99" in the input files.

**Review and Quality Assurance.** WSE inputs are calculated for each of the 15,742 model nodes located within flood bypass areas for each of the 492 model time-steps. A spreadsheet was developed to plot WSE for all bypass area nodes compared to ground surface to review and check input files in each time-step. These plots were saved and compiled into a single AVI file to allow for easier review. Figure 21 is an example of one plot for the January 1995 time-step when most of the flood bypass areas were flooded.

Figure 21 is a plot of ground surface and WSE for each of the 15,742 model nodes in January 1995. The x-axis is the northing, so that the left side of the plot illustrates the downstream end of the flood bypass areas, the lower Yolo Bypass, and the right side illustrates the upstream end or upper Butte Basin. Cross sections are denoted by the black vertical lines that also mark changes in slope in the WSE line. Multiple ground surface elevations for a given northing indicate the multiple model nodes in the east-west direction across the flood bypass area. In the lower Yolo Bypass, many nodes have ground surface elevations above the WSE in this time-step and are not flooded. This is consistent with the topography of the lower Yolo Bypass where areas on the western side of the bypass are at higher elevation and flood less frequently than the eastern side.

***Reservoir Water Surface Elevation.*** The final surface water bodies simulated in SACFEM2013 using MicroFEM's wadi package are the major reservoirs located within the interior of the SVGB, Black Butte Reservoir and Thermalito Afterbay. The lake bottom elevations were assumed to be constant for both reservoirs, and were simulated as 100 feet below the average DEM elevation (assumed to represent lake stage) for Black Butte Reservoir and 40 feet below the average DEM elevation for Thermalito Afterbay. The wc1 values were assumed to be 1 for both reservoirs. The lake-stage elevation was assumed to be constant spatially across each reservoir; however, historical data were evaluated to develop monthly-variable lake-stage datasets for the SACFEM2013 simulation period.

**Groundwater Discharge to Land Surface.** MicroFEM's drainage package was used to simulate boundary conditions across the top surface of the model, excluding nodes where wadi boundaries exist. Drainage boundary conditions are one-way head-dependent boundaries that allow the transfer of water out of the model domain only. The elevation of the drain boundaries were set at the land surface. The drain boundaries were included in the model to represent a combination of surficial processes that occur in areas of shallow groundwater, including evapotranspiration and groundwater discharge to the surface. Additionally, specific streams and flood bypasses were converted from wadi boundary conditions to drain boundary conditions during periods when a given surface water body was interpreted as being dry.

Groundwater discharge to a drain is simulated as follows if h1 > dh1:

$$Q_{outflow} = a * (h1 - dh1) / dc1 \quad (7)$$

Where:

Q = volumetric flux ($L^3/T$)
a = nodal area ($L^2$)
h1 = simulated groundwater elevation in model layer 1 (L)
dh1 = simulated drainage boundary elevation (L)
dc1 = resistance of the drainage boundary ($T^{-1}$)

Groundwater discharge to a drain is simulated as follows if h1 < dh1:

$$Q_{outflow} = 0 \quad (8)$$

The parameter dc1 represents the drain conductance and is a measure of the resistance to flow across the drain boundary. The dc1 was assumed to be 500 throughout the model domain.

#### 3.2.4.2 Specified-flux Boundaries

Three sets of specified-flux boundary conditions were implemented in the SACFEM2013 model. These conditions are as follows: (1) deep percolation of applied water and precipitation along with agricultural pumping, (2) mountain-front recharge, and (3) urban pumping. Each is discussed in more detail below.

**Deep Percolation of Applied Water, and Precipitation and Agricultural Pumping.** The first set of specified-flux boundary conditions reflects the deep percolation of precipitation and applied water across the Valley, as well as the regional agricultural pumping. The deep percolation flux values were applied to every surface node in the model. The pumping stresses due to agricultural pumping were applied at selected locations in model Layers 2 through 4 (the depths of the regional producing zones across the Valley). The spatial distribution and magnitudes of these fluxes were derived from the surface water budget calculations described in full detail in the Surface Water Budget, Section 3.2.5.

**Mountain-front Recharge.** The second set of specified-flux boundary conditions represents the subsurface inflow of precipitation falling within the Sacramento River watershed but outside the extent of the model domain. To estimate these flux values, the USGS 30-meter DEM along with GIS-based hydrography coverages for the SVGB were used to delineate the drainage areas that are tributary to the model domain but fall outside of the watersheds of the streams explicitly represented in the model. It is these areas that can contribute water to the model domain but are not accounted for in the wadi boundary conditions defined in the model. After the extents of these watershed areas were defined, they were intersected with monthly PRISM[4] rainfall datasets using GIS tools, and the volume of precipitation falling on the watershed was computed. Using the computed total volume of precipitation, the deep percolation to the groundwater system was calculated using the following empirical relationship developed by Turner (1991):

$$DP = (PPT-2.32)*(PPT)^{0.66} \quad (9)$$

Where:

DP = average annual deep percolation of precipitation (inches per year)
PPT = annual precipitation (inches per year)

The process that was used to estimate the quantity of subsurface inflow, otherwise known as mountain-front recharge, is summarized as follows:

[4] http://prism.oregonstate.edu/

1. The area of each drainage basin tributary to the model domain that is not represented by streams explicitly simulated in SACFEM2013 was computed using a GIS-based analysis of the land surface topography. The extent of these smaller watersheds is shown on Figure 22.
2. Each drainage area polygon was then intersected with a GIS coverage of annual total rainfall estimated using the PRISM model for each year of the simulation period. This distribution of annual average rainfall was then used to calculate the total volume of rainfall falling on the small watershed areas, and an overall average rainfall rate was computed (inches per year).
3. The total annual rainfall rate was then used to compute a deep percolation quantity using the relationship between annual rainfall and deep percolation rate developed by Turner (1991) and described above.
4. The annual volume of deep percolation computed in Step 3 was then converted into monthly values that were based on the monthly distribution of streamflow measured in ungaged sections of Deer Creek (Table 5). These monthly deep percolation quantities were then introduced at the model domain boundary of each small watershed polygon using injection wells into Layer 1. The quantity applied to each model boundary node was proportional to boundary length of each element divided by the total boundary length of the drainage polygon.
5. The deep percolation rates for individual drainage basins were adjusted during SACFEM2013 calibration to improve the match between simulated and measured groundwater elevations. Final factors applied to the deep percolation rates range from 0.5 to 1.5 (Table 6).

TABLE 5
**Monthly Distribution of Total Annual Mountain Front Recharge**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Month | Percentage of Annual Mountain Front Recharge (%) |
|---|---|
| January | 14.2 |
| February | 15.2 |
| March | 15.4 |
| April | 13.6 |
| May | 10.3 |
| June | 5.1 |
| July | 3.1 |
| August | 2.6 |
| September | 2.4 |
| October | 3.0 |
| November | 4.9 |
| December | 10.2 |




**LEGEND**

- City
- Major Stream
- Flood Bypass
- Levee
- SACFEM2013 Model Boundary

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 20**
**Flood Bypass Areas and Subareas**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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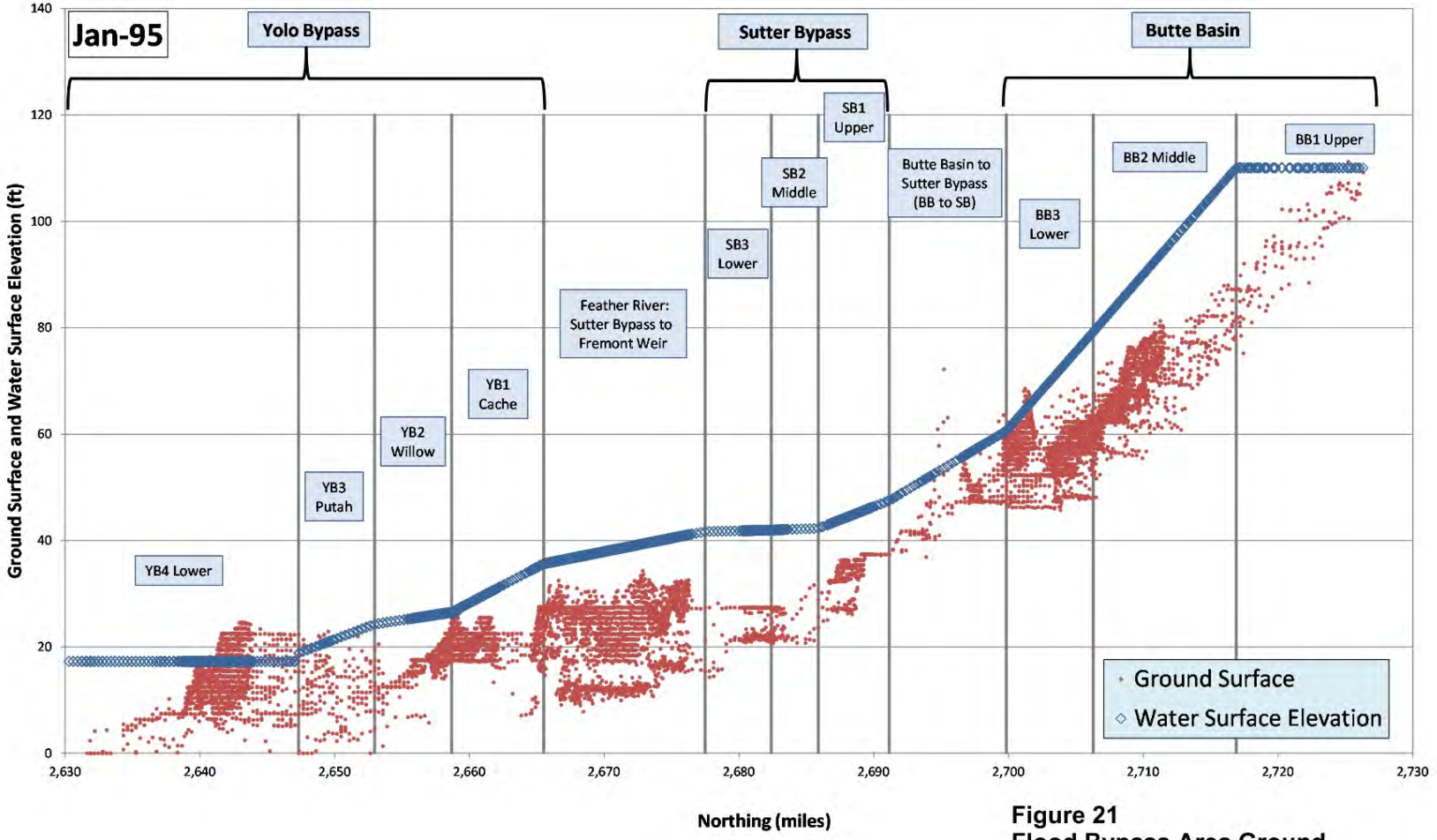


**Figure 21**
**Flood Bypass Area Ground Surface and Water Surface Elevation**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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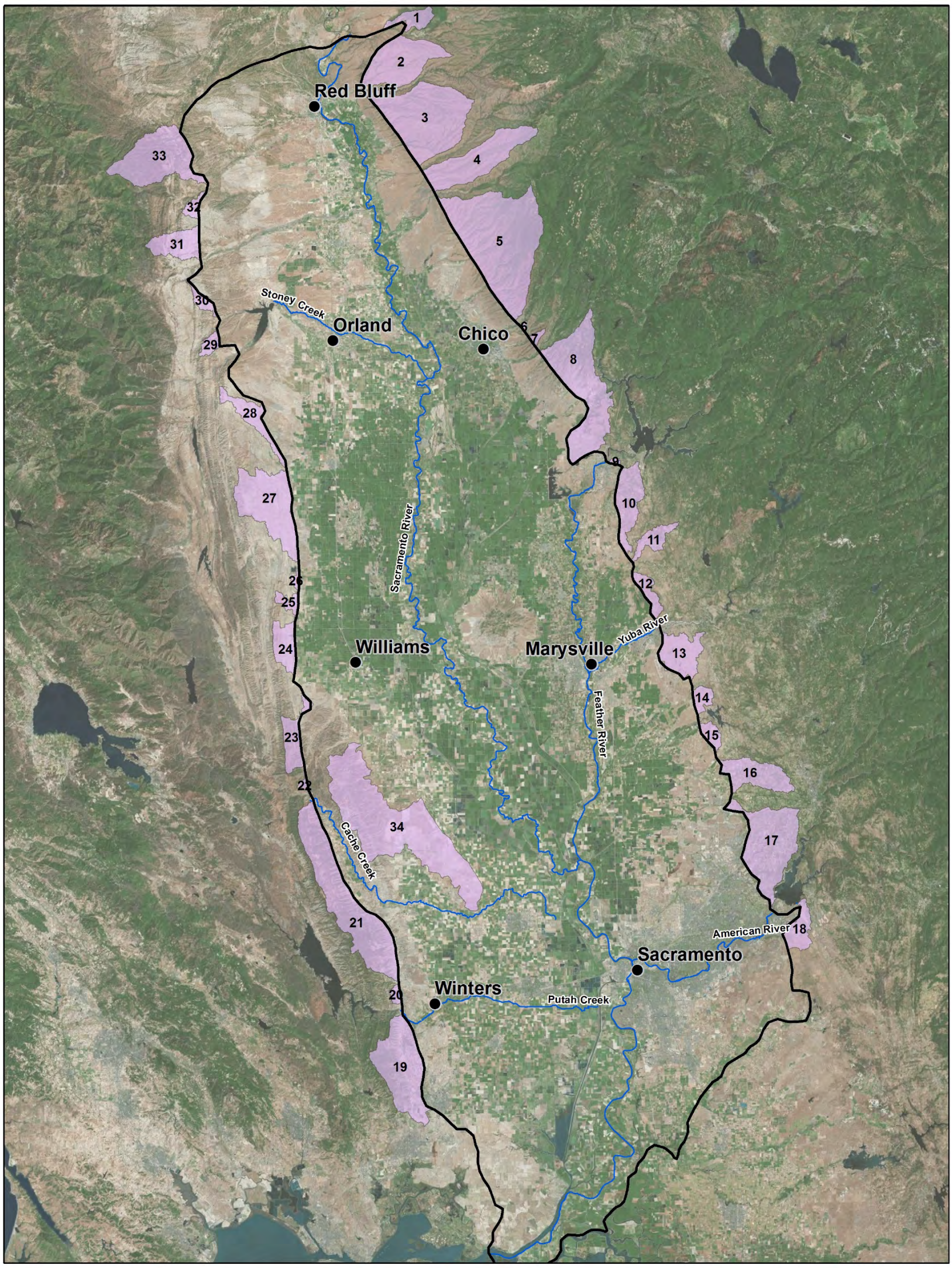


**LEGEND**

- City
- Major Stream
- SACFEM2013 Model Boundary
- SACFEM2013 Mountain Front Polygon

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 22**
**Mountain Front Recharge Watershed Areas**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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TABLE 6
**Mountain Front Recharge Adjustment Factors**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Sub-watershed Number | Adjustment Factor | Sub-watershed Number | Adjustment Factor |
|---|---|---|---|
| 1 | 0.5 | 18 | 0.5 |
| 2 | 0.5 | 19 | 1.5 |
| 3 | 0.5 | 20 | 1 |
| 4 | 0.5 | 21 | 1 |
| 5 | 0.5 | 22 | 1.5 |
| 6 | 1 | 23 | 1.5 |
| 7 | 1 | 24 | 1 |
| 8 | 1 | 25 | 1 |
| 9 | 1 | 26 | 1 |
| 10 | 1 | 27 | 1 |
| 11 | 1 | 28 | 1 |
| 12 | 1 | 29 | 1 |
| 13 | 1 | 30 | 1 |
| 14 | 1.5 | 31 | 1 |
| 15 | 1.5 | 32 | 1 |
| 16 | 1.5 | 33 | 1 |
| 17 | 0.5 | 34 | 1 |

**Urban Pumping.** The final set of specified-flux boundary conditions applied in the SACFEM2013 model reflects urban pumping within the model domain. The distribution of agricultural pumping that was developed using the surface water budgeting methodologies described below does not include urban pumping. As a first step to estimate the quantity of urban pumping to apply to the model, the year 2010 U.S. Census[5] data were evaluated. Each municipal area with a population greater than 5,000 that used groundwater as a source of municipal supply was further assessed. For municipalities where urban water management plans were available, the reported annual groundwater use was simulated in SACFEM2013. For cities that do not have a current water management plan, a pumping volume that was based on an annual average per capita value of 271 gallons/capita/day was simulated. Further, municipalities in the northern Sacramento area pumping rates were assigned consistent with the SacIGSM model (WRIME, 2011). Table 7 presents the annual urban pumping volumes included in SACFEM2013. Urban pumping was assigned spatially to all SACFEM2013 nodes within a given city area and was apportioned equally to model Layers 2 through 4. Figure 23 presents the locations of municipalities and SacIGSM subareas included in SACFEM2013. The monthly variability in urban pumping quantity was distributed based on typical seasonal trends for municipal water use listed in Table 8.

[5] http://www.census.gov/2010census/

TABLE 7
**Urban Pumping**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Urban Area | SACFEM2013 Pumping Volume (acre-feet/year) | Source |
|---|---|---|
| Beale Air Force Base | 401 | Per Capita Estimate (census 2010) |
| Chico | 26,800 | 2010 Urban Water Management Plan |
| Colusa | 1,814 | Per Capita Estimate (census 2010) |
| Corning | 2,328 | Per Capita Estimate (census 2010) |
| Davis | 11,955 | 2010 Urban Water Management Plan |
| Dixon | 5,575 | Per Capita Estimate (census 2010) |
| Durham | 1,676 | Per Capita Estimate (census 2010) |
| Elk Grove | 46,484 | Per Capita Estimate (census 2010) |
| Florin | 14,434 | Per Capita Estimate (census 2010) |
| Gold River | 2,404 | Per Capita Estimate (census 2010) |
| Gridley | 2,000 | Per Capita Estimate (census 2010) |
| La Riviera | 3,282 | Per Capita Estimate (census 2010) |
| Lincoln | 962 | 2010 Urban Water Management Plan |
| Linda | 5,399 | Per Capita Estimate (census 2010) |
| Live Oak | 5,212 | Per Capita Estimate (census 2010) |
| Marysville | 2,365 | 2010 Urban Water Management Plan |
| Olivehurst and Plumas Lake | 2,900 | 2010 Urban Water Management Plan |
| Orland | 2,215 | Per Capita Estimate (census 2010) |
| Oroville | 0 | Urban Water Management Plan |
| Palermo | 0 | Urban Water Management Plan |
| Parkway, Fruitridge, and Lemon | 10,389 | Per Capita Estimate (census 2010) |
| Rancho Cordova | 19,678 | Per Capita Estimate (census 2010) |
| Red Bluff | 4,276 | Per Capita Estimate (census 2010) |
| Rio Vista | 2,420 | 2010 Urban Water Management Plan |
| Rocklin | 0 | 2010 Urban Water Management Plan for Placer Co. Water Agency |
| Rosemont | 6,890 | Per Capita Estimate (census 2010) |
| Roseville | 0 | Urban Water Management Plan |
| Sacramento | 0 | |
| South Oroville | 1,744 | Per Capita Estimate (census 2010) |
| Thermalito | 2,019 | Per Capita Estimate (census 2010) |
| University of California Davis | 1,758 | Per Capita Estimate (census 2010) |

TABLE 7
**Urban Pumping**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Urban Area | SACFEM2013 Pumping Volume (acre-feet/year) | Source |
|---|---|---|
| Vacaville | 6,500 | 2010 Urban Water Management Plan |
| Vineyard | 7,545 | Per Capita Estimate (census 2010) |
| West Sacramento | 14,808 | Per Capita Estimate (census 2010) |
| Williams | 1,556 | Per Capita Estimate (census 2010) |
| Willows | 1,937 | 2010 Urban Water Management Plan |
| Winters | 2,012 | Per Capita Estimate (census 2010) |
| Woodland | 13,921 | 2010 Urban Water Management Plan |
| Yuba City | 3,600 | 2005 Urban Water Management Plan |
| **North Sacramento SacIGSM Subarea** | | |
| Cal-AmAntelope | 3,784 | SacIGSM (1970-2004 average) |
| Cal-AmLincolnOaks | 8,092 | SacIGSM (1970-2004 average) |
| CarmichaelWD | 4,524 | SacIGSM (1970-2004 average) |
| CitrusHeightsWD | 3,202 | SacIGSM (1970-2004 average) |
| CityOfFolsom | 142 | SacIGSM (1970-2004 average) |
| CityOfSacramentoEast | 16,845 | SacIGSM (1970-2004 average) |
| CityOfSacramentoWest | 8,917 | SacIGSM (1970-2004 average) |
| FairOaksWD | 1,516 | SacIGSM (1970-2004 average) |
| McClellanPark | 3,634 | SacIGSM (1970-2004 average) |
| Natomas Unorganized | 2,488 | SacIGSM (1970-2004 average) |
| NatomasMWC East | 1,650 | SacIGSM (1970-2004 average) |
| NatomasMWC West | 1,953 | SacIGSM (1970-2004 average) |
| OrangevaleWC | 773 | SacIGSM (1970-2004 average) |
| Rio Linda North | 4,873 | SacIGSM (1970-2004 average) |
| Rio Linda South | 4,478 | SacIGSM (1970-2004 average) |
| SacIntlAirport | 3,670 | SacIGSM (1970-2004 average) |
| SacramentoSuburbanTownAndCountry | 27,164 | SacIGSM (1970-2004 average) |
| SacSuburbanNorthHighlands | 5,559 | SacIGSM (1970-2004 average) |
| SacSuburbanNorthridge | 14,318 | SacIGSM (1970-2004 average) |
| SanJuanWD | 527 | SacIGSM (1970-2004 average) |

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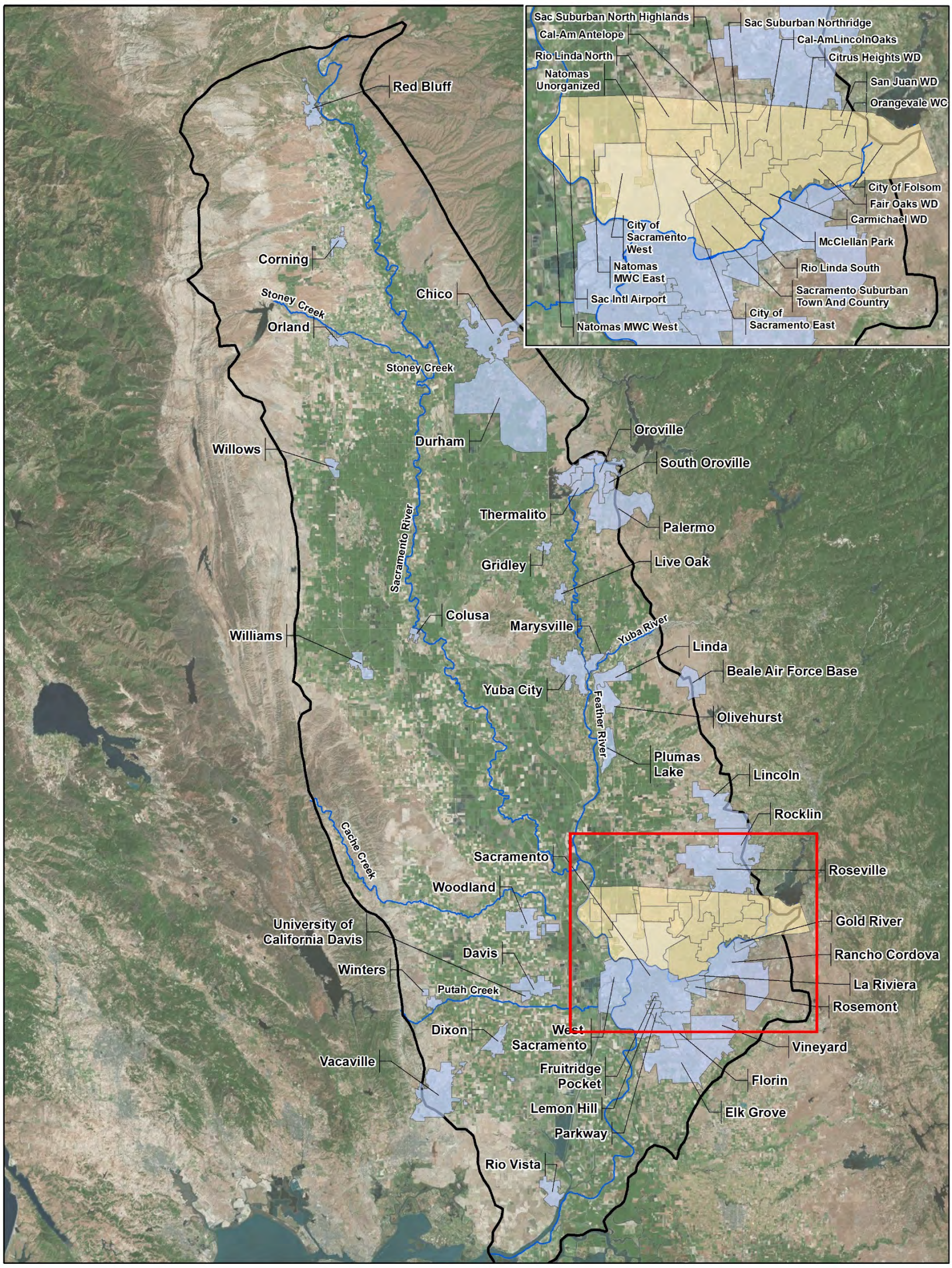


**Figure 23**
**Areas of Urban Groundwater Pumping**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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TABLE 8
**Monthly Distribution of Annual Urban Pumping**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Month | Percentage of Annual Total Urban Pumping |
|---|---|
| January | 4.6 |
| February | 4.6 |
| March | 4.6 |
| April | 6.1 |
| May | 6.1 |
| June | 10.9 |
| July | 14.8 |
| August | 15.3 |
| September | 13.1 |
| October | 10.7 |
| November | 4.6 |
| | 4.6 |

#### 3.2.4.3 No-flow Boundaries

A no-flow boundary was specified across the bottom boundary of the model, representing the freshwater/ brackish water interface.

### 3.2.5 Agricultural Water Budget

One of the most critical components to the successful operation of the SACFEM2013 is computing transient agricultural water budget components. These water budget components were estimated by using a variety of spatial information including land use, cropping patterns, source of irrigation water, surface water availability in different year types and locations, and the spatial distribution of precipitation. Surface water budget components include deep percolation of applied water, deep percolation of precipitation, and agricultural pumping.

#### 3.2.5.1 Background and Approach

A root-zone model was used to calculate agricultural water budgets and determine two major fluxes for input to SACFEM2013; deep percolation of precipitation and applied agricultural water and agricultural groundwater pumping. The root-zone model simulates the movement of irrigation water and precipitation that infiltrates below ground surface and into the root-zone where water is either used by plant evapotranspiration or drained as deep percolation when moisture content exceeds soil holding capacity.

#### 3.2.5.2 Overview of the Method

Root-zone dynamics are simulated using the Integrated Water Flow Model Demand Calculator (IDC) developed by DWR's Bay Delta Office. IDC calculates agricultural demand for applied water based on soil parameters and crop water use, and routes infiltrated applied water and precipitation through the soil column to determine evapotranspiration, deep percolation, and soil moisture storage. An approach was developed to create the needed inputs for SACFEM2013 without simulating the entire SACFEM2013 model domain and grid in IDC. This approach involved simulating root-zone water balances for one unit acre of land for each unique combination of crop type, soil, and historical precipitation throughout the SVGB. This process provides a time-series of deep percolation and demand for applied water. These unit-area time-

series are applied to uniquely classified areas developed in GIS to calculate time-series of deep percolation and agricultural groundwater pumping for each node.

#### 3.2.5.3 Development of GIS Dataset

A GIS dataset that contains information on crop type, soils, water source, and geographic location (used to determine the availability of surface water) was developed from a variety of sources. These datasets are intersected with the SACFEM2013 model grid to provide detailed data for the agricultural water budget for each SACFEM2013 model node. The following sections describe the source of data compiled in the GIS dataset.

**Land Use.** DWR's Land and Water Use Program historically conducted land use surveys of major agricultural counties throughout the state every 5 years. These data are in geo-referenced shapefiles that provide land use at approximately the field level. The most recent surveys of counties within the SACFEM2013 model domain were combined to create a single shapefile.

SACFEM revisions in 2011 included updates to land use data for Glenn and Colusa Counties. These data were developed by Davids Engineering based on multiple sources including DWR land use surveys conducted in 2003, U.S. Department of Agriculture, Glenn County, local water districts, and field surveys by Davids Engineering in 2010 (Davids Engineering, Inc., 2011).Table 9 provides the source and survey year for the land use data of each county within the SACFEM2013 model domain. Land use data were from the most recent surveys available in 2011.

TABLE 9
**Land Use Data Source and Year by County**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| County | Land Use Source, Survey Year |
|---|---|
| Butte | DWR, 2004[a] |
| Colusa | DWR, 2003[a] and Davids Engineering, 2010[b] |
| Glenn | DWR, 2003 and Davids Engineering, 2010[b] |
| Placer | DWR, 1994[a] |
| Sacramento | DWR, 2000[a] |
| Solano | DWR, 1994[a] |
| Sutter | DWR, 2004[a] |
| Tehama | DWR, 1999[a] |
| Yolo | DWR, 1997[a] |
| Yuba | DWR, 1995[a] |

Notes:
[a] California Department of Water Resources land use survey data downloaded from http://www.water.ca.gov/landwateruse/lusrvymain.cfm
[b] Davids Engineering land use data from Davids Engineering, Inc. (2011)

Land use data are aggregated into 20 categories with 16 agricultural crop types, native vegetation, urban areas, bare soil, and water bodies. Figure 24 illustrates the distribution of land use data across the different categories used in SACFEM2013, minus urban areas and water bodies that are not included in the agricultural water budgets. The SACFEM2013 model domain covers approximately 3.6 million acres of land on the Sacramento Valley floor. The largest single land use category within the SACFEM2013 model domain is native vegetation. The largest agricultural crop type is rice.

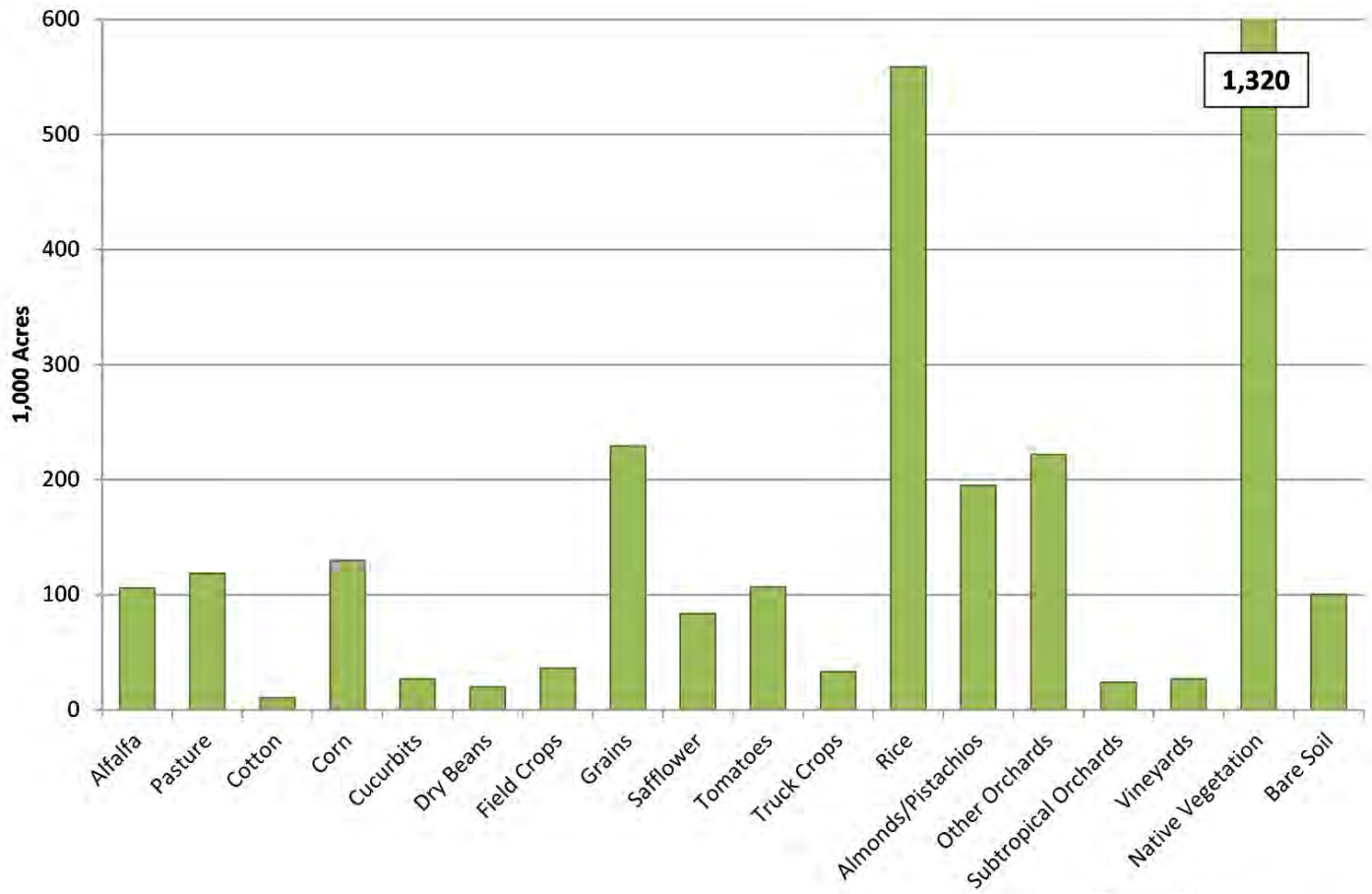


**Figure 24**
**SACFEM2013 Land Use Data**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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**Water Source.** DWR's land use surveys typically include information on the source of water used for irrigation. Survey data classify the water source as either surface water, groundwater, mixed, or unknown. Water source data are included in the land-use dataset developed for agricultural water budgets and used in calculating agricultural groundwater pumping as described in subsequent sections.

**Soils Data.** The land use and water source data were joined with hydrologic soils group data from the Natural Resource Conservation Service Soil Survey Geographic (SSURGO) database. The hydrologic soils group characterizes soils and classifies them into four groups (A through D) based on transmission rate of water, texture, structure, and runoff response. Hydrologic soils group data are used to determine inputs to IDC, specifically soil parameters that determine the potential for rainfall or applied water to infiltrate the root zone.

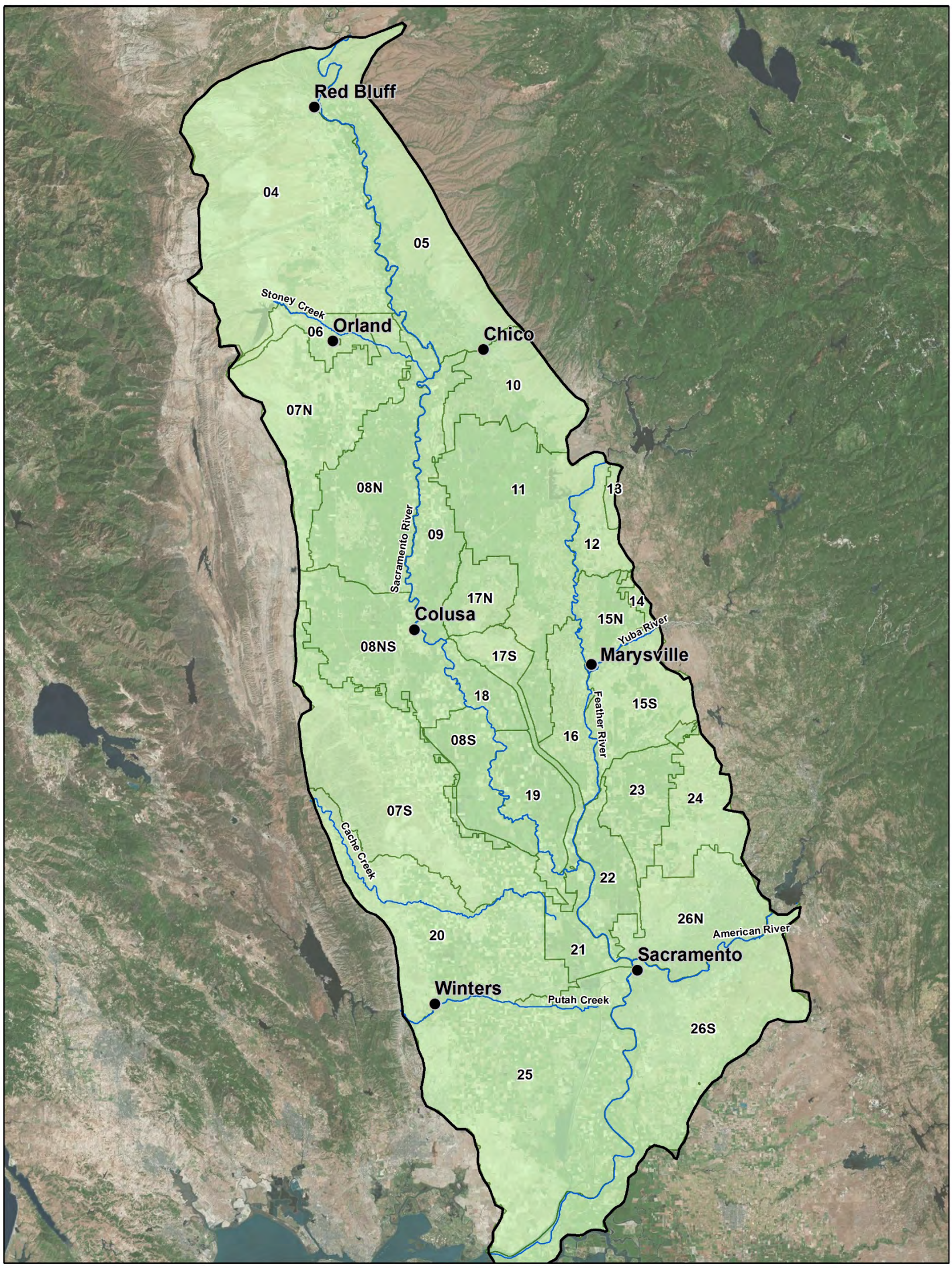
**Water Budget Areas.** Land use, water source, and soils data are then joined with boundaries of water budget areas (WBAs) within the SVGB. The SVGB was previously disaggregated into WBAs for the purpose of developing water budgets and inputs to other models such as CALSIM III. WBAs were defined by irrigation district boundaries, historical planning areas such as DWR's depletion study areas, and physical boundaries such as rivers, creeks, or canals. WBAs are areas wherein availability and source of water, climate, and other factors that govern water use are similar. WBAs are used to determine IDC inputs for precipitation and availability of surface water as described in subsequent sections. Figure 25 shows how the entire SACFEM2013 model domain is split into various WBAs.

**Land Use Data by SACFEM2013 Node.** Lastly, the combined data on land use, soils, WBAs, and water source were intersected with the SACFEM2013 model grid and resulting areas for each component were calculated. The result of this final process is a dataset that defines the land use, soils, and WBA of areas that contribute to all of the SACFEM2013 model nodes. There are multiple records for many nodes (that is, the area of a given model node intersects multiple land use, soils, WBA, or water source categories). As such, the final dataset approaches a half million unique records. Acreages in this dataset were combined with unit-area time-series from IDC on deep percolation and applied water demand (AWD) to develop time-series of deep percolation and agricultural groundwater pumping at each node for the SACFEM2013 period of simulation. Figure 26 illustrates the five data sets that are combined in the final GIS data set.

#### 3.2.5.4 IDC Model Inputs

The GIS dataset is combined with unit-area time-series from IDC to calculate SACFEM2013 input. IDC was set up to simulate 1-acre areas for each unique combination of land use, soils, and precipitation. These three factors affect simulation of the root zone and the resulting deep percolation and AWD. IDC simulation of the root-zone was performed on a daily time-step. A daily time-step was appropriate for determining rainfall infiltration, and provides a more accurate calculation of AWD compared to using a weekly or monthly time-step. The following sections describe the source of data used as input to IDC. Additional detail on the computational methods and theory within IDC can be found in the documentation and users' manual (DWR, 2014).

**Precipitation.** Daily rainfall records from seven stations were collected from the National Climatic Data Center maintained by the National Oceanic and Atmospheric Administration and California Data Exchange Center maintained by DWR. Some WBAs are located between these seven stations and, for these areas, an average of two stations was used. The result of this analysis was a total of 12 different precipitation time-series comprising the seven stations and five averaged time-series from two different stations. Table 10 summarizes the 12 precipitation time-series and associated WBAs. The seven precipitation stations are also shown on Figure 25 in relation to associated WBAs.




**LEGEND**

- City/Precipitation Station
- Major Stream
- Water Budget Area
- SACFEM2013 Model Boundary

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

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**Figure 25**
**Water Budget Areas**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

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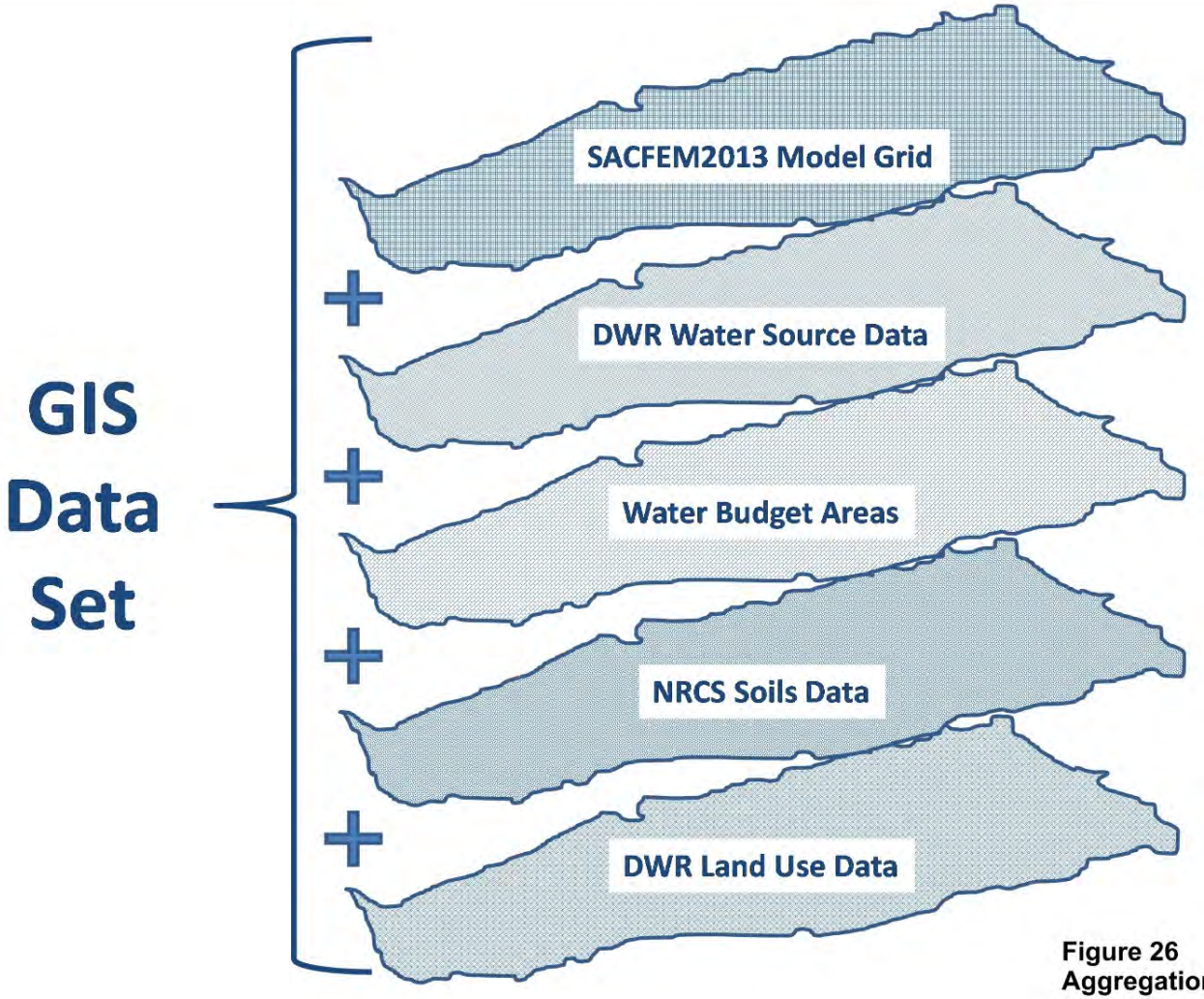



**Figure 26**
**Aggregation of GIS Datasets for Agricultural Water Budgets**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

TABLE 10
**Precipitation Stations and Associated Water Budget Areas**
*SACFEM2013, Sacramento Valley Finite Element Groundwater Model, User's Manual*

| Time-Series | Precipitation Station(s) | Associated WBA(s) |
|---|---|---|
| 1 | Red Bluff | 4, 5 |
| 2 | Orland | 6, 7N |
| 3 | Chico | 10 |
| 4 | Colusa | 7S, 8NS, 17N, 17S, 18 |
| 5 | Marysville | 14, 15N, 15S, 16 |
| 6 | Winters | 20, 25 |
| 7 | Sacramento | 21, 22, 26N |
| 8 | Avg. Orland & Colusa | 8N |
| 9 | Avg. Chico & Colusa | 9 |
| 10 | Avg. Chico & Marysville | 11, 12, 13 |
| 11 | Avg. Colusa & Winters | 8S |
| 12 | Avg. Marysville & Sacramento | 19, 23, 24 |

**Evapotranspiration.** Monthly evapotranspiration (ET) values used in IDC were developed from data published by the Irrigation Training and Research Center at California Polytechnic State University (ITRC, 2003). ITRC published crop ET values for wet, typical, and dry years for reference ET zones throughout California. The majority of the SVGB is within ITRC zones 12 and 14, and an average crop ET value from these two zones was used in IDC. Therefore, crop ET values used in IDC do not vary spatially throughout the model, but can vary by year for three different year-types of wet, typical, and dry. The Sacramento Valley Water Year Type (40-30-30) Index was used to determine the year-type with above normal and below normal 40-30-30 Index years being defined as typical, dry, and critical 40-30-30 Index years defined as dry, and wet 40-30-30 Index years defined as wet.

**Soil Parameters.** IDC inputs for soil parameters include field capacity, wilting point, total porosity, pore size distribution index, and saturated hydraulic conductivity. These parameters are used in IDC to characterize the movement of water in the root zone. Soil parameters used in IDC were determined in part by hydrologic soils group and land use. A range of magnitudes covering the classifications of the hydrologic soils group were determined and applied in IDC. Values for rice and native vegetation land uses typically differed from non-ponded crops. For example, it was assumed that rice was grown on soils with lower saturated hydraulic conductivity and a higher field capacity than soil used to grow other crops.

**Crop Parameters.** An irrigation season is input to IDC for each irrigated crop. The irrigation season flag is used to determine months when AWD is calculated. Most crops are irrigated starting in March or April and continuing through August, September, or October. AWD is not calculated outside of these months. Additionally, rice includes an AWD for cultural practices that flood fields to suppress weed growth and decompose rice straw. The timing and quantity of applied water for spring flood-up and fall decomposition used in IDC is representative of practices in the Sacramento Valley.

A second parameter input to IDC for simulation of the root-zone is the rooting depth for each crop and for native vegetation. Rooting depth, in combination with inputs such as field capacity, is used to determine soil moisture storage capacity. Soil moisture storage affects deep percolation and applied water demand and crops with shallower rooting depths may have more deep percolation because there is less capacity to water in the root zone.

**Surface Runoff.** IDC uses a modified version of the Natural Resource Conservation Service (previously the Soil Conservation Service) curve number method to simulate rainfall runoff and infiltration of precipitation. The curve number method is described in Technical Reference number 55 and the National Engineering

Handbook (USDA, 2004). A curve number is determined from land use and soil type. IDC uses the curve number in combination with antecedent soil moisture conditions to determine the portion of precipitation that runs off versus infiltrates into the soil.

### 3.2.5.5 Calculation of SACFEM2013 Inputs

Time-series of output for deep percolation and AWD from IDC for unit-acres of each unique land use and soil type were combined with the GIS dataset for each model node in SACFEM2013. Python scripts were used to calculate time-series of deep percolation and groundwater pumping inputs for each model node. The following sections describe the process used for each input.

**Deep Percolation.** Output from IDC is a time-series of deep percolation per unit-acre for each unique combination of land use, soil type, and precipitation (indicated by associated WBA). The GIS dataset contains records for all agricultural and native vegetation areas that contribute to each model node. The GIS dataset includes identifiers for WBA, land use, and soil type that are used by the Python script to reference the correct output time-series from IDC and calculate the deep percolation for each node as the sum of the deep percolation for individual areas that contribute to each node. Figure 27 is an example of the calculation performed for an individual node and time-step.

**Agricultural Groundwater Pumping.** Time-series of groundwater pumping were developed for each SACFEM2013 model node based on land use data, water source data, and surface water availability for areas that contribute to each SACFEM2013 node. Calculated groundwater pumping is based on AWD of the crop as calculated in IDC. A similar process as illustrated on Figure 27 is performed to calculate the AWD for each node. Several additional steps are then performed to calculate agricultural groundwater pumping.

Groundwater pumping for areas identified as being met from groundwater in DWR surveys is the AWD (AWDgw). This is one component of agricultural groundwater pumping calculated for each node in SACFEM2013. For areas met from non-groundwater sources (surface, mixed, or unknown), groundwater pumping is calculated as AWD for the area not identified as met from groundwater in DWR surveys (AWDnon-gw) multiplied by a pumping percentage. The pumping percentage is used to estimate pumping when surface water supplies are not adequate to meet the AWD, such as during drought periods. This is the second component of agricultural groundwater pumping in SACFEM2013. Total groundwater pumping for a node is the sum of these two components, as shown in Equation 10.

$$Groundwater\ Pumping_{node\ \bar{A}} = \bar{A}\bar{A}\bar{A}_{\ \bar{A}\bar{A}\bar{A}-\bar{A}\bar{A}} * Pumping\ Percentage + \bar{A}\bar{A}\bar{A}_{\ \bar{A}\bar{A}} \quad (10)$$

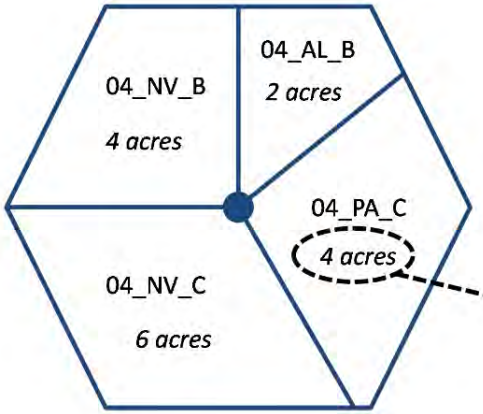
Many nodes include areas that are met from both groundwater and non-groundwater sources, areas of different crops and soils and, therefore different AWD or different pumping percentage. Groundwater pumping is calculated separately for each area and summed for the node each month.

Pumping percentage is calculated based on surface water availability. Surface water availability can change from year-to-year and by water district or other boundaries in the SVGB. Surface water availability is identified by WBA. Therefore, pumping percentage is calculated based on AWDnon-gw and available surface water for a WBA with the same water supply, such as Glenn-Colusa Irrigation District. Pumping percentage is calculated annually for each area as follows:

$$Pumping\ Percentage_{area\ \bar{A}} = 1 - Minimum.\ \frac{Surface\ \ Supply_{\ area\ j}}{AWD_{non\ -gw\ area\ j}}\ or\ 1. \quad (11)$$

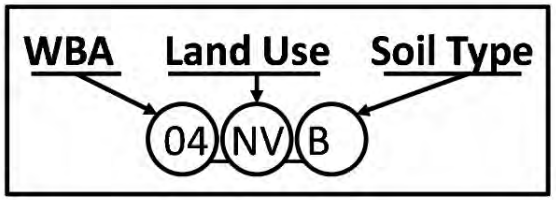
AWD used in the denominator is the annual AWD of the area minus any AWD from lands identified as supplied by groundwater. In some years, available surface supply can exceed AWDnon-gw and the pumping percentage is zero. An annual pumping percentage is calculated for most areas and multiplied by the AWDnon-gw each month. Available surface water supply was estimated from a variety of data sources including historical diversion records, contracts for water, historical hydrology, CALSIM II output, and assumptions based on knowledge of the Sacramento Valley. Many areas of the Sacramento Valley have

**GIS Data Set for Nodal Area**




| IDC Output for Unit Areas (feet) | | | | |
|---|---|---|---|---|
| Date | 04_NV_B | 04_NV_C | 04_AL_B | 04_PA_C |
| Oct 1969 | 0.001 | 0.000 | 0.005 | 0.013 |
| Nov 1969 | 0.001 | 0.000 | 0.003 | 0.002 |
| Dec 1969 | 0.039 | 0.037 | 0.026 | 0.103 |
| … | … | … | … | … |
| Sep 2010 | 0.001 | 0.000 | 0.018 | 0.014 |

$$\text{Node Deep Perc.}_{\text{Oct 1969}} = 4 \times 0.001 + 6 \times 0.000 + 2 \times 0.005 + 4 \times 0.013$$




Note:
IDC = Integrated Water Flow Model Demand Calculator

**Figure 27**
**Example Calculation of Nodal Deep Percolation using GIS Dataset and IDC Output**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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relatively stable surface water supplies that are only reduced during periods of extreme or prolonged drought. Additional detail on estimates of available surface water supply is contained in a technical memorandum titled, *Response to SacFEM Peer Review Tier 1 Findings 1, 2, and 3* (MBK, 2013).

#### 3.2.5.6 Review and Quality Assurance

Deep percolation and agricultural groundwater pumping inputs to SACFEM2013 are large datasets of more than 75 million values each (492 monthly time-steps for the more than 153,000 SACFEM2013 model nodes). Additionally, both input parameters are typically only estimated with little to no available observed data for comparison with calculated values. However, calculated values from IDC and final SACFEM2013 inputs were aggregated for different areas and compared against available data. Additionally, values for the entire SACFEM2013 model domain were aggregated and compared to generally accepted estimates.

**Detailed Water Budgets.** Calculated values for both groundwater pumping and deep percolation within Glenn-Colusa Irrigation District were compared with detailed water budget estimates developed by Davids Engineering, Inc. for the period 2001 through 2010. Detailed water budgets included applied surface water, groundwater pumping, runoff/return flow, and estimated deep percolation as the closure term based on a root-zone simulation model. IDC-calculated values for groundwater pumping, total applied water demand, runoff/return flow, and deep percolation compared well with measured and calculated values from Davids Engineering, Inc. IDC input values for soil parameters such as field capacity and saturated hydraulic conductivity were adjusted and calibrated as part of this comparison.

**Applied Water Demand.** AWD is calculated in IDC as a function of crop type, soils data, and precipitation. AWD calculated in IDC was validated by comparison with historical surface water delivery data for areas known to be irrigated only, or primarily with surface water. These comparisons were made for a common period of available IDC output and observed surface water diversion data. Examples of these validations are presented in Appendix A. AWD calculated in IDC compared well for most comparison areas. AWD calculated in IDC is the basis for much of the calculated groundwater pumping.

**Model Domain Comparisons.** Values for total deep percolation and groundwater pumping were reviewed as monthly and annual time-series and compared for different crop types and soil conditions. Figure 28 illustrates the annual volume of deep percolation for the entire model domain throughout the simulation period plotted with average precipitation for the seven stations used as input to IDC. Figure 28 illustrates how deep percolation generally fluctuates with precipitation and can vary significantly from year-to-year with a range of approximately 0.5 million acre-feet (MAF) to 3.5 MAF.

Figure 29 illustrates annual agricultural groundwater pumping inputs to SACFEM2013. The average annual groundwater pumping for the entire simulation period is approximately 2.75 MAF and generally falls in the range of 2.0 to 2.5 MAF in non-drought years. General estimates of average typical year groundwater pumping for the SVGB are on the order of 2.0 to 2.5 MAF.

## 3.3 Model Assumptions

The groundwater flow model construction, described in the preceding sections, followed the following inherent assumptions:

- Groundwater flow is simulated under confined conditions under all model layers. This assumes that changes in aquifer transmissivity due to processes such as groundwater extraction are negligible.
- Transmissivity of the modeled system does not change through time.
- Lateral groundwater underflow is not included in SACFEM2013. The model assumes that all groundwater enters and exits the model through the boundary conditions listed in Section 3.2.4.
- Effects of water density and viscosity variations to groundwater flow are negligible.
- Hydrologic variations occurring at a temporal scale finer than monthly are not simulated.

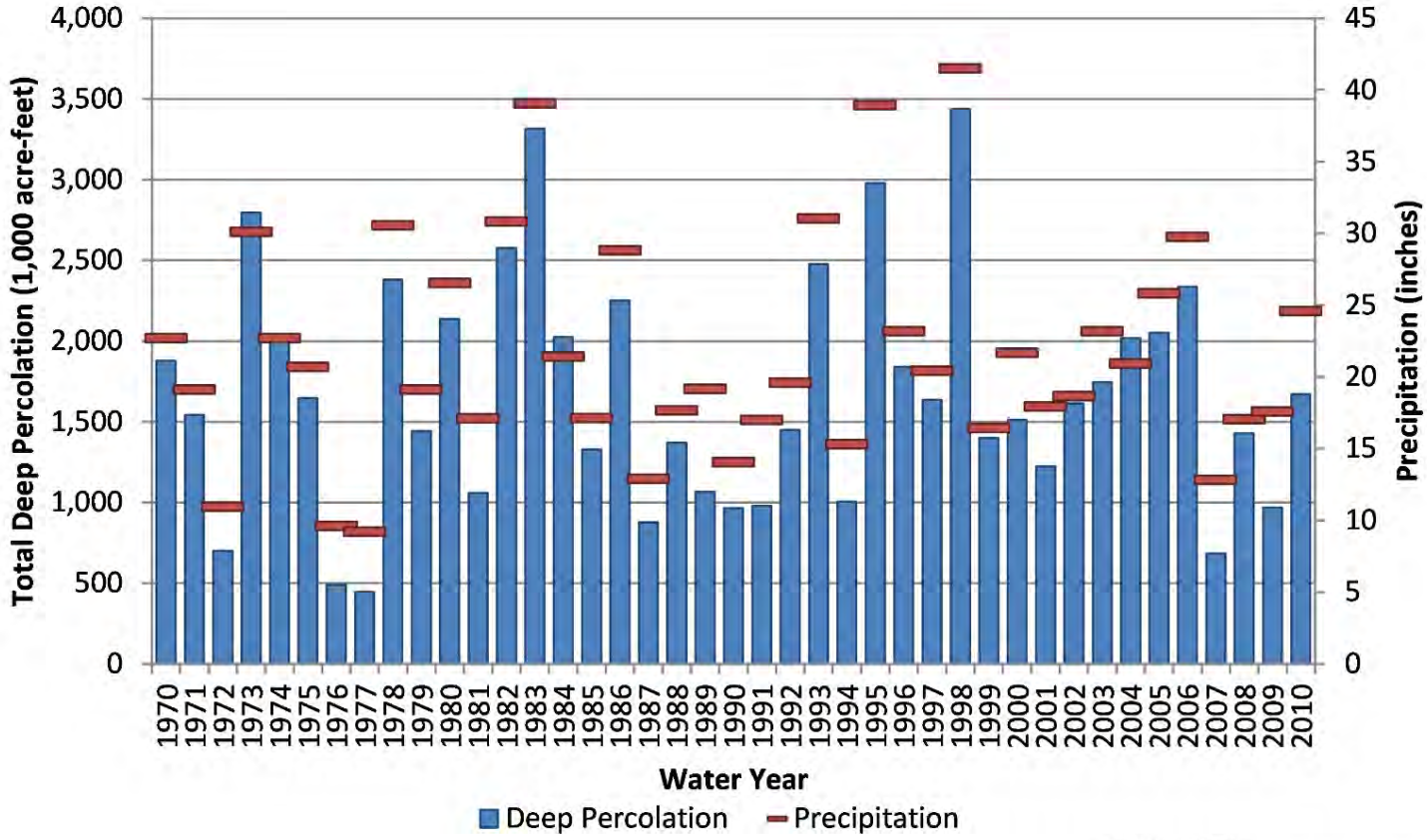


**Figure 28**
**Annual Deep Percolation from Agricultural and Native Vegetation Areas**

*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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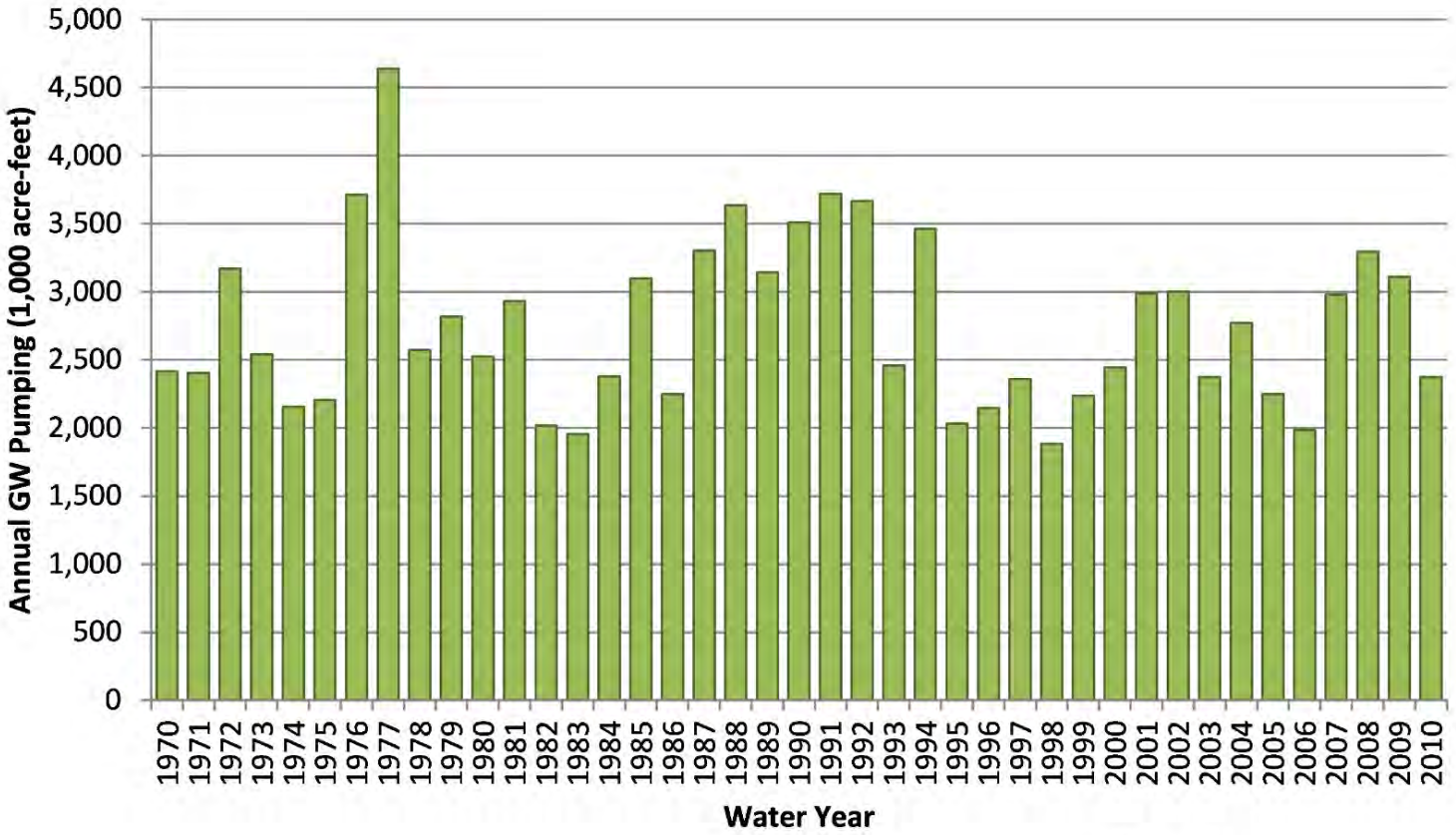


**Figure 29**
**Annual Agricultural Groundwater Pumping**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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SECTION 4

# Groundwater Flow Model Calibration

Model calibration is a process of systematically altering model parameters to simulate subsurface flow conditions measured in the field. For SACFEM2013, this process ensured that the numerical model could accurately replicate the hydrologic processes observed within the SVGB, and that the model was a reliable tool to use to forecast future hydraulic conditions resulting from changes in water management within the basin. SACFEM2013 was generally calibrated in accordance with the *Standard Guide for Calibrating a Ground-Water Flow Model Application* (American Society for Testing and Materials [now ASTM International], 1996).

## 4.1 Calibration Process

As is discussed in earlier sections of this report, CH2M HILL incorporated details of the SVGB physical system into SACFEM2013, and then a step-wise calibration approach was implemented to achieve sufficient calibration to observed conditions in the Valley as efficiently as possible.

### 4.1.1 Selection of Calibration Targets

Calibration targets are defined as the selected field-measured values that quantify hydrologic conditions of interest with consideration of data quality and worth. Both qualitative and quantitative calibration targets were selected to evaluate the progress of calibration during development of SACFEM2013. Following is a discussion of how the specific quantitative and qualitative calibration targets were selected for this effort.

#### 4.1.1.1 Quantitative Calibration Targets

SACFEM2013 underwent a transient calibration; therefore, selected field-measured heads recorded between WY1970 and WY2010 served as quantitative calibration targets, or target heads. Calibration target wells were selected from the DWR Water Data Library. The selection process generally proceeded as follows:

- DWR databases were queried to identify all wells with well construction information; wells with unknown construction were eliminated from consideration.
- The number of data records that were associated with each of the remaining wells was summarized within the SACFEM2013 simulation period (WY1970-WY2010); wells with a higher number of records were preferred.
- The spatial location of wells identified in the previous two steps were plotted to ensure that the final wells selected as calibration targets provided a good geographic distribution throughout the model domain, both within individual layers and with depth. This step was performed using a visual identification method as opposed to an automated query.
- The final step was to review additional target well locations recommended during the peer review of the previous version of SACFEM (WRIME, 2011). Select wells that did not necessarily meet the criterion of having a long period of record, but that provided good spatial or vertical (i.e., well clusters) coverage, were added to the calibration target dataset.

The overall result of this process was that 210 wells were identified as transient groundwater elevation targets over the simulation period. The locations of the calibration wells within each model layer are shown on Figure 30. Calibration summary statistics were computed to provide a quantitative measure of the ability of the model to replicate calibration target heads. Head calibration was evaluated using a variety of summary statistics, including the following:

- Residual error, computed as the simulated head value minus the target head value
- Mean error (ME), computed as the sum of all residual errors divided by the number of observations (n)

- Coefficient of determination ($R^2$), computed as the square of the correlation coefficient
- Root mean squared error (RMSE), computed as the square root of the mean of all residual squared errors
- RMSE divided by the range of target head values (RMSE/Range)

Rather than setting arbitrary goals for individual summary statistics as part of quantitative calibration, CH2M HILL moved forward with the following general goals:

- Minimize spatial bias of residual errors in key areas of the domain
- Minimize residual error, ME, RMSE, and RMSE/Range values
- Have $R^2$ values as close to 1.00 as possible

Appendix B presents the quantitative calibration targets selected for SACFEM2013, which included 210 target head locations. The target groundwater elevations are also included on the hydrographs in Appendix C.

#### 4.1.1.2 Qualitative Calibration Targets

Qualitative calibration targets refer to general observations of temporal or spatial patterns of the field problem that were compared with model output. These targets included general patterns of gaining and losing streams and bypasses under differing hydrologic conditions. Calibration summary statistics were not used to characterize the ability of SACFEM2013 to replicate qualitative calibration targets; rather, these targets were evaluated to determine if the model is generally able to replicate the expected overall patterns in stream gain/loss. Although the exact stream reaches that gain or lose flow because of surface water/groundwater interaction are not fully delineated, and this relationship changes over time with fluctuating groundwater levels and stream stages, the general pattern observed in the Valley is that the major trunk streams, such as the Sacramento, Feather, and American Rivers, tend to gain flow, especially in their lower reaches. Smaller upper tributaries near the basin margin tend to lose flow to the groundwater system.

### 4.1.2 Calibration Parameters

Parameter values of streambed Kv, mountain front recharge adjustment factor, Kh, and Kh:Kv were adjusted during the calibration of SACFEM2013. No modifications were made to deep percolation of applied water/precipitation or agricultural pumping data estimated from IDC.

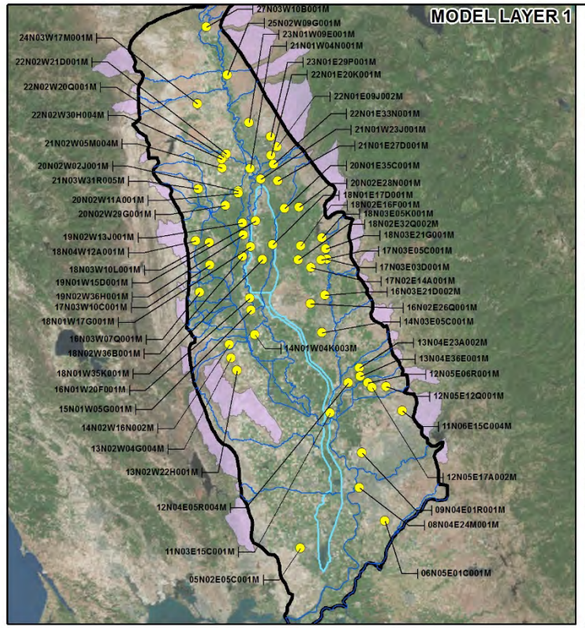
### 4.1.3 Iterative Manual Calibration Procedure

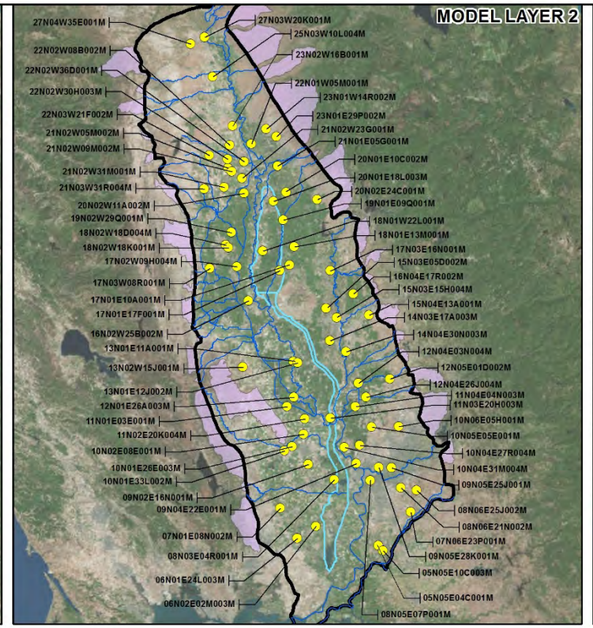
The general calibration procedure was an iterative process executed using manual techniques. During the calibration phase, property zones were spatially defined and assigned values. This involved manually running the simulations, comparing model results with qualitative and quantitative calibration targets to assess the progress of calibration, and making manual changes to parameter values and boundary conditions (or both) in areas where important calibration mismatches were noted for the next round of simulations. This procedure was repeated until only minor improvements in calibration were achieved with each round of simulations, and the calibration was deemed appropriate.

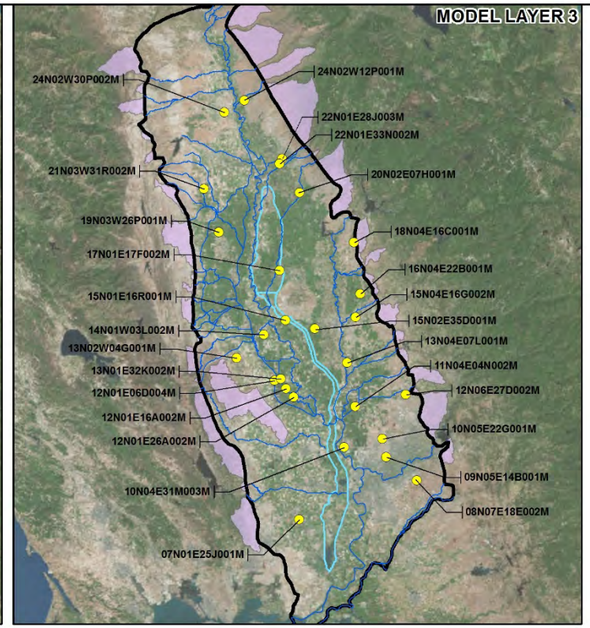
## 4.2 Calibration Results

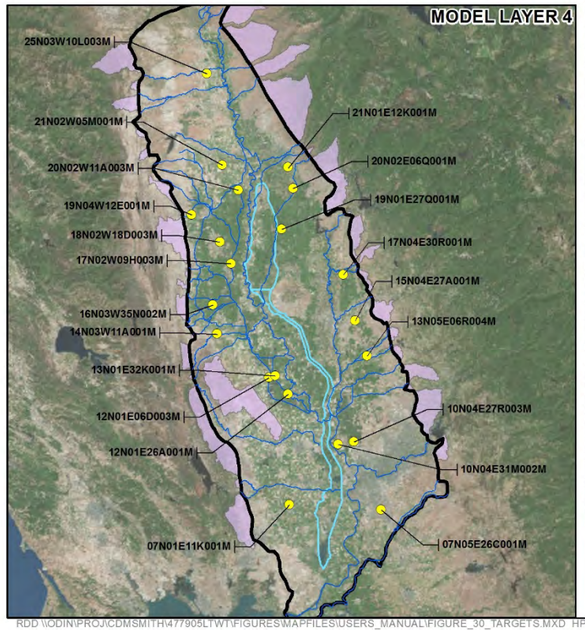
### 4.2.1 Groundwater Elevations

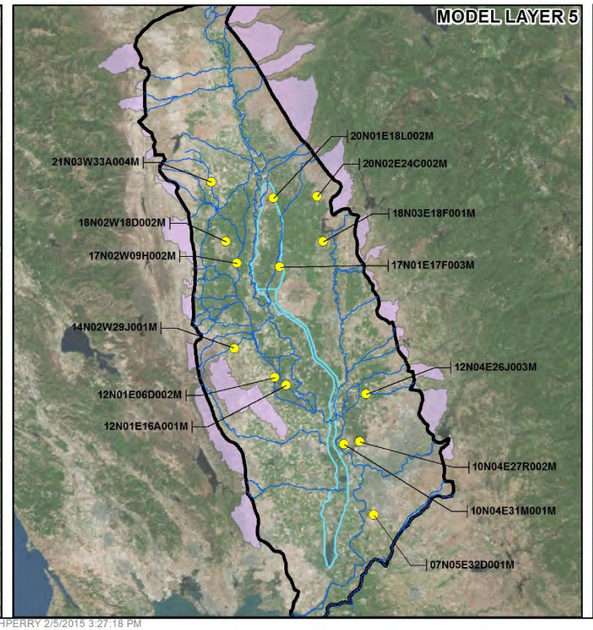
Locations of SACFEM2013 calibration target wells selected for this evaluation are shown on Figure 30. Measured heads for each calibration target well, along with the associated calibration statistics, are summarized in Appendix B. The purpose of computing summary statistics is to quantify the goodness of fit between simulated and target head data. Goodness-of-fit statistics that accompany model calibration are not necessarily good indicators of the predictive capabilities of a model. Summary statistics are highly sensitive to the number of observations, quality of measured data, and outlier data. Poor calibration statistics can result from a variety of reasons, as described in Section 4.3.

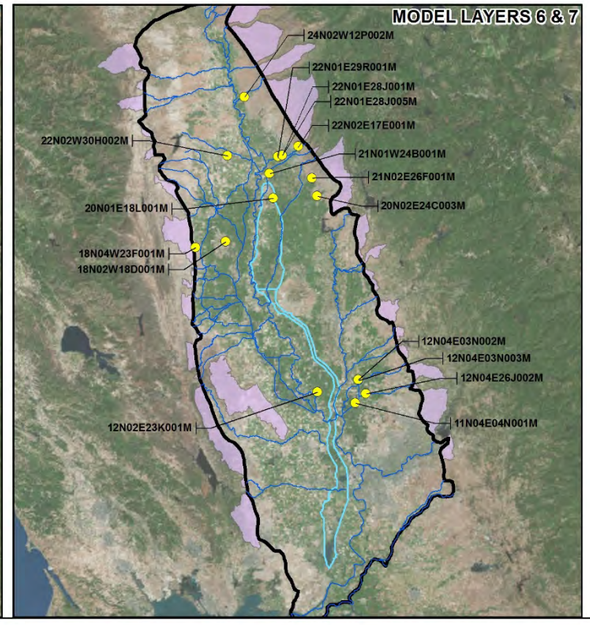


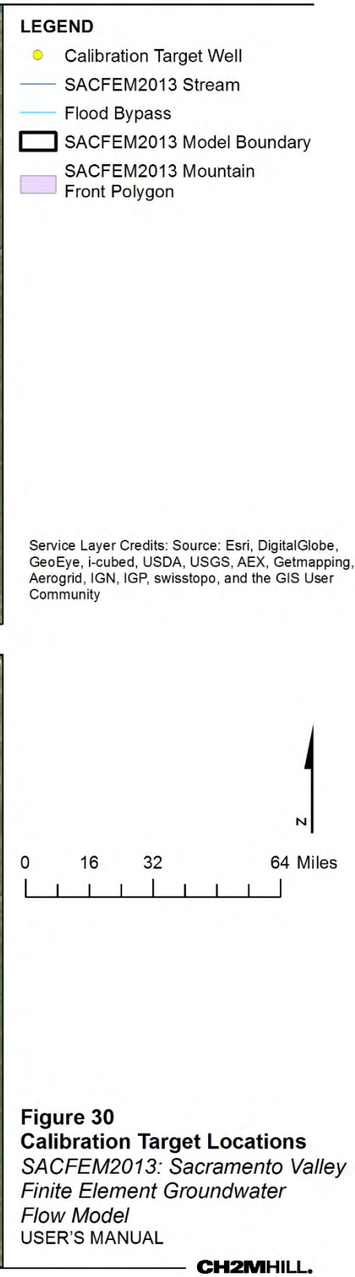




**Figure 30**
**Calibration Target Locations**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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Figure 31 is a scatter plot of individual simulated-versus-target head values. The summary statistics for data presented on Figure 31 and defined in Section 4.1.1.1 are as follows:

- ME = 1.6 feet
- RMSE = 19.6 feet
- Range in calibration target head values = 417.8 feet
- RMSE/Range = 5 percent
- $R^2$ = 0.93
- n = 32,263

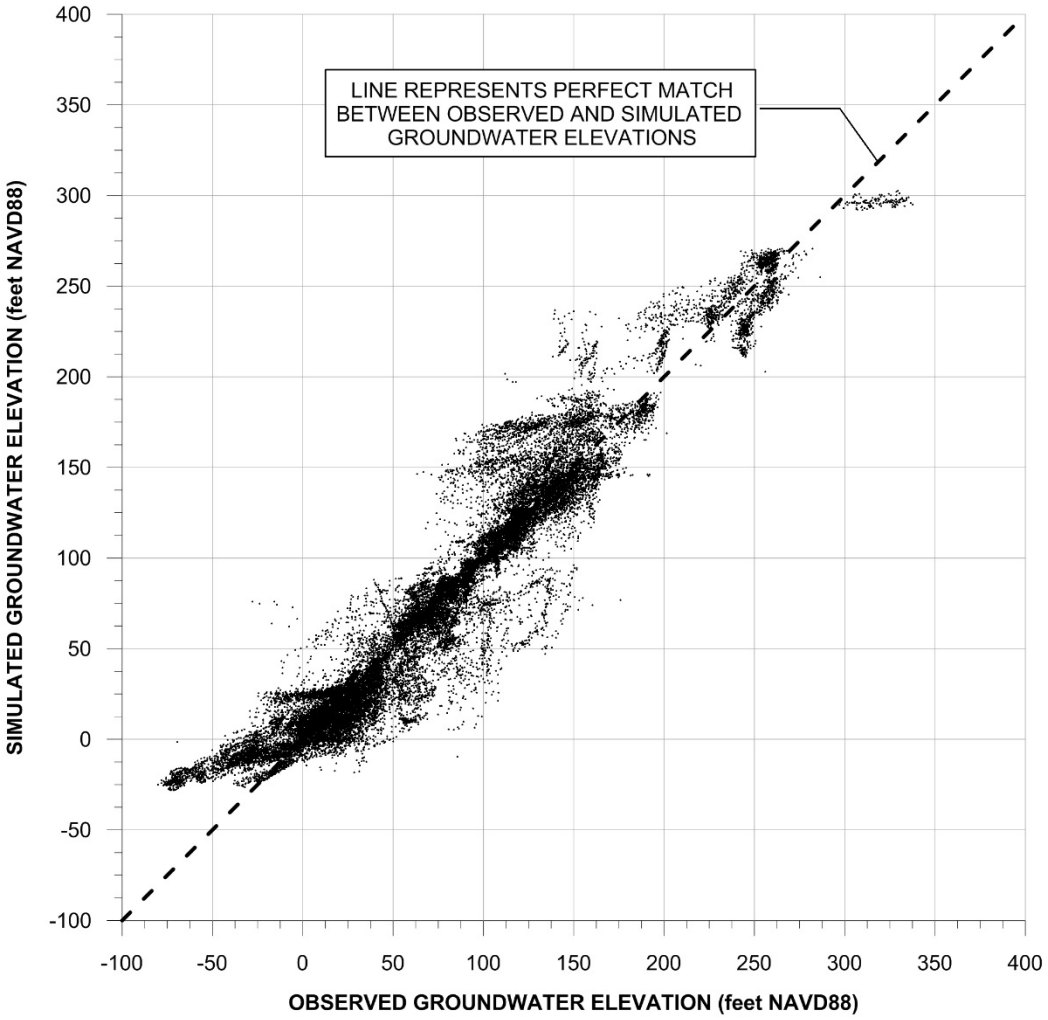
The ME value of 1.6 feet indicates that SACFEM2013 slightly over-predicted heads throughout the domain, as shown by the positive value. However, the ME, RMSE, and RMSE/Range are relatively small, particularly given the scale of the model domain. Additionally, as shown on Figure 31, there is a strong correlation ($R^2$ = 0.93) between simulated and target head data. A well-calibrated model should also have mostly low residual errors, with some simulated heads above and below their target heads. Figure 31 shows that points are above and below the 1:1 correlation line. Thus, the calibration results for this effort do not indicate global bias (that is, all positive or all negative residual errors).

Figure 32 shows the spatial distribution of the mean error in simulated heads that are listed in Appendix B by model layer. The data presented on Figure 32 and in Appendix B indicate that mean error in nearly half of the target wells is within ±5 feet. The data further suggest that there may be slight spatial bias indicating that wells east of Dunnigan Hills and in Placer County/southeastern Sutter County are simulated low, and wells near the southern model boundary (Sacramento County) and in northern Butte County are simulated slightly high. This is likely the result of small-scale features not explicitly simulated in SACFEM2013. Overall, the statistics listed above and presented in Appendix B and Figure 32 are considered to represent good calibration.

The other method used to evaluate the quality of the transient calibration was to compare the simulated hydrographs for each of the 210 target monitoring wells with the measured hydrograph data. These hydrograph comparisons are presented on Appendix C. Examination of the time-series simulated and measured groundwater hydrographs helps to inform the mean errors presented on Figure 32. For example, in the southeastern portion of the model domain (06N05E01C001M, model Layer 1) the time series data show that SACFEM2013 does a good job of replicating the transient groundwater level fluctuations; however, the simulated heads are overestimated. Another example, 15N04E13A001M (model Layer 2) suggests that SACFEM2013 does an excellent job of replicating the later-time measured groundwater elevations; however, there are local factors not explicitly simulated that result in over-estimation of the earlier time groundwater elevations. The result is a mean error of approximately 21 feet, which is biased by the early time data. Finally, there are select calibration targets (such as 07N01E11K001M, model Layer 4) that appear to be in close proximity to a pumping well, as suggested by the large seasonal variability in measured groundwater elevations. Because individual pumping wells are not explicitly simulated in SACFEM2013, the magnitude of simulated groundwater fluctuation is less than observed. Although some deviations remain between simulated and observed data during certain periods at select locations, SACFEM2013 generally does a good job of replicating both the absolute groundwater elevations and transient trends in the majority of the 210 calibration target wells within the model domain.

### 4.2.2 Stream Gain/Loss

As discussed above, the general patterns of losing and gaining reaches of streams and bypasses were included as qualitative targets during the calibration of SACFEM2013. Figure 5 presents water year type designations for the SACFEM2013 simulation period. Stream and bypass reaches predicted by the model to




n = 32,263
ME (ft) = 1.6
RMSE (ft) = 19.6
Range (ft) = 417.8
RMSE/Range = 0.05
$r^2$ = 0.93

Notes:
1. n = number of measurements
2. ME = mean error
3. RMSE = root mean squared error
4. Range = range in measured groundwater elevations
5. RMS/Range is a measure of model calibration and is equal to the root mean squared error (RMS) divided by the range in measured groundwater elevation.
6. NAVD88 = North American Vertical Datum of 1988.

**Figure 31**
**Simulated versus Observed Groundwater Elevations**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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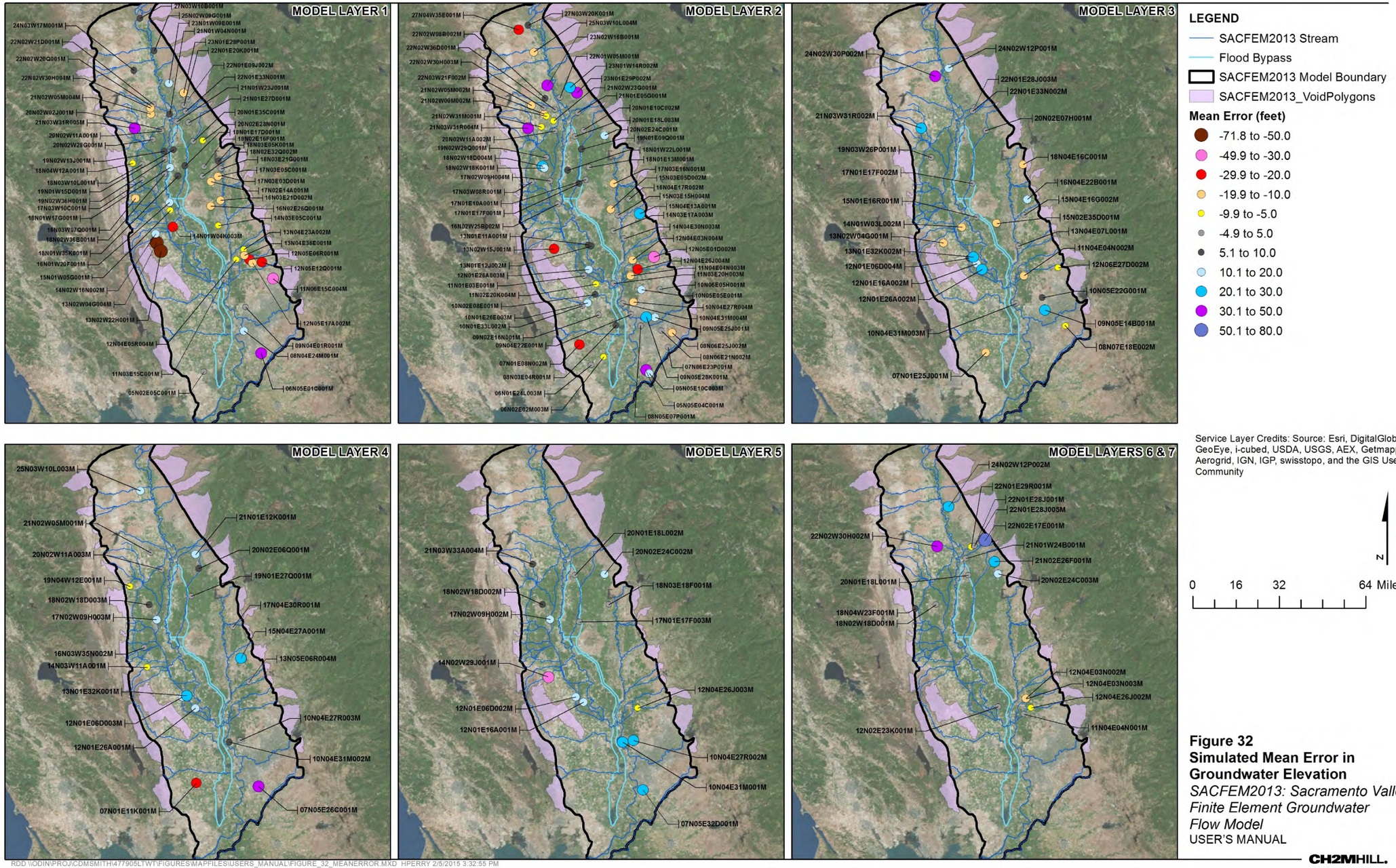


**Figure 32**
**Simulated Mean Error in Groundwater Elevation**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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gain or lose flow to the groundwater aquifer were evaluated under typical above-normal hydrologic conditions (April 2000, see Figure 33), extreme drought (July 1977, see Figure 34), and wet conditions (January 1983, see Figure 35). As shown on Figure 33, the pattern of predicted stream gain/loss during April 2000 is consistent with what would be expected during an above-normal period. The major trunk streams throughout the Valley, such as the Sacramento and Feather Rivers, are gaining, while the smaller tributaries are losing flow to the groundwater system. Further, the flood bypasses are not active under these hydrologic conditions. Figure 34 presents the distribution of simulated gaining/losing stream reaches in July 1977. Model output suggests that the majority of streams throughout the Valley are losing flow to the aquifer system, which is consistent with what would be expected under this critically dry condition. Many of the smaller tributary streams as well as the flood bypasses are inactive during this period, as evidenced by the lack of stream gain/loss symbology (i.e. blue or yellow circle). Finally, the predicted distribution of stream and bypass gain/loss during January 1983 is presented on Figure 35. Model output suggests that, although there are limited gaining stream reaches, the vast majority of streams and bypasses are losing flow to the groundwater system. This is likely a result of high stream stage elevations during runoff in this extremely wet hydrologic period. Overall, the patterns predicted by the calibrated groundwater flow model are reasonably consistent with expected stream gains and losses under the varying hydrologic conditions, and calibration of SACFEM2013 against this qualitative target is considered good.

### 4.2.3 Calibrated Hydraulic Parameters

Figures 12 and 13 show the modeled hydraulic conductivity values that resulted from the calibration process. These values are within a reasonable range of literature values for heterogeneous unconsolidated deposits and bedrock. As discussed in Section 3.2.2.2, a Kh:Kv of 50:1 was assigned in model Layer 1, 500:1 was assigned in model Layers 2 through 7, and 1:1 was assigned to bedrock areas in all model layers throughout most of the model domain. The final set of mountain front recharge adjustment factors is included in Table 6, and the final streambed Kv values are presented on Figure 15 and in Table 2.

### 4.2.4 Groundwater Balance

Figures 36 and 37 summarize the primary inflow and outflow components of the transient groundwater budget for SACFEM2013. These plots were generated by totaling the monthly inflows and outflows for each of the components by water year. The SACFEM2013 model output presented on these figures indicates that the inflows are highly variable from year to year, while the outflows are more or less consistent. Figure 36 presents the annual volumes for the SACFEM2013 inflow components, deep percolation of applied irrigation water and precipitation, groundwater recharge from stream leakage, and groundwater recharge along the mountain front. The pattern in annual volumes of inflow to SACFEM2013 are such that the magnitudes are highest during wet hydrologic periods and lowest during dry hydrologic periods. For example, the maximum annual inflow (approximately 6.5 MAF) occurs during the extremely wet period of WY1983 and the minimum annual inflow (approximately 1.8 MAF) occurs during the critical drought of WY1976-WY1977. Groundwater recharge from streams comprises the largest component of the water budget, ranging from 33 to 68 percent of the annual inflow. Deep percolation of applied water and precipitation ranges from 24 to 54 percent of the annual inflow, and recharge along the mountain front ranges from 4 to 17 percent of the total annual inflow.

Figure 37 presents the annual volumes for the SACFEM2013 outflow components, groundwater pumping, groundwater discharge to streams, and groundwater discharge to land surface. The volumes of outflow from SACFEM2013 have an opposite pattern with respect to hydrologic cycles in the SVGB than groundwater inflow components. The minimum annual outflow occurs during wet periods, such as WY1982-WY1983 and WY1995-WY1999, and the maximum annual outflow occurs during dry periods, such as the critical drought of WY1976-WY1977. Groundwater pumping is by far the largest outflow component of the water budget, ranging from 56 percent (2.3 MAF) to 96 percent (5 MAF) of the annual outflow. Groundwater discharge to land surface ranges from 1 to 33 percent of the total annual outflow, and groundwater discharge to streams ranges from 3 to 13 percent of the annual outflow. It should be noted that the boundary condition used to simulate groundwater discharge to land surface (discussed in Section 3.2.4.1) represents surficial processes

including groundwater discharge to low-lying topographic areas, such as riparian to streams, as well as small tributaries not explicitly simulated in SACFEM2013. For practical purposes, this component of the water budget can be considered groundwater discharge to streams.

Figure 38 presents the cumulative change in storage over the WY1970 through WY2010 simulation period. These SACFEM2013 results indicate that simulated changes in aquifer storage correlate to the hydrologic cycles. Periods of decrease in storage correspond to drought cycles, such as WY1976-WY1977 and WY1987-WY1992, and increases in aquifer storage correspond to wetter periods such as WY1982-WY1984 and WY1995-WY1999. Overall, the trends and magnitudes of SACFEM2013 are appropriate and consistent with the generally accepted water balance for the SVGB.

## 4.3 Potential Sources of Error

Calibration target values and simulated output each have associated errors or error potential, 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).

### 4.3.1 Transient Effects

Groundwater-level measurements in wells could reflect the presence of transient effects in the groundwater system that might not be represented in SACFEM2013. The only available subsurface access for directly monitoring groundwater conditions is through groundwater wells. If transient effects of the groundwater system manifest in groundwater levels at timescales other than those represented in the numerical model, some portion of the residual error between the field-measured groundwater level and the simulated output could be due to these transient effects.

### 4.3.2 Human Errors

It is not possible to guarantee that the modeling results presented in this manual are free of human error. However, CH2M HILL strived to avoid introducing human errors by adhering to quality assurance protocols. The following are examples of potential sources of 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 error between the field-measured data and the simulated output could be due to measurement error in the calibration target value.
- **Data Management Errors.** Errors can 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 error between the field-measured data and the simulated output could be due to data management errors.
- **Conceptualization Errors.** Errors can be introduced as a result of inadequately conceptualizing the field problem. The absence of important Site information can lead to errors associated with assumptions that are necessary to perform predictive simulations. Thus, some portion of the residual error between the field-measured data and the simulated output could be due to conceptualization errors.

### 4.3.3 Scaling Effects

A numerical model uses discrete space to represent the hydrologic system. SACFEM2013 grid was built in an effort to strike a balance between maximizing the number of nodes in key areas of the domain and minimizing the numerical burden and associated model run times. However, 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 elements.

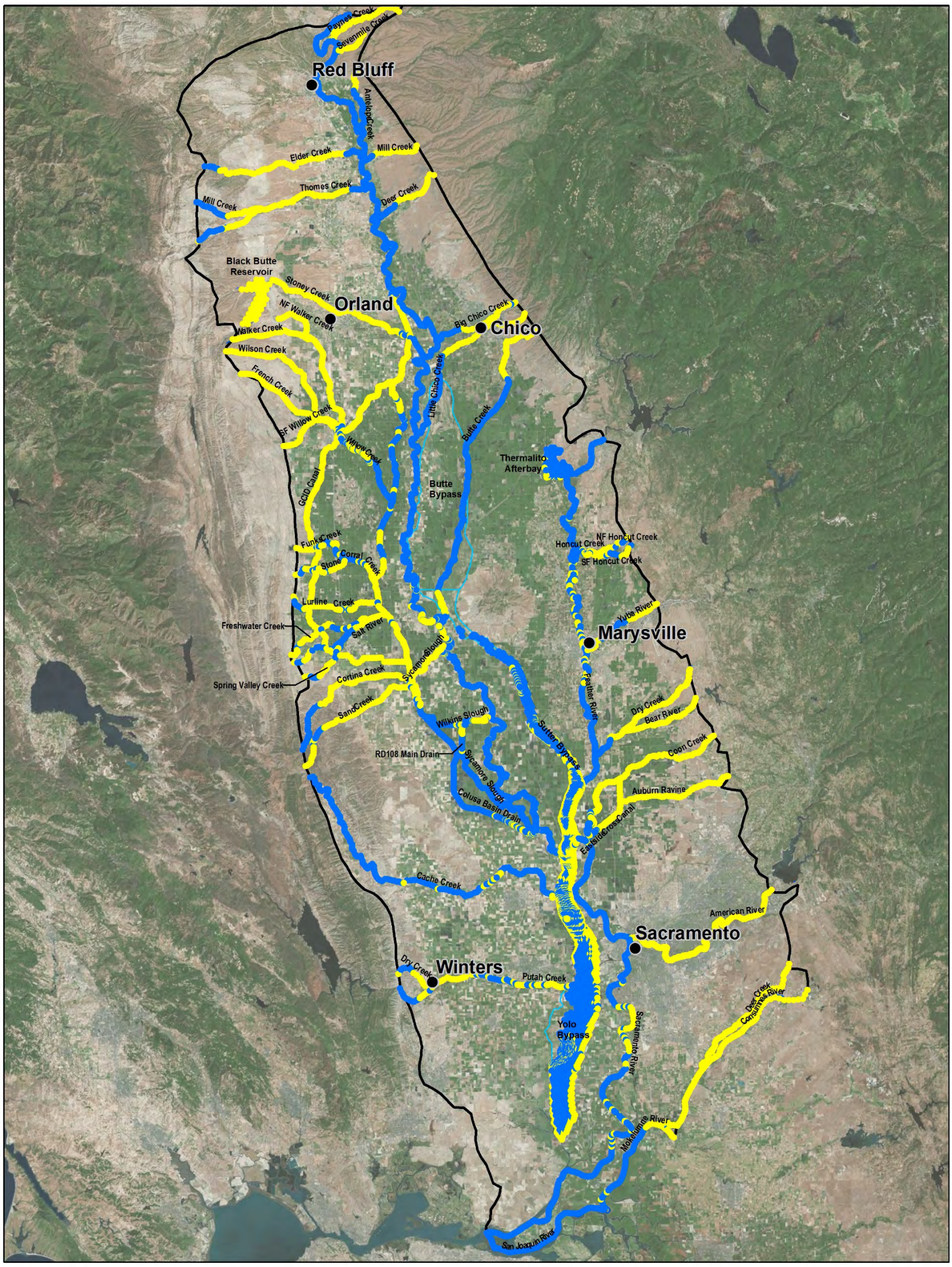


**Figure 33**
**Distribution of Simulated Stream Gain and Loss; April 2000**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
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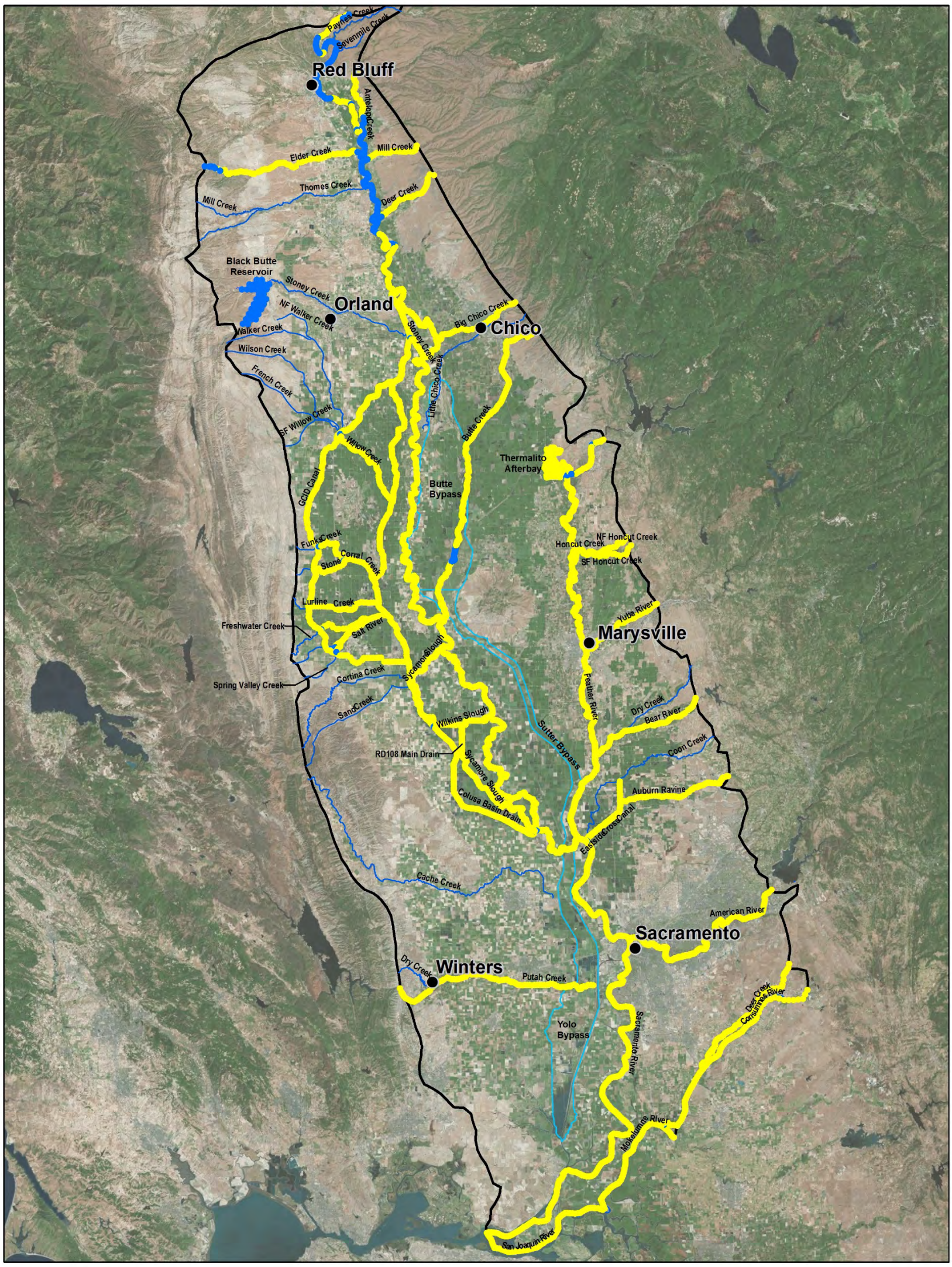



**LEGEND**

- City
- SACFEM2013 Stream
- Flood Bypass
- SACFEM2013 Model Boundary
- Simulated Losing Stream Reach
- Simulated Gaining Stream Reach

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

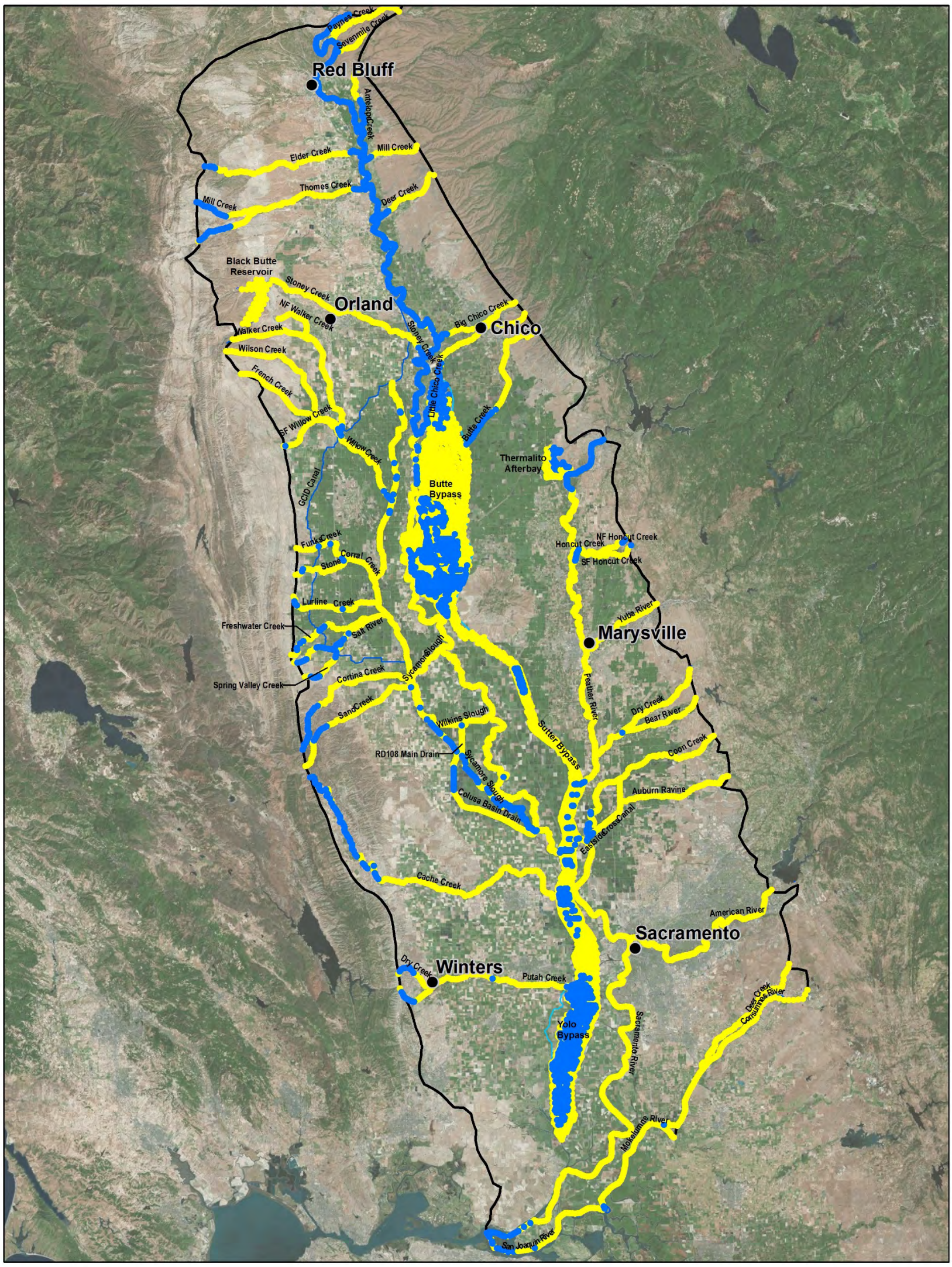
N

0 6 12 24 Miles

**Figure 34**
**Distribution of Simulated Stream Gain and Loss; July 1977**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

RDD \\ODIN\PROJ\CDMSMITH\477905LTWT\FIGURES\MAPFILES\USERS_MANUAL\FIGURE_34_JUL1977_STREAMGL.MXD HPERRY 2/5/2015 3:54:05 PM

CH2MHILL.




**LEGEND**

- City
- SACFEM2013 Stream
- Flood Bypass
- SACFEM2013 Model Boundary
- Simulated Losing Stream Reach
- Simulated Gaining Stream Reach

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

N

0 6 12 24 Miles

**Figure 35**
**Distribution of Simulated Stream Gain and Loss; January 1983**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

RDD \\ODIN\PROJ\CDMSMITH\477905LTWT\FIGURES\MAPFILES\USERS_MANUAL\FIGURE_35_JAN1983_STREAMGL.MXD HPERRY 11/17/2014 5:30:56 PM

CH2MHILL.

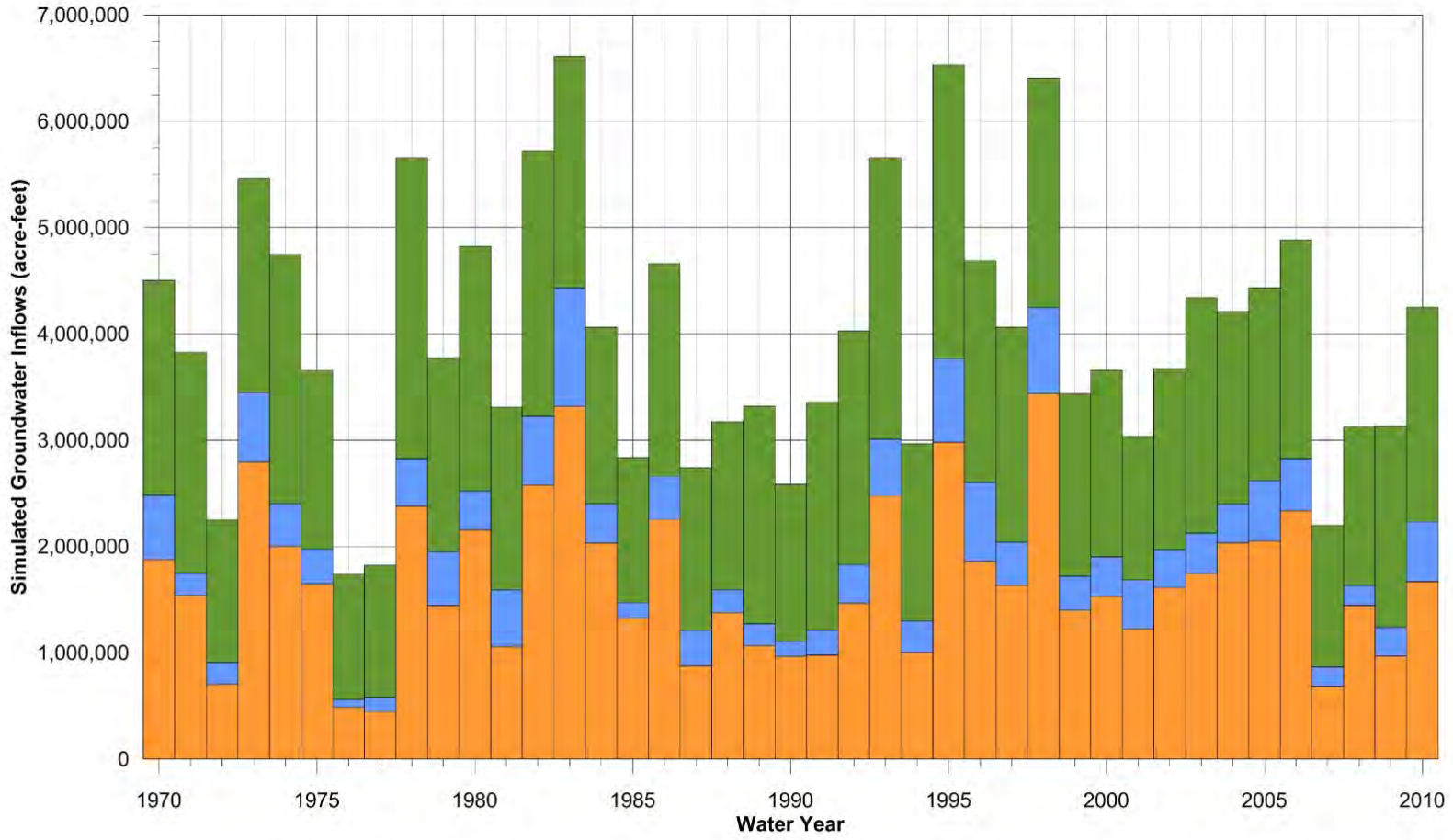
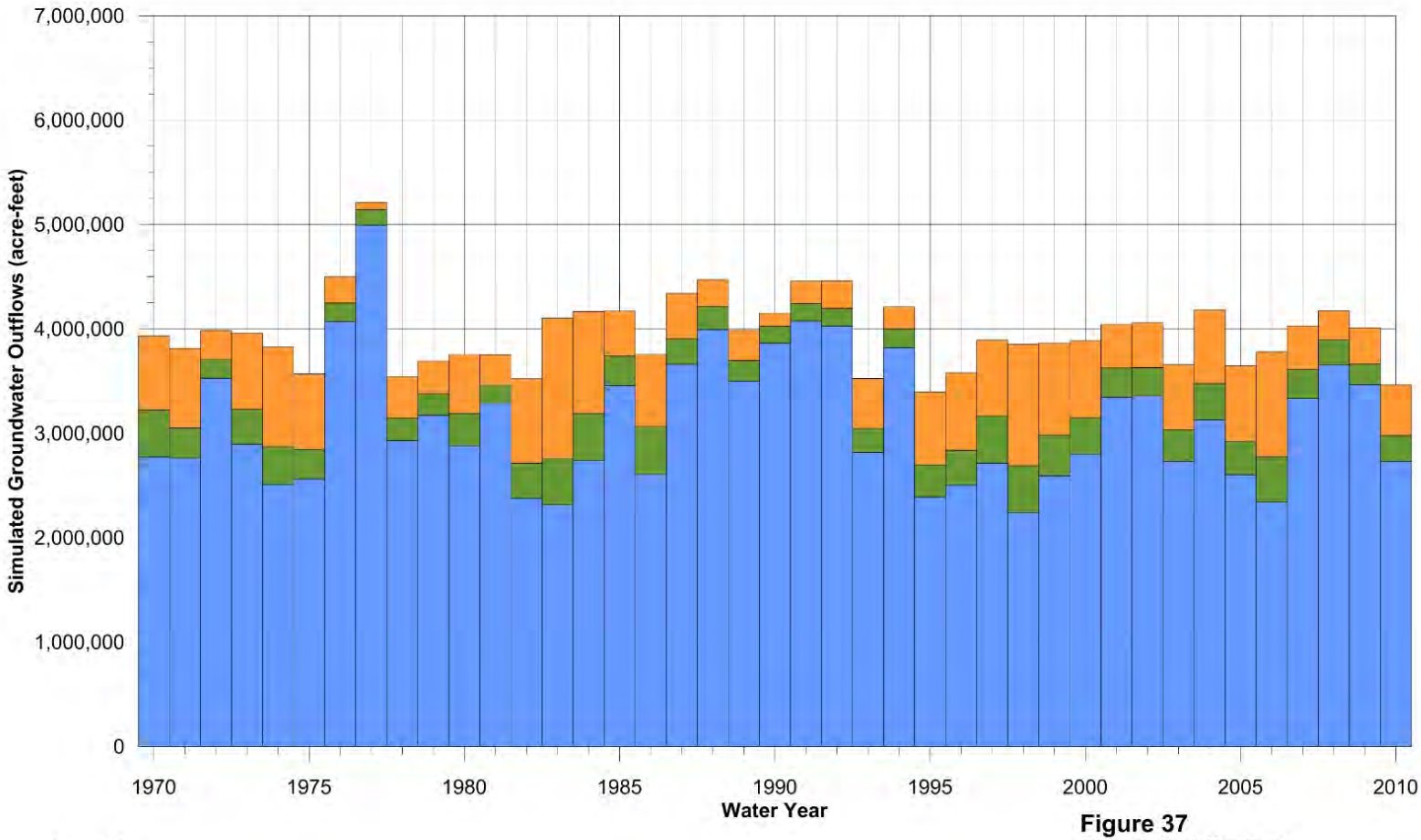



**Figure 36**
**Simulated Inflow Components of Transient Water Budget**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

CH2MHILL




Note:
Discharge to land surface is a boundary condition that represents surficial processes including groundwater discharge to low-lying topographic areas, such as those riparian to streams, as well as small tributaries not explicitly simulated in SACFEM2013. For practical purposes, this component of the water budget can be considered groundwater discharge to streams.

**Figure 37**
**Simulated Outflow Components of Transient Water Budget**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

CH2MHILL

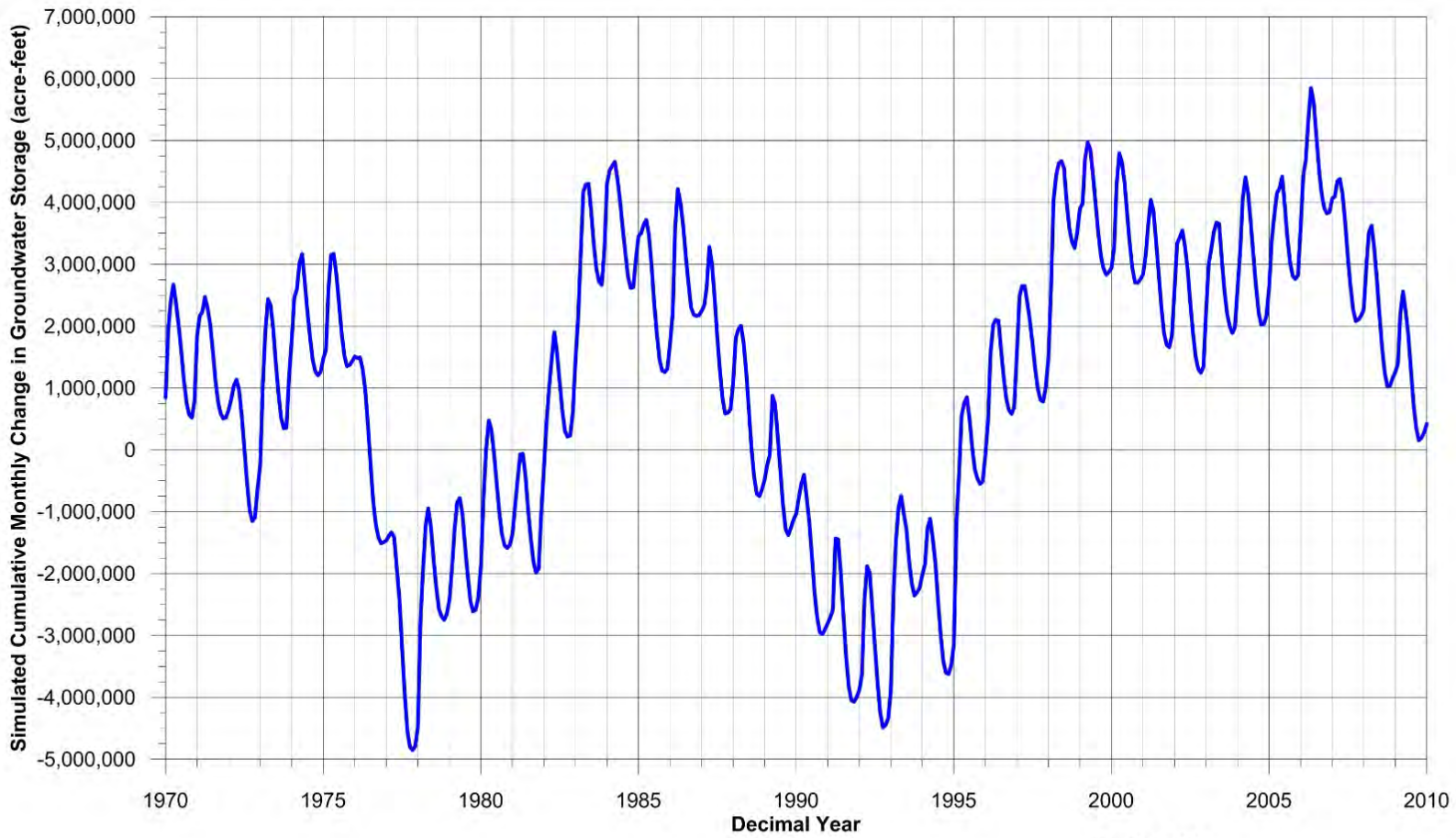



**Figure 38**
**Simulated Cumulative Monthly Change in Groundwater Storage**
*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

CH2MHILL

### 4.3.4 Interpolation Effects

Interpolation errors can result from spatially distributing point values of parameters or stresses over the model domain. In an effort to manage interpolation errors, one of the goals for selecting calibration target locations for SACFEM2013 was to seek a relatively uniform spatial distribution of calibration targets over SACFEM2013 domain. Having a reasonable number of spatially distributed calibration targets and types of calibration targets (for example, qualitative and quantitative) helps make model output more reliable over a wide range of conditions for the entire domain.

### 4.3.5 Numerical Errors

Errors associated with the way a model solves the governing flow equations, coupled with the assumptions in the governing equations being solved, are inherent in 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 results in fewer simulations being completed because of longer run times and possible convergence problems. CH2M HILL minimized introduction of numerical errors by selecting convergence criteria that resulted in converged solutions that provided mass balances of flow.

## 4.4 Calibration Outcome

A relatively high-resolution, three-dimensional numerical groundwater flow model of the SVGB has been developed to support the evaluation of conjunctive water management projects across the Valley. Specifically, SACFEM2013 was developed to assess the transient effects of groundwater pumping on groundwater levels and to estimate changes in surface water/groundwater interaction.

The current finite-element groundwater flow model grid has a resolution on the order of 410 feet (125 meters) in areas where conjunctive water management projects are being considered and effects are being evaluated. The model has been constructed so that future project-specific grids can be developed, and the 41-year agricultural water budget can be projected onto the new grid using a semi-automated GIS-based tool. The vertical resolution of the model consists of seven model layers. The uppermost model layer was limited to 65 feet or less in thickness to allow assessment of impacts on streams as well as riparian habitat and wetlands. Model Layers 2 through 5 were selected to represent typical groundwater production zones within the Valley. Layers 6 and 7 were developed to represent the Lower Tuscan Formation, where it exists, within the northeastern and central portions of the Valley.

The surface water budget, including agricultural pumping and deep percolation of precipitation and applied water, was developed using a GIS-based analysis that considers land use, crop types, water source, seniority of water rights, and availability of surface water on a monthly time step. These deep percolation fluxes and agricultural pumping fluxes are independently computed for each element in the model. The fluxes associated with mountain-front recharge and urban pumping were also simulated on a monthly time-step. Time-variable surface stream and flood bypass stages were defined by using available data, including USGS topographic maps and stream gage elevations.

The SACFEM2013 model was calibrated to transient groundwater elevation data sets. Groundwater elevations recorded during the hydrologic period from water years 1970 through 2010 were used as transient calibration targets. More qualitative calibration targets such as the magnitude of the water budget components and the pattern and magnitude of surface water/groundwater interaction were also considered.

The SACFEM2013 model represents a valuable analytical tool to estimate the effects of groundwater pumping on both groundwater levels and changes in surface water/groundwater interaction within the SVGB.

SECTION 5

# SACFEM Application

The following section describes the process of executing a SACFEM2013 model simulation, including preparation of input datasets, description of the SACFEM2013 model files, and post-processing of model output.

## 5.1 SACFEM2013 Project File

SACFEM2013 comprises numerous individual files, which will be described in more detail below. The primary file is the SACFEM2013 project file (*.fpr). A MicroFEM project file, such as SACFEM_2013.fpr is an ASCII file, which can be opened via a text editor or directly via the MicroFEM interface. When opened with a text editor, the project file is essentially a list of all data files (or parameter files) that make up a groundwater model. The following is a display of the file "SACFEM_2013.fpr" in text editor mode:

Base-model=SACFEM_2013.fem
Thickness=SACFEM_2013.thi
Storativity=SACFEM_2013.sto
Precipitation=SACFEM_2013.ppn
Drain system H1=SACFEM_2013.dh1
Drain system C1=SACFEM_2013.dc1
Wadi-recharge system L1=SACFEM_2013.wh1
Wadi-recharge system H1=SACFEM_2013.wh1
Wadi-recharge system C1=SACFEM_2013.wc1
Batch-file=SACFEM_2013.fpr[6]
Xtra=SACFEM_2013.xtr

Figure 39 presents the display of SACFEM_2013.fpr when opened directly via the MicroFEM interface. This figure presents the SACFEM2013 model grid (note: nodal points rather than model elements are displayed) in the main body of the display window with the MicroFEM file "tabs" located along the right-hand margin. Each MicroFEM tab contains a different set of data, as described in the following subsections. MicroFEM files can be loaded directly into registers on each of the model tabs or can be loaded via the MicroFEM project manager (see Figures 40 and 41).

[6] The MicroFEM batch file is discussed in detail in Section 5.2.2.

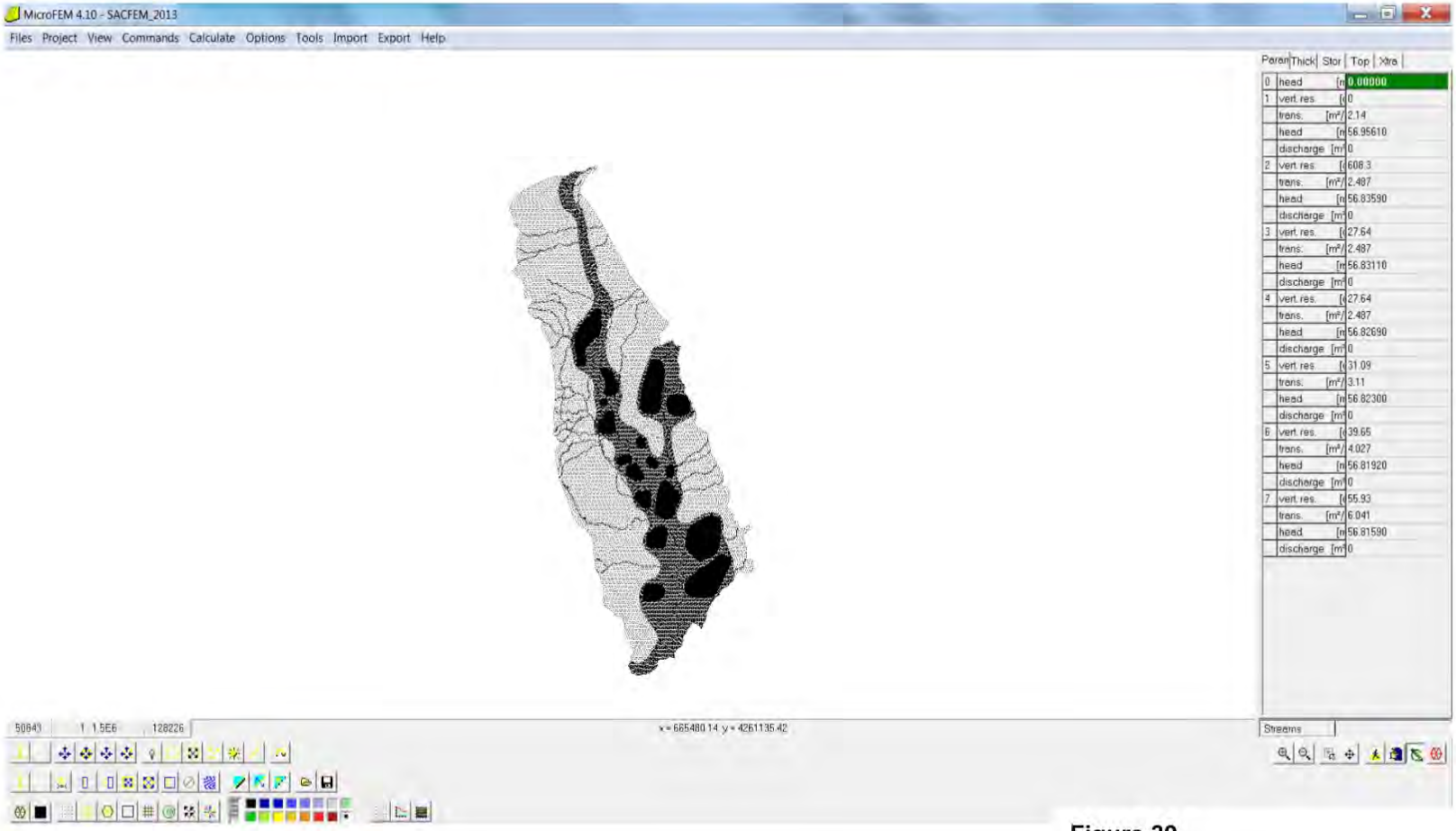



**Figure 39**
**View of SACFEM2013.fpr via MicroFEM Interface**

*SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

CH2MHILL.

FIGURE 40
**MicroFEM Project Manager, Main Window**

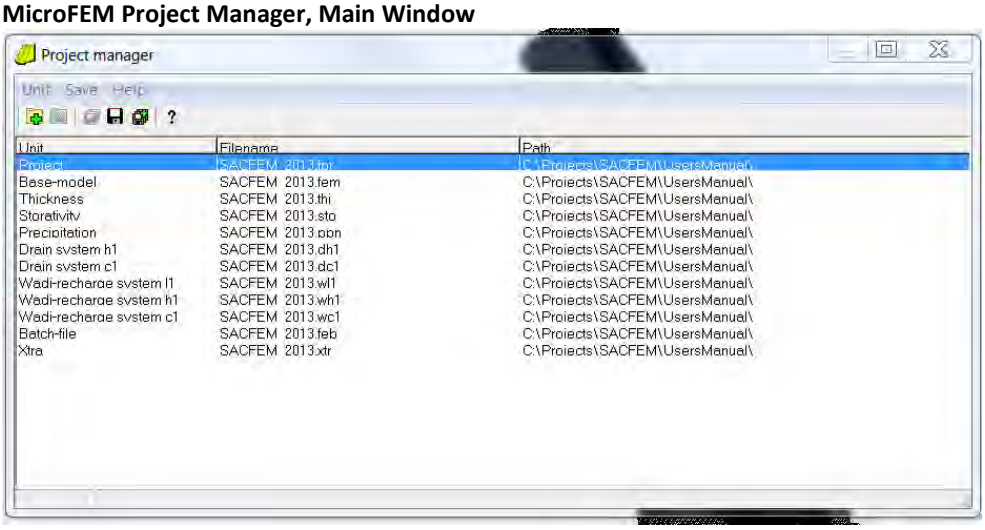
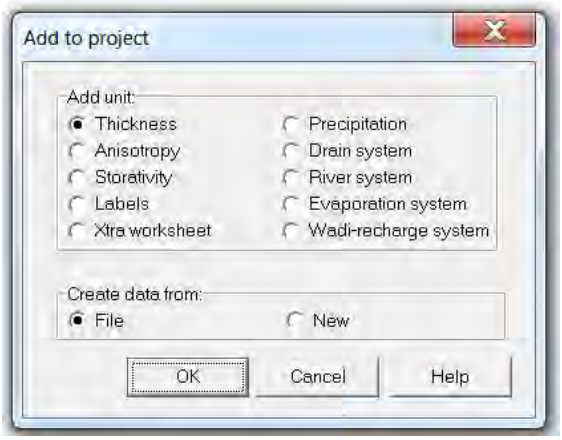



FIGURE 41
**MicroFEM Project Manager, Load File Window**




## 5.1.1 SACFEM2013 Base-model ("Param" tab)

The first tab displayed in the MicroFEM interface, as presented on Figure 39, is the Parameter tab. The parameter tab is essentially a display of all data included in the MicroFEM Base-model (*.fem file). A MicroFEM Base-model is an ASCII file[7] containing both network (grid) information, and basic groundwater model information. As shown on Figure 39, SACFEM_2013.fem contains nodal values of vertical resistance, transmissivity, head, and discharge for each of the seven model layers. The base-model also retains the "label 1" register; in the example provided on Figure 39, this is a stream label file. Individual parameter files (that is, files containing a list of numerical values for every model node) can be loaded for any of the registers either directly in the MicroFEM interface or via a batch file during transient simulation (as will be discussed in a subsequent section).

**Note – the "head 0" and "vert. resist. 1" registers at the top of the Parameter tab can be used to simulate leakage from a feature, such as a lake, into model Layer 1. These registers are similar to the top system boundary conditions (i.e., there are specified head and resistance terms). In SACFEM_2013.fem, these registers have value of zeros at every node. Non-zero values should NOT be loaded into these registers when running SACFEM2013.*

[7]All MicroFEM files are in ASCII format and can be opened in a text editor. The reader is directed to the MicroFEM help menu or User's Manual for additional format/structure of raw data files.

## 5.1.2 SACFEM2013 Thickness File ("Thick" Tab)

The thickness file (SACFEM_2013.thi) contains the nodal saturated thickness values for all model layers. A display of the thickness tab via the MicroFEM interface is included on Figure 42. As shown on Figure 40, the thickness tab (*.thi file) contains registers for both aquifer and aquitard saturated thickness for all model layers. SACFEM2013 does not include explicit simulation of aquitards; therefore, the values in these registers is zero for all model layers. Individual parameter files (that is, files containing a list of numerical values for every model node) can be loaded for any of the registers either directly in the MicroFEM interface or via a batch file during transient simulation (as will be discussed in a subsequent section).

**Note – the top level register can be populated with water table elevations (H1 values) so that model layer elevations are internally calculated/displayed when viewing the model in profile or when running groundwater flowlines. For the purposes of the current analysis, the top level values in SACFEM2013 are zero for all nodes.*

FIGURE 42
**SACFEM2013 Thickness Tab**

Parar | Thick | Stor | Top | Xtra

| | | |
|---|---|---|
| 0 | top level | [r 0.00000 |
| 1 | aquitard | [r 0.00000 |
| | aquifer | [n 18.46144 |
| 2 | aquitard | [r 0.00000 |
| | aquifer | [n 29.53829 |
| 3 | aquitard | [r 0.00000 |
| | aquifer | [n 29.53829 |
| 4 | aquitard | [r 0.00000 |
| | aquifer | [n 29.53829 |
| 5 | aquitard | [r 0.00000 |
| | aquifer | [n 40.61520 |
| 6 | aquitard | [r 0.00000 |
| | aquifer | [n 49.23040 |
| 7 | aquitard | [r 0.00000 |
| | aquifer | [n 73.57520 |

## 5.1.3 SACFEM2013 Storativity File (Stor Tab)

The storativity file (SACFEM_2013.sto) contains the storage values for all model nodes. This includes the specific yield of model Layer 1 and the specific storage values for model Layers 2 through 7. A display of the thickness tab via the MicroFEM interface is included on Figure 43. Individual parameter files (that is, files containing a list of numerical values for every model node) can be loaded for any of the registers either directly in the MicroFEM interface or via a batch file during transient simulation (as will be discussed in a subsequent section).

FIGURE 43
**SACFEM2013 Storage Tab**

Parar | Thick | Stor | Top | Xtra

| | | |
|---|---|---|
| 1 | coefficient | 0.12 |
| 2 | coefficient | 0.002458 |
| 3 | coefficient | 0.002458 |
| 4 | coefficient | 0.002458 |
| 5 | coefficient | 0.003606 |
| 6 | coefficient | 0.003941 |
| 7 | coefficient | 0.005421 |

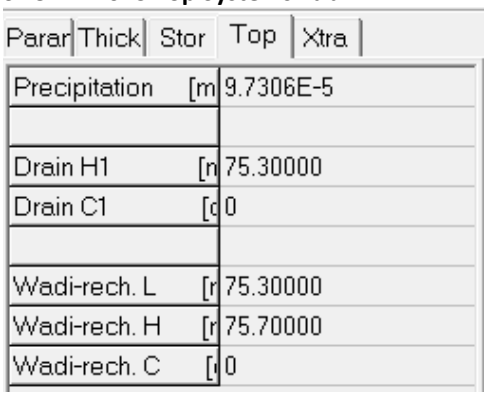
### 5.1.4 SACFEM2013 Top Systems ("Top" Tab)

The top systems tab comprises the data for boundary conditions that are applied to the "top" of the SACFEM2013 model. This means that the data are either head-dependent boundary conditions that are calculated relative to the simulated groundwater elevations in model Layer 1 or specified flux conditions that are applied to the top of the water table. SACFEM2013 contains the following top systems, as shown on Figure 44:

- Precipitation file (*.ppn) – includes a linear rate representing groundwater recharge from precipitation and applied irrigation water at every model node.
- Drainage file (*.dh1 and *.dc1) – contains the drain elevation and resistance term for every model node for a given stress period.
- Wadi System (*.wh1, *.wl1, and *.wc1) – contains the stream stage (*.wh1) and streambed (*.wl1) elevations and streambed resistance term (*.wc1) for all active stream nodes for a given stress period.

**Note: In the Example on Figure 44, both the drain and wadi resistance terms are 0, denoting that there are no active head-dependent boundary conditions for this particular node during this stress period (i.e., likely a dry or critical stress period).*

FIGURE 44
**SACFEM2013 Top Systems Tab**




As will be discussed in more detail in a subsequent section, the transient SACFEM2013 simulation includes the loading of a new and unique set of top system data files for every stress-period in the 41-year model simulation.

### 5.1.5 SACFEM2013 Extra Register ("Xtra" Tab)

The extra file (SACFEM_2013.xtr) contains 99 registers that are used to store numerical data for every model node. The data stored in the extra register are not used directly by MicroFEM when running the model; however, the data stored in a particular register can be referenced in a calculation during a transient simulation. The first 38 registers of SACFEM_2013.xtr are shown on Figure 45. The use of the extra register during SACFEM2013 simulations is discussed in a subsequent section.

### 5.1.6 Other MicroFEM Files

There are two other basic types of files used in MicroFEM, label files (*.lb) and parameter files (*.par). These are ASCII files that contain a MicroFEM header line followed by lines containing data for every model node. Label files contain text strings (alpha/numeric characters), and parameter files contain numerical values. Both text and numeric data can be assigned to each of the respective file types for all or a subset of the model nodes. In the event that data are assigned to a subset of the model domain, nodes without data will have null lines in the label file and a value of zero in a parameter file (that is the ASCII file will still have a line for every model node).

FIGURE 45
**SACFEM2013 Xtra Register**

Parar | Thick | Stor | Top | Xtra

| | | |
|---|---|---|
| x1 | mdist (meters) | 6533.006 |
| x2 | ... | 0 |
| x3 | NODE NUMBI | 2639 |
| x4 | Nodal Area (m | 391707.6 |
| x5 | GSE combine | 75.3 |
| x6 | Kx 1 m/d | 10.55371 |
| x7 | Kx 2-5 m/day | 10.55371 |
| x8 | Kx 6-7 m/day | 10.55371 |
| x9 | ... | 0 |
| x10 | Kh:Kv | 500 |
| x11 | ... | 0 |
| x12 | wl1 (mNAVD8 | 75.3 |
| x13 | ... | 0 |
| x14 | DEM min mNA | 76.241 |
| x15 | DEM mean ml | 77.5118 |
| x16 | ... | 0 |
| x17 | wc1 nearest n | 484.733 |
| x18 | wc1 old grid | 0 |
| x19 | ... | 0 |
| x20 | UrbanQ | 0 |
| x21 | ... | 0 |
| x22 | Mtn Front Rec | 0 |
| x23 | Mtn Front Fact | 0 |
| x24 | ... | 0 |
| x25 | temp wc1 | 484.733 |
| x26 | ... | 0 |
| x27 | 09/86 h1 ft NA | 235.4629 |
| x28 | DTW_ftbgs | 11.59637 |
| x29 | L1Bottom_ftbg | 77.21637 |
| x30 | L2 Bottom ft bg | 193.2653 |
| x31 | L3 Bottom ft bg | 309.3143 |
| x32 | L4 Bottom ft bg | 425.3633 |
| x33 | L5 Bottom ft bg | 591.6729 |
| x34 | L6 Bottom ft bg | 854.2366 |
| x35 | L7 Bottom ft bg | 1454.076 |
| x36 | ... | 0 |
| x37 | Orig wc1 | 484.733 |
| x38 | Run02 WC1 | 484.733 |

# 5.2 Preparation of Input Data-Sets

As discussed in Sections 3.2.4 and 3.2.5, detailed evaluations have been performed to develop transient surface water and agricultural water budgets as well as distributions of stream stage and flood bypass inundation. This section describes the utility that processes these raw data into monthly SACFEM2013 input files. Monthly model input files and the SACFEM2013 transient batch file are generated with the pre-processing utility "*PPN_Q_Generator_SACFEM_2013.xlsm.*" This utility is an Excel-based file containing several macros to generate the various SACFEM2013 files.

## 5.2.1 SACFEM2013 Input File Generation – The "Input" Worksheet

The Input worksheet of the pre-processing utility contains three macros that are used to generate the monthly deep percolation of precipitation/applied water (*.PPN), pumping (*.q), and wadi/drain (*.wh1, *.wc1, and *.dc1) files.

### 5.2.1.1 Water Budget Input File Information

This portion of the worksheet (see Figure 46) directs the macros to the water budget and stream stage files. In the first row, the user should enter the complete file path to the folder in which the files are saved. The file names for the deep percolation, agricultural pumping, and stream stage files are entered on the following lines. The files are in a space-delimited ASCII format where rows represent data for each SACFEM2013 model node and columns represent each month of the simulation period. The data contained in the deep percolation and agricultural pumping files are in units of acre-feet per month (ac-ft/month). As will be discussed below, the pre-processing utility converts these arrays to the appropriate units for input to SACFEM2013, m/day (*.PPN) and $m^3$/day (*.q). The surface water stage file contains data representing the stream, bypass, or reservoir stage (in units of meters [m] NAVD88) for each SACFEM2013 model node. A flag of -99 is assigned to non-surface water nodes (for all stress periods) and to surface water nodes for stress periods when the stream or bypass is dry. The use of this flag in the SACFEM2013 input file generation will be discussed further below.

*Note: If any of the water budget or stream input files are revised in the future, it is important that they be formatted consistently with the ASCII text files included in the SACFEM2013 release. Any differences in number of header rows, column spacing/number, etc. could result in generation of input files with incorrect values or failure of the macro to run successfully.*

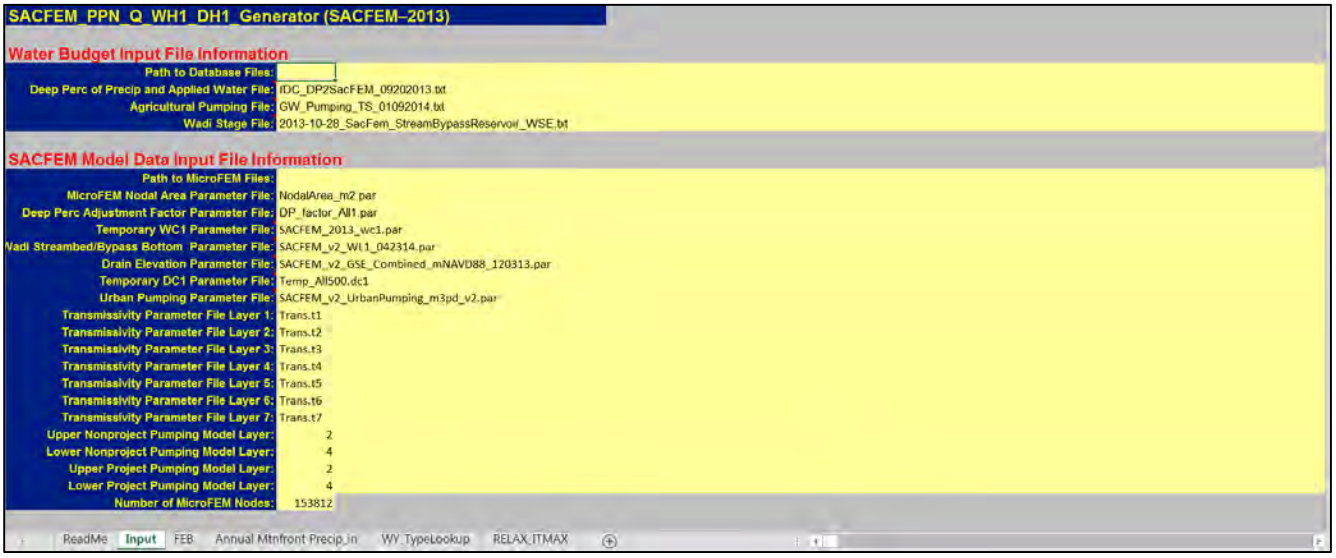
### 5.2.1.2 SACFEM2013 Model Data Input File Information

This portion of the worksheets (see Figure 46) directs the macros to generate the SACFEM2013 parameter files necessary for the various calculations and conversions. The first line is where the user inputs the file path to the parameter files. The necessary parameter files include the following:

- **MicroFEM nodal area**: a parameter file that contains the area of every SACFEM2013 model node ($m^2$)
- **Deep percolation adjustment factor**: a parameter file that can be used to assign multipliers to the groundwater recharge arrays for all or a subset of the model domain. For SACFEM2013, the adjustment factors are 1 for all model nodes, meaning that no adjustments are made to the IDC deep percolation values.
- **Temporary wc1**: a parameter file containing the streambed resistance term ($days^{-1}$) for stream, bypass, and reservoir nodes (calculated using Equation 6) and a value of 0 for all non-surface water nodes. These data are used when generating *.wc1 files.
- **Wadi streambed/bypass bottom**: a parameter file containing the stream, bypass, and reservoir bottom elevations (mNAVD88) and a value of 0 for all non-surface water nodes. These data are used to assign *.wl1 values.
- **Drain elevation**: a parameter file containing ground surface elevations (mNAVD88) for all SACFEM2013 model nodes. These data are used when generating *.dh1 files.

- **Temporary dc1**: a parameter file containing the drain resistance term (for SACFEM2013 this value is 500 for all nodes). This file is used when generating *.dc1 files.
- **Urban pumping**: a parameter file containing total annual urban pumping (described in Section 3.2.4.2) values ($m^3$/day). These data are combined with the agricultural pumping data when generating *.q files.
- **Transmissivity parameter**: parameter files containing nodal transmissivity values ($m^2$/day) for all SACFEM2013 nodes for each model layer. These data are used to apportion pumping to model layers based on relative transmissivity.
- **Upper and lower nonproject pumping model layer**: these rows are where the user specifies the upper and lower layers to which agricultural and urban pumping will be assigned. For SACFEM2013, agricultural and urban pumping are assigned to model Layers 2 through 4.
- **Upper/lower project pumping model layer**: these rows are where the user specifies the upper and lower layers to which any additional pumping (for a "with project" simulation) will be assigned. This user's manual assumes a no-action simulation; however, it is necessary to populate these rows for the macros to run.
- **Number of MicroFEM nodes**: the user inputs the total number of model nodes in this cell.

FIGURE 46
**PPN_Q_Generator_SACFEM_2013.xlsm, Input Worksheet (Upper Portion)**




*Note: Agricultural and or project pumping should never be assigned to model Layer 1 using this pre-processing utility, as the data will be over-written with the mountain-front recharge data calculated/ assigned during the transient model simulation. If shallow pumping is desired, these data should be manually assigned in the SACFEM2013 batch file.*

*Note: The user-defined upper/lower pumping model layers cannot vary by stress periods. This means that the user-defined layers for agricultural/urban and pumping model layers are the same for the entire simulation period (i.e., pumping will always be assigned to model Layers 2 through 4 in this example on Figure 46 and will not shift to shallower or deeper layers for individual stress periods).*

### 5.2.1.3 Output File Information

This section of the worksheet (see Figure 47) provides the macros to generate the output file information. The first row is where the user inputs the file path to the folder where all SACFEM2013 input files created by the macros will be stored. The next row is where the user specifies the MicroFEM header information that the macros include when generating the parameter files. The final set of rows is where the user defines the

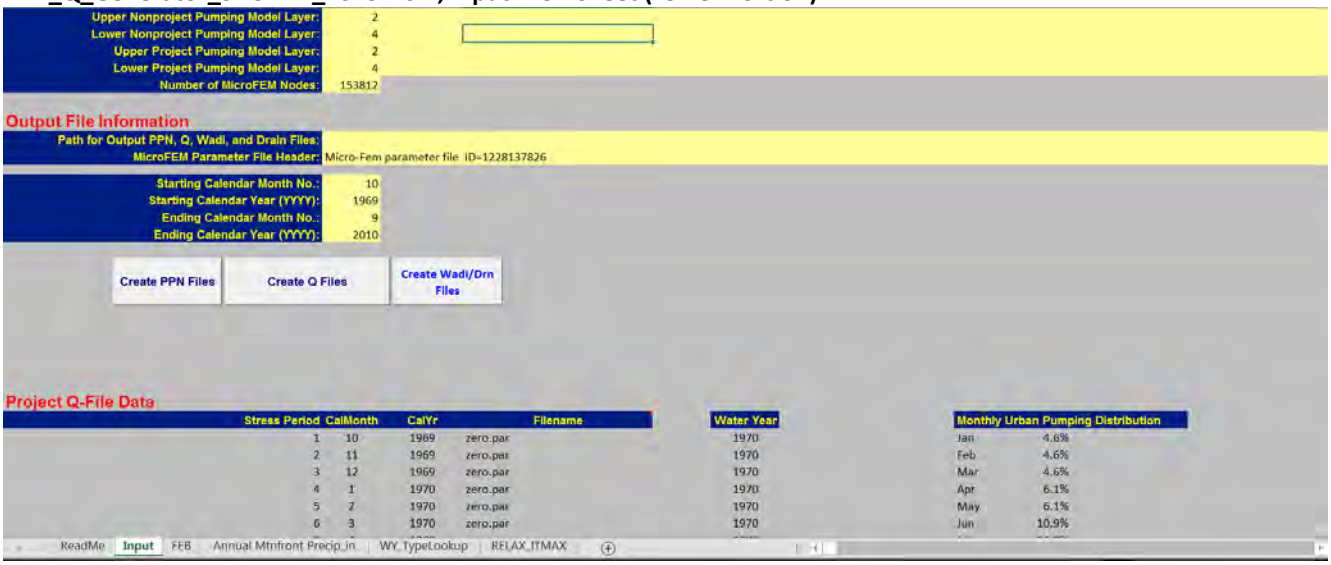
beginning and ending month/year for the simulation period. The macros use this information when naming the parameter files.

### 5.2.1.4 Project Q-File Data

As previously discussed, this user's manual describes the construction and calibration of a no-action version of SACFEM2013. Should the user wish to perform simulations that include additional project pumping (for example, to evaluate potential impacts of conjunctive water management projects), this Project Q-File Data section of the worksheet (see Figure 47) is where these data are incorporated. Although not completely displayed on Figure 47, this section of the worksheet includes rows for each of the 492 SACFEM2013 stress periods, with columns for the stress period number, the calendar month of the stress period, the calendar year of the stress period, and project pumping file name. The last column is where the user can input the name of a file containing nodal project pumping data ($m^3$/day). This file should contain pumping data only for nodes representing wells/project areas and should contain a value of 0 for all other nodes. The file name is entered only in cells representing stress periods when this additional pumping will occur (for example, during the irrigation season of dry or critical water years). The pumping information will then be apportioned vertically based on the model layer assignments defined in the preceding section and will be added to the agricultural/urban pumping data. In the example included in Figure 47, the parameter file zero.par is assigned to all stress periods. This means that when the macro is run, a value of 0 extra pumping will be added to the agricultural/urban pumping data.

This portion of the worksheet also includes the monthly distribution factors that the macro uses to distribute the annual urban pumping information (see Table 8).

FIGURE 47
**PPN_Q_Generator_SACFEM_2013.xlsm, Input Worksheet (Lower Portion)**




### 5.2.1.5 Create PPN Files Macro

The "Create PPN Files" button on the Input worksheet runs the macro that generates the monthly *.PPN input files. The macro reads the deep percolation of precipitation/applied water array, multiplies the data by the deep percolation adjustment factor (all 1 for SACFEM2013), and converts the data from values in units of ac-ft/month to linear rates of m/day. The macro then generates parameter files for each of the 492 stress periods with the naming convention of mm_yy.ppn, where mm represents the calendar month and yy represents the last two digits of the calendar year.

### 5.2.1.6 Create Q Files Macro

The "Create Q Files" button on the Input worksheet runs the macro that generates the monthly *.q input files. In general, the macro performs the following for each stress period:

- Reads the agricultural pumping array and converts the data from values in units of ac-ft/month to rates of $m^3$/day
- Apportions the annual urban pumping data based on the monthly distribution (see Table 8)
- Combines the agricultural and project-specific pumping data and apportions vertically based on the user-defined upper/lower model layers. The macro uses a weighting factor based on the relative transmissivity at each node for each model layer to apportion the pumping data. For example, the weighting factor for model Layer 2 is as follows:

$$Factor = \frac{\bar{A}_2}{\bar{A}_2 + \bar{A}_3 + \bar{A}_4} \quad (12)$$

Where T is the transmissivity ($L^2$/T) for a given model layer (2 through 4).

- Reads the project pumping parameter file and apportions vertically to the user-defined upper/lower "project" model layers using a similar factor as that defined in Equation 12 (modified as appropriate for the assigned model layers)
- Combines the agricultural, urban, and project (if included) pumping for all stress periods

The macro then generates parameter files for each of the 492 stress periods with the naming convention of mm_yy.$q_x$, where mm represents the calendar month, yy represents the last two digits of the calendar year, and x represents the model layer.

#### 5.2.1.7 Create Wadi/Drain Files Macro

The "Create Wadi/Drn Files" button on the Input worksheet runs the macro that generates the monthly *.wh1, *.wc1, and *.dc1 input files. As will be discussed in Section 5.3.2, the streambed elevation (*.wl1) and drain elevation (*.dh1) values are assigned during the first stress period and do not vary throughout the SACFEM2013 simulation. This macro reads the stream/bypass/reservoir elevation array and writes the values to *.wh1 files for each of the SACFEM2013 stress periods. The macro also uses this array to generate stream (wc1) and drain (dc1) conductance files as follows:

- If the flag "-99" is present for any node/stress period, the macro will output a value of 0 to the corresponding *.wc1 file (meaning that the stream/bypass/reservoir is inactive at that node for that stress period) and will write the corresponding value from the user-specified temporary dc1 file (defined in the SACFEM2013 Model Data Input File Information section of the worksheet) to the *.dc1 file at that node for that stress period.
- If the flag "-99" is **not** present (i.e., a "true" elevation value is present) for any node/stress period, the macro will output the corresponding value from the user-specified temporary wc1 file (defined in the SACFEM2013 Model Data Input File Information section of the worksheet) to the *.wc1 file (meaning that the stream/bypass/reservoir is active at that node for that stress period) and will write a value of 0 (meaning that the drain boundary condition is inactive for that node/stress period) to the corresponding *.dc1 file at that node for that stress period.

Similar to the deep percolation and pumping files, the naming conventions for the wadi and drain files are mm_yy.wh1, mm_yy.wc1, and mm_yy.dc1.

### 5.2.2 SACFEM2013 Batch File Generation – The "FEB" Worksheet

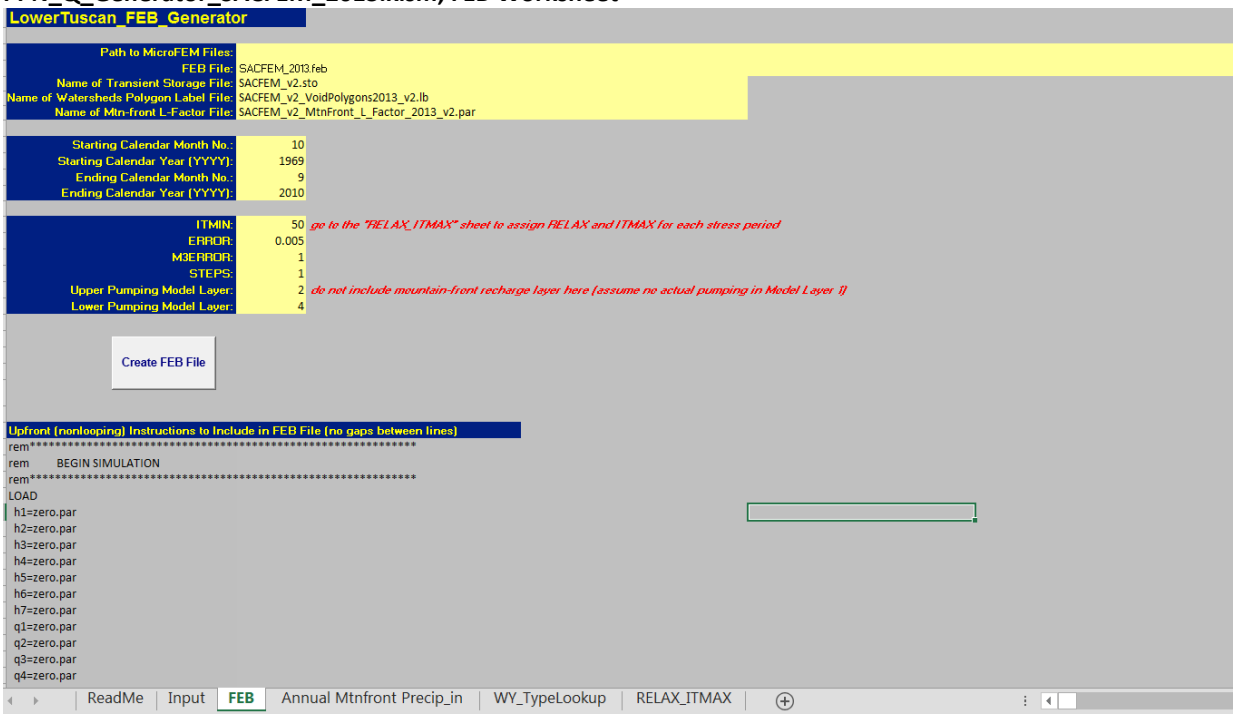
The FEB worksheet of the pre-processing utility contains one macro that is used to generate the batch file (*.feb) that runs the transient SACFEM2013 simulation. The SACFEM_2013.feb file is included as Appendix D for reference and is discussed in detail in Section 5.3.

#### 5.2.2.1 User-Defined Information

The first section of the FEB worksheet includes cells where the user can define specific model input files as follows (see Figure 48):

- **Path to MicroFEM Files**: The user specifies the file path to the folder where the *.feb file will be saved in this cell.
- **FEB File**: The user specifies the name of the *.feb file in this cell.
- **Name of Transient Storage File**: The user specifies the name of the SACFEM2013 storage file in this cell. The file will not be accessed by the macro; however, the file name will be written to the *.feb file in the appropriate locations where it will be accessed during the transient simulation.
- **Name of Watersheds Polygon Label File**: The user specifies the name of the SACFEM2013 label file containing for the mountain-front recharge polygons in this cell. The file will not be accessed by the macro; however, the file name will be written to the *.feb file in the appropriate locations where it will be accessed during the transient simulation.
- **Name of Mtn-front L-Factor File**: The user specifies the name of SACFEM2013 parameter file used to scale the total mountain-front recharge for each polygon in this cell. The file will not be accessed by the macro; however, the file name will be written to the *.feb file in the appropriate locations where it will be accessed during the transient simulation.

FIGURE 48
**PPN_Q_Generator_SACFEM_2013.xlsm, FEB Worksheet**




The next section of the FEB worksheet includes cells where the user defines the beginning and ending calendar months and years for the simulation period (see Figure 48). The following section includes cells where the user defines criteria that are written to the TIME and RUN statements for each stress period. These include ITMIN (minimum number of iterations for each stress period), ERROR (closure criteria for error in heads, m), M3ERROR (closure criteria for water budget error for all stress periods, $m^3$/day), and STEPS (number of time steps for all stress periods). The assignment of ITMAX (maximum number of iterations for each stress period) and RELAX (solver relaxation factor) will be discussed in the macro execution section. The upper and lower pumping model layer cells are used to define the shallowest and deepest model layers where pumping (agricultural, urban, or project) occurs. The macro uses this information to determine how many *.q files for which to write load statements for all stress periods.

#### 5.2.2.2 Non-Looping Batch File Text

The section of the FEB worksheet (following the cell containing the text "Upfront [non-looping] Instructions to include in FEB File ["no gaps between lines"]) includes syntax that is written verbatim directly to the batch file (See Figure 48). A detailed discussion of this portion of the batch file is provided in Section 5.3.1. In general, this portion of the batch file assigns initial model input parameters and opens model output files. If the user would like to change any input our output files, the file names and calculations can be updated in this portion of the pre-processor. Refer to Appendix D for an example of the SACFEM_2013.feb file and to Section 5.3.1 for a complete discussion of the syntax.

*Note: There can be no blank rows in this portion of the worksheet. The macro will only write text to the *.feb file up to the first blank row.*

#### 5.2.2.3 Other Worksheets

There are three other worksheets accessed by the macro that generates the SACFEM2013 batch file, including "*Annual Mtnfront Precip_in,*" "*WY_TypeLookup,*" and "*RELAX_ITMAX*" (see Figure 48). The "*Annual Mtnfront Precip_in*" worksheet contains the data written to the *.feb file to estimate subsurface inflow along the margin of the model domain (see Figures 49a through 49d). The worksheet contains a column for each of the 34 mountain-front recharge polygons shown on Figure 22. The first three rows list the polygon number, the adjustment factor (multiplier to increase or decrease recharge for each polygon), and the area (in acres) of each polygon. The worksheet contains the following "blocks" of data that progress through the calculation of deep percolation for each calendar year and mountain front recharge polygons:

- Average precipitation (inches) across each polygon based on the PRISM dataset (see Box 47a)
- Deep percolation of precipitation (inches) for each polygon calculated using Equation 9 (see Figure 49b)
- Volumetric deep percolation of precipitation ($m^3$), calculated using the deep percolation values in the previous bullet and the polygon areas (see Figure 49c)
- Monthly distribution factors for mountain front recharge based on the distribution of unimpaired runoff of Deer Creek at the Vina stream gage (see Figure 49d).

The "*WY_TypeLookup*" worksheet contains data related to the water year index for the Sacramento and San Joaquin Valleys (see Figure 50). These data include unimpaired runoff, water year index, and water year classification. In SACFEM2013, this information is written as the header for each stress period of the simulation period for informational purposes only.

The "*RELAX_ITMAX*" worksheet is where the user can paste the simulation summary information from a previous simulation (see Figure 51) from the SACFEM2013 Run Log Reader (discussed below in Section 5.5.1). This information is used to determine if additional iterations or solver relaxation are needed for any stress periods.

FIGURE 49A

**PPN_Q_Generator_SACFEM_2013.xlsm, Annual Mtnfront Precip_in Worksheet, PRISM Data**

| Subwatershed > | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mountain-front Adj Factor > | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| Acreage > | 6,612 | 28,490 | 52,512 | 30,281 | 79,440 | 441 | 1,319 | 49,227 | 637 | 16,749 | 6,939 |
| Calendar Year | | | | | | | | | | | |
| Annual Mountain-front Precipitation from PRISM/GIS (inches) | | | | | | | | | | | |
| 1969 | 37.04 | 37.21 | 42.48 | 58.42 | 64.43 | 52.73 | 57.33 | 54.62 | 40.32 | 39.51 | 39.98 |
| 1970 | 38.29 | 38.70 | 43.87 | 59.13 | 64.90 | 50.45 | 54.95 | 52.63 | 39.51 | 38.06 | 38.58 |
| 1971 | 21.01 | 20.95 | 23.36 | 30.08 | 29.16 | 20.96 | 22.77 | 23.19 | 18.61 | 18.41 | 19.95 |
| 1972 | 28.17 | 27.56 | 29.43 | 37.08 | 37.98 | 29.12 | 31.41 | 30.62 | 23.45 | 23.29 | 24.17 |
| 1973 | 41.09 | 41.09 | 46.05 | 63.26 | 72.27 | 57.37 | 62.00 | 60.34 | 47.53 | 46.50 | 47.40 |
| 1974 | 30.46 | 30.23 | 33.62 | 45.59 | 49.16 | 38.74 | 42.55 | 40.10 | 28.47 | 28.07 | 28.52 |
| 1975 | 28.77 | 28.93 | 32.23 | 42.25 | 45.27 | 35.86 | 39.14 | 37.76 | 28.91 | 29.48 | 30.53 |
| 1976 | 13.40 | 13.12 | 14.14 | 17.12 | 16.92 | 13.24 | 14.18 | 12.87 | 9.31 | 9.61 | 9.55 |
| 1977 | 25.38 | 25.26 | 26.37 | 31.38 | 32.27 | 23.93 | 25.67 | 24.58 | 17.66 | 17.97 | 19.13 |
| 1978 | 36.06 | 36.19 | 39.34 | 51.17 | 58.29 | 45.99 | 49.37 | 46.63 | 33.49 | 33.26 | 34.14 |
| 1979 | 37.91 | 37.90 | 40.94 | 51.60 | 56.27 | 44.20 | 47.55 | 45.50 | 34.19 | 34.61 | 35.13 |
| 1980 | 27.18 | 27.28 | 30.10 | 40.45 | 45.77 | 34.66 | 37.52 | 34.94 | 22.68 | 23.05 | 24.54 |
| 1981 | 40.68 | 41.10 | 45.46 | 59.50 | 65.03 | 48.82 | 52.63 | 49.92 | 34.14 | 35.22 | 38.19 |
| 1982 | 36.22 | 36.62 | 40.96 | 55.04 | 60.33 | 47.63 | 51.72 | 51.37 | 39.45 | 39.87 | 43.09 |
| 1983 | 59.53 | 59.89 | 65.80 | 85.50 | 92.46 | 73.30 | 77.89 | 75.72 | 62.42 | 60.27 | 59.88 |
| 1984 | 24.05 | 23.71 | 25.91 | 33.31 | 35.08 | 27.26 | 29.45 | 28.88 | 22.57 | 21.93 | 22.50 |
| 1985 | 19.37 | 19.19 | 20.46 | 26.18 | 28.77 | 23.08 | 24.80 | 24.38 | 19.68 | 19.74 | 20.76 |
| 1986 | 32.68 | 33.21 | 37.22 | 50.70 | 54.54 | 41.97 | 45.43 | 44.97 | 36.86 | 34.57 | 33.12 |
| 1987 | 25.31 | 25.55 | 28.54 | 38.94 | 44.36 | 36.39 | 40.02 | 38.03 | 26.78 | 25.99 | 26.22 |
| 1988 | 24.96 | 24.68 | 26.20 | 33.16 | 36.20 | 28.32 | 31.08 | 30.63 | 22.68 | 22.57 | 24.23 |
| 1989 | 27.35 | 27.17 | 29.36 | 38.24 | 39.80 | 30.61 | 32.91 | 31.37 | 23.27 | 24.81 | 26.64 |
| 1990 | 20.11 | 19.81 | 21.09 | 27.05 | 30.22 | 24.11 | 26.64 | 26.91 | 21.29 | 21.14 | 22.74 |
| 1991 | 22.93 | 23.16 | 25.46 | 33.43 | 38.89 | 32.17 | 34.95 | 34.31 | 27.63 | 27.54 | 28.19 |
| 1992 | 26.62 | 27.76 | 30.50 | 38.63 | 44.42 | 35.57 | 38.08 | 37.50 | 30.20 | 29.96 | 30.06 |
| 1993 | 39.40 | 38.95 | 41.79 | 53.57 | 58.78 | 48.71 | 52.90 | 52.02 | 41.64 | 39.88 | 39.13 |
| 1994 | 25.79 | 25.52 | 26.79 | 32.92 | 37.34 | 31.02 | 33.33 | 32.61 | 26.26 | 25.06 | 25.10 |

FIGURE 49B

**PPN_Q_Generator_SACFEM_2013.xlsm, Annual Mtnfront Precip_in Worksheet, Deep Percolation (inches)**

| Subwatershed > | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mountain-front Adj Factor > | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| Acreage > | 6,612 | 28,490 | 52,512 | 30,281 | 79,440 | 441 | 1,319 | 49,227 | 637 | 16,749 | 6,939 |
| Calendar Year | | | | | | | | | | | |
| Annual Deep Percolation of Mountain-front Precipitation via Turner Equation (inches) | | | | | | | | | | | |
| 1969 | 11.88 | 11.97 | 14.93 | 24.43 | 28.16 | 20.96 | 23.75 | 22.10 | 13.71 | 13.25 | 13.52 |
| 1970 | 12.57 | 12.80 | 15.73 | 24.86 | 28.46 | 19.59 | 22.30 | 20.90 | 13.25 | 12.44 | 12.73 |
| 1971 | 3.70 | 3.68 | 4.80 | 8.14 | 7.67 | 3.68 | 4.52 | 4.72 | 2.63 | 2.55 | 3.22 |
| 1972 | 7.16 | 6.85 | 7.81 | 11.90 | 12.40 | 7.65 | 8.84 | 8.43 | 4.84 | 4.76 | 5.18 |
| 1973 | 14.14 | 14.14 | 17.00 | 27.43 | 33.15 | 23.78 | 26.64 | 25.61 | 17.86 | 17.26 | 17.79 |
| 1974 | 8.34 | 8.22 | 10.01 | 16.73 | 18.82 | 12.82 | 14.97 | 13.58 | 7.32 | 7.11 | 7.34 |
| 1975 | 7.47 | 7.55 | 9.27 | 14.80 | 16.54 | 11.23 | 13.04 | 12.27 | 7.54 | 7.83 | 8.38 |
| 1976 | 0.54 | 0.43 | 0.81 | 2.00 | 1.92 | 0.48 | 0.83 | 0.34 | 0.00 | 0.00 | 0.00 |
| 1977 | 5.77 | 5.71 | 6.26 | 8.82 | 9.29 | 5.07 | 5.92 | 5.38 | 2.23 | 2.36 | 2.86 |
| 1978 | 11.34 | 11.40 | 13.15 | 20.02 | 24.34 | 16.96 | 18.95 | 17.33 | 9.94 | 9.82 | 10.29 |
| 1979 | 12.36 | 12.35 | 14.05 | 20.28 | 23.11 | 15.92 | 17.87 | 16.67 | 10.32 | 10.54 | 10.83 |
| 1980 | 6.67 | 6.72 | 8.15 | 13.78 | 16.83 | 10.57 | 12.14 | 10.73 | 4.47 | 4.65 | 5.36 |
| 1981 | 13.91 | 14.15 | 16.65 | 25.09 | 28.54 | 18.62 | 20.90 | 19.28 | 10.29 | 10.87 | 12.51 |
| 1982 | 11.43 | 11.64 | 14.06 | 22.36 | 25.61 | 17.92 | 20.35 | 20.14 | 13.21 | 13.45 | 15.28 |
| 1983 | 25.11 | 25.33 | 29.03 | 41.79 | 46.43 | 33.81 | 36.79 | 35.37 | 26.90 | 25.57 | 25.33 |
| 1984 | 5.12 | 4.96 | 6.03 | 9.85 | 10.80 | 6.71 | 7.82 | 7.53 | 4.42 | 4.12 | 4.39 |
| 1985 | 2.97 | 2.88 | 3.45 | 6.16 | 7.47 | 4.66 | 5.49 | 5.28 | 3.10 | 3.13 | 3.59 |
| 1986 | 9.51 | 9.79 | 11.98 | 19.74 | 22.05 | 14.64 | 16.63 | 16.36 | 11.78 | 10.52 | 9.75 |
| 1987 | 5.74 | 5.85 | 7.35 | 12.93 | 16.01 | 11.52 | 13.54 | 12.42 | 6.46 | 6.07 | 6.19 |
| 1988 | 5.56 | 5.43 | 6.17 | 9.77 | 11.41 | 7.24 | 8.67 | 8.43 | 4.48 | 4.42 | 5.21 |
| 1989 | 6.75 | 6.66 | 7.77 | 12.54 | 13.41 | 8.42 | 9.63 | 8.82 | 4.75 | 5.49 | 6.39 |
| 1990 | 3.29 | 3.16 | 3.74 | 6.60 | 8.22 | 5.15 | 6.39 | 6.53 | 3.83 | 3.76 | 4.50 |
| 1991 | 4.59 | 4.70 | 5.81 | 9.91 | 12.90 | 9.24 | 10.73 | 10.38 | 6.89 | 6.85 | 7.18 |
| 1992 | 6.39 | 6.96 | 8.36 | 12.76 | 16.05 | 11.07 | 12.45 | 12.13 | 8.21 | 8.08 | 8.13 |
| 1993 | 13.19 | 12.94 | 14.54 | 21.46 | 24.64 | 18.56 | 21.06 | 20.53 | 14.45 | 13.46 | 13.04 |
| 1994 | 5.97 | 5.84 | 6.47 | 9.64 | 12.04 | 8.64 | 9.86 | 9.47 | 6.20 | 5.61 | 5.63 |

FIGURE 49C

**PPN_Q_Generator_SACFEM_2013.xlsm, Annual Mtnfront Precip_in Worksheet, Deep Percolation (cubic meters)**

| Subwatershed > | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mountain-front Adj Factor > | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| Acreage > | 6,612 | 28,490 | 52,512 | 30,281 | 79,440 | 441 | 1,319 | 49,227 | 637 | 16,749 | 6,939 |
| Calendar Year | | | | | | | | | | | |
| Annual Volumetric Deep Percolation of Mountain-front Precipitation via Turner Equation (m³) | | | | | | | | | | | |
| 1969 | 8,071,480 | 35,050,083 | 80,605,692 | 76,028,964 | 229,983,341 | 949,454 | 3,220,633 | 111,833,985 | 897,801 | 22,812,497 | 9,639,695 |
| 1970 | 8,540,053 | 37,478,822 | 84,904,385 | 77,394,633 | 232,419,920 | 887,594 | 3,023,540 | 105,745,704 | 867,913 | 21,415,694 | 9,077,969 |
| 1971 | 2,514,789 | 10,762,618 | 25,894,427 | 25,346,695 | 62,628,598 | 166,697 | 612,367 | 23,868,833 | 172,431 | 4,385,048 | 2,298,967 |
| 1972 | 4,868,526 | 20,071,262 | 42,148,923 | 37,034,436 | 101,218,583 | 346,541 | 1,198,707 | 42,633,113 | 317,006 | 8,202,694 | 3,695,924 |
| 1973 | 9,611,016 | 41,405,970 | 91,739,838 | 85,387,637 | 270,678,006 | 1,077,150 | 3,612,435 | 129,581,549 | 1,170,179 | 29,711,012 | 12,686,701 |
| 1974 | 5,671,034 | 24,073,294 | 54,051,945 | 52,062,486 | 153,711,320 | 580,557 | 2,030,326 | 68,704,380 | 479,358 | 12,246,062 | 5,237,541 |
| 1975 | 5,076,445 | 22,107,389 | 50,033,016 | 46,059,780 | 135,048,448 | 508,549 | 1,768,261 | 62,106,245 | 493,996 | 13,487,115 | 5,975,688 |
| 1976 | 364,180 | 1,270,798 | 4,371,530 | 6,216,931 | 15,643,786 | 21,708 | 112,292 | 1,732,334 | 0 | 0 | 0 |
| 1977 | 3,922,187 | 16,735,807 | 33,782,660 | 27,461,024 | 75,898,513 | 229,521 | 802,062 | 27,233,785 | 145,809 | 4,057,033 | 2,040,307 |
| 1978 | 7,704,806 | 33,398,259 | 70,990,153 | 62,312,836 | 198,791,587 | 768,284 | 2,569,035 | 87,707,900 | 651,265 | 16,905,719 | 7,339,410 |
| 1979 | 8,399,181 | 36,160,859 | 75,858,293 | 63,113,538 | 188,686,579 | 721,149 | 2,423,463 | 84,374,426 | 676,092 | 18,152,619 | 7,721,904 |
| 1980 | 4,530,364 | 19,666,373 | 44,005,930 | 42,887,189 | 137,424,347 | 479,008 | 1,645,796 | 54,282,984 | 292,992 | 8,006,408 | 3,825,351 |
| 1981 | 9,452,107 | 41,423,908 | 89,869,165 | 78,091,343 | 233,084,406 | 843,629 | 2,833,713 | 97,540,479 | 674,270 | 18,722,112 | 8,922,968 |
| 1982 | 7,765,646 | 34,092,872 | 75,913,344 | 69,593,014 | 209,089,117 | 811,982 | 2,759,548 | 101,910,316 | 865,577 | 23,155,986 | 10,899,293 |
| 1983 | 17,067,438 | 74,178,240 | 156,674,788 | 130,083,151 | 379,133,110 | 1,531,712 | 4,988,155 | 178,994,011 | 1,762,346 | 44,019,941 | 18,063,191 |
| 1984 | 3,482,213 | 14,530,594 | 32,560,686 | 30,653,605 | 88,206,781 | 303,817 | 1,060,246 | 38,087,114 | 289,638 | 7,100,445 | 3,130,109 |
| 1985 | 2,015,730 | 8,446,822 | 18,635,763 | 19,187,783 | 61,010,114 | 211,153 | 743,781 | 26,741,988 | 203,096 | 5,388,490 | 2,558,045 |
| 1986 | 6,463,058 | 28,681,604 | 64,640,404 | 61,450,113 | 180,071,696 | 663,300 | 2,255,280 | 82,806,498 | 771,442 | 18,118,156 | 6,950,492 |
| 1987 | 3,899,282 | 17,145,857 | 39,683,449 | 40,242,453 | 130,753,610 | 521,718 | 1,835,205 | 62,843,763 | 423,466 | 10,455,525 | 4,412,129 |
| 1988 | 3,782,340 | 15,897,637 | 33,329,303 | 30,405,928 | 93,180,662 | 328,086 | 1,175,221 | 42,656,604 | 293,155 | 7,615,765 | 3,717,639 |
| 1989 | 4,587,624 | 19,505,064 | 41,953,255 | 39,024,206 | 109,519,337 | 381,508 | 1,306,154 | 44,613,700 | 311,201 | 9,455,969 | 4,558,933 |
| 1990 | 2,237,427 | 9,249,149 | 20,175,056 | 20,540,861 | 67,099,018 | 233,406 | 866,674 | 33,044,837 | 250,815 | 6,474,223 | 3,212,291 |
| 1991 | 3,121,374 | 13,759,252 | 31,367,924 | 30,848,415 | 105,354,343 | 418,467 | 1,454,818 | 52,543,534 | 451,297 | 11,785,025 | 5,117,497 |
| 1992 | 4,340,502 | 20,375,485 | 45,145,519 | 39,703,341 | 131,035,548 | 501,361 | 1,688,332 | 61,370,967 | 537,726 | 13,916,972 | 5,801,050 |
| 1993 | 8,962,523 | 37,888,549 | 78,462,276 | 66,811,794 | 201,232,422 | 840,727 | 2,855,416 | 103,898,597 | 946,792 | 23,165,189 | 9,298,666 |
| 1994 | 4,060,245 | 17,105,728 | 34,922,717 | 30,006,312 | 98,328,646 | 391,194 | 1,336,880 | 47,926,602 | 406,316 | 9,663,304 | 4,016,904 |

FIGURE 49D

**PPN_Q_Generator_SACFEM_2013.xlsm, Annual Mtnfront Precip_in Worksheet, Monthly Distribution**

| Subwatershed > | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mountain-front Adj Factor > | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 |
| Acreage > | 6,612 | 28,490 | 52,512 | 30,281 | 79,440 | 441 | 1,319 | 49,227 | 637 | 16,749 | 6,939 |
| Calendar Year | | | | | | | | | | | |
| Assumed Monthly Distribution of Deep Percolation of Mountain-front Precipitation from Mean of Monthly Streamflows for Deer Creek Near Vina (percent) | | | | | | | | | | | |
| Jan | 14.2% | | | | | | | | | | |
| Feb | 15.2% | | | | | | | | | | |
| Mar | 15.4% | | | | | | | | | | |
| Apr | 13.6% | | | | | | | | | | |
| May | 10.3% | | | | | | | | | | |
| Jun | 5.1% | | | | | | | | | | |
| Jul | 3.1% | | | | | | | | | | |
| Aug | 2.6% | | | | | | | | | | |
| Sep | 2.4% | | | | | | | | | | |
| Oct | 3.0% | | | | | | | | | | |
| Nov | 4.9% | | | | | | | | | | |
| Dec | 10.2% | | | | | | | | | | |
| Sum | 100.0% | | | | | | | | | | |

FIGURE 50

**PPN_Q_Generator_SACFEM_2013.xlsm, WY_TypeLookup Worksheet**

| | Sacramento Valley | | | | | San Joaquin Valley | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| WY | Oct-Mar (maf) | Apr-Jul (maf) | WYsum (maf) | Index | Yr-type | Oct-Mar (maf) | Apr-Jul (maf) | WYsum (maf) | Index | Yr-type | Source: http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST |
| 1970 | 18.87 | 4.35 | 24.06 | 10.4 | W | 2.55 | 2.96 | 5.61 | 3.18 | AN | |
| 1971 | 12.71 | 8.9 | 22.57 | 10.37 | W | 1.56 | 3.23 | 4.91 | 2.89 | BN | |
| 1972 | 7.61 | 5.02 | 13.43 | 7.29 | BN | 1.25 | 2.22 | 3.57 | 2.16 | D | |
| 1973 | 12.8 | 6.38 | 20.05 | 8.58 | AN | 1.87 | 4.48 | 6.47 | 3.5 | AN | |
| 1974 | 21.69 | 9.78 | 32.5 | 12.99 | W | 2.43 | 4.53 | 7.12 | 3.9 | W | |
| 1975 | 9.24 | 8.95 | 19.23 | 9.35 | W | 1.37 | 4.65 | 6.18 | 3.85 | W | |
| 1976 | 4.63 | 2.75 | 8.2 | 5.29 | C | 0.78 | 1.07 | 1.97 | 1.57 | C | |
| 1977 | 2.49 | 1.93 | 5.12 | 3.11 | C | 0.22 | 0.8 | 1.05 | 0.84 | C | |
| 1978 | 14.9 | 8.12 | 23.92 | 8.65 | AN | 2.57 | 6.5 | 9.65 | 4.58 | W | |
| 1979 | 6.06 | 5.64 | 12.41 | 6.67 | BN | 1.87 | 3.99 | 5.98 | 3.67 | AN | |
| 1980 | 15.49 | 6 | 22.33 | 9.04 | AN | 3.74 | 5.41 | 9.47 | 4.73 | W | |
| 1981 | 6.81 | 3.63 | 11.1 | 6.21 | D | 0.85 | 2.29 | 3.22 | 2.44 | D | |
| 1982 | 20.56 | 11.82 | 33.41 | 12.76 | W | 3.78 | 7 | 11.41 | 5.45 | W | |
| 1983 | 22.75 | 13.66 | 37.68 | 15.29 | W | 5.42 | 8.73 | 15.01 | 7.22 | W | |
| 1984 | 15.98 | 5.52 | 22.35 | 10 | W | 3.51 | 3.48 | 7.13 | 3.69 | AN | |
| 1985 | 6.24 | 4 | 11.04 | 6.47 | D | 1.11 | 2.41 | 3.6 | 2.4 | D | |
| 1986 | 19.45 | 5.45 | 25.83 | 9.96 | W | 4.36 | 4.92 | 9.5 | 4.31 | W | |
| 1987 | 5.85 | 2.8 | 9.27 | 5.86 | D | 0.55 | 1.48 | 2.08 | 1.86 | C | |
| 1988 | 5.78 | 2.9 | 9.23 | 4.65 | C | 0.86 | 1.55 | 2.48 | 1.48 | C | |
| 1989 | 9.03 | 5.07 | 14.82 | 6.13 | D | 1.07 | 2.42 | 3.56 | 1.96 | C | |
| 1990 | 4.94 | 3.72 | 9.26 | 4.81 | C | 0.83 | 1.59 | 2.46 | 1.51 | C | |
| 1991 | 3.9 | 4.01 | 8.44 | 4.21 | C | 0.56 | 2.57 | 3.2 | 1.96 | C | |
| 1992 | 5.41 | 2.93 | 8.87 | 4.06 | C | 0.86 | 1.66 | 2.58 | 1.56 | C | |
| 1993 | 12.44 | 8.98 | 22.21 | 8.54 | AN | 2.49 | 5.65 | 8.38 | 4.2 | W | |
| 1994 | 4.55 | 2.73 | 7.81 | 5.02 | C | 0.66 | 1.8 | 2.54 | 2.05 | C | |
| 1995 | 19.83 | 13.6 | 34.55 | 12.89 | W | 3.67 | 8.01 | 12.32 | 5.95 | W | |
| 1996 | 13.05 | 8.37 | 22.29 | 10.26 | W | 2.57 | 4.51 | 7.22 | 4.12 | W | |
| 1997 | 20.22 | 4.39 | 25.42 | 10.82 | W | 5.75 | 3.59 | 9.51 | 4.13 | W | |
| 1998 | 17.65 | 12.54 | 31.4 | 13.31 | W | 2.82 | 7.11 | 10.43 | 5.65 | W | |

ReadMe | Input | FEB | Annual Mtnfront Precip_in | **WY_TypeLookup** | RELAX_ITMAX

FIGURE 51

**PPN_Q_Generator_SACFEM_2013.xlsm, RELAX_ITMAX Worksheet**

| Stress Period -1 | Sim Time | Time Units | Month | CalYr | DecYr | Iterations | Max Head Diff (m) | Max Flux Diff ($m^3$) | Node of Max Head Change | Layer of Max Head Change | Relax | Itmax | NewRelax | NewItmax |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 31 | days | 9 | 1969 | 1969.75 | 399 | 0.002608 | 0.9976 | 45850 | 4 | 1 | 1000 | 1 | 1000 |
| 1 | 61 | days | 10 | 1969 | 1969.833333 | 131 | 0.004949 | 0.737 | 43548 | 1 | 0 | 600 | 0 | 600 |
| 2 | 92 | days | 11 | 1969 | 1969.916667 | 128 | 0.0041 | 0.9641 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 3 | 123 | days | 12 | 1969 | 1970 | 131 | 0.003624 | 0.9822 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 4 | 151 | days | 1 | 1970 | 1970.083333 | 123 | 0.002967 | 0.9893 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 5 | 182 | days | 2 | 1970 | 1970.166667 | 126 | 0.002978 | 0.9665 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 6 | 212 | days | 3 | 1970 | 1970.25 | 118 | 0.004924 | 0.9967 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 7 | 243 | days | 4 | 1970 | 1970.333333 | 126 | 0.002797 | 0.9878 | 87289 | 7 | 0 | 600 | 0 | 600 |
| 8 | 273 | days | 5 | 1970 | 1970.416667 | 126 | 0.002521 | 0.9906 | 84930 | 7 | 0 | 600 | 0 | 600 |
| 9 | 304 | days | 6 | 1970 | 1970.5 | 131 | 0.002365 | 0.9859 | 87289 | 7 | 0 | 600 | 0 | 600 |
| 10 | 335 | days | 7 | 1970 | 1970.583333 | 119 | 0.001876 | 0.9969 | 88471 | 7 | 0 | 600 | 0 | 600 |
| 11 | 365 | days | 8 | 1970 | 1970.666667 | 94 | 0.00181 | 0.9648 | 87337 | 7 | 0 | 600 | 0 | 600 |
| 12 | 396 | days | 9 | 1970 | 1970.75 | 343 | 0.002854 | 0.9979 | 45849 | 4 | 1 | 1000 | 1 | 1000 |
| 13 | 426 | days | 10 | 1970 | 1970.833333 | 122 | 0.004281 | 0.9745 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 14 | 457 | days | 11 | 1970 | 1970.916667 | 129 | 0.003085 | 0.9812 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 15 | 488 | days | 12 | 1970 | 1971 | 126 | 0.002772 | 0.9669 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 16 | 516 | days | 1 | 1971 | 1971.083333 | 115 | 0.00281 | 0.9997 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 17 | 547 | days | 2 | 1971 | 1971.166667 | 117 | 0.003296 | 0.9762 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 18 | 577 | days | 3 | 1971 | 1971.25 | 116 | 0.003933 | 0.9648 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 19 | 608 | days | 4 | 1971 | 1971.333333 | 125 | 0.002472 | 0.9698 | 84930 | 7 | 0 | 600 | 0 | 600 |
| 20 | 638 | days | 5 | 1971 | 1971.416667 | 129 | 0.002367 | 0.981 | 84930 | 7 | 0 | 600 | 0 | 600 |
| 21 | 669 | days | 6 | 1971 | 1971.5 | 133 | 0.002037 | 0.9813 | 84930 | 7 | 0 | 600 | 0 | 600 |
| 22 | 700 | days | 7 | 1971 | 1971.583333 | 121 | 0.001801 | 0.9673 | 89645 | 7 | 0 | 600 | 0 | 600 |
| 23 | 730 | days | 8 | 1971 | 1971.666667 | 96 | 0.001704 | 0.9689 | 88450 | 7 | 0 | 600 | 0 | 600 |
| 24 | 761 | days | 9 | 1971 | 1971.75 | 121 | 0.002808 | 0.9706 | 84930 | 7 | 0 | 600 | 0 | 600 |
| 25 | 791 | days | 10 | 1971 | 1971.833333 | 205 | 0.003164 | 0.999 | 12308 | 4 | 1 | 1000 | 1 | 1000 |
| 26 | 822 | days | 11 | 1971 | 1971.916667 | 122 | 0.003222 | 0.9737 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 27 | 853 | days | 12 | 1971 | 1972 | 118 | 0.003397 | 0.9798 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 28 | 881 | days | 1 | 1972 | 1972.083333 | 113 | 0.002897 | 0.9904 | 56065 | 1 | 0 | 600 | 0 | 600 |
| 29 | 912 | days | 2 | 1972 | 1972.166667 | 109 | 0.004912 | 0.9697 | 56065 | 1 | 0 | 600 | 0 | 600 |

ReadMe | Input | FEB | Annual Mtnfront Precip_in | WY_TypeLookup | **RELAX_ITMAX**

#### 5.2.2.4 Create FEB File Macro

The "Create FEB File" button on the FEB worksheet runs the macro that generates the SACFEM2013 transient batch file. As described above, the static (non-looping) text included on the FEB worksheet is written directly to the batch file. For each stress period, the macro performs the following:

- Writes statements for each mountain front polygon to assign the annual volumetric deep percolation of precipitation (from the *Annual Mtnfront Precip*_worksheet) along the mountain front to an extra register
- Writes equations for each mountain front polygon to calculate the daily volumetric flux for the stress period, incorporating the monthly distribution factor and the mountain-front recharge adjustment factor (from the *Annual Mtnfront Precip*_worksheet) as well as the number of days in the month
- Writes a statement to apportion the mountain-front recharge among the nodes for each polygon and loads/saves the volumetric flux as a *.q1 (model Layer 1 pumping file)
- Writes a header specifying the water year type (from the *WY_TypeLookup* worksheet)
- Writes statements to load the *.ppn, *.wh1, *.wc1, *.dc1, and *.q files (based on the user-defined upper/lower pumped layers on the FEB worksheet)
- Writes the TIME and RUN statements populated with the user-defined time steps, iterations, and closure criteria. For ITMAX and RELAX, the macro reads the specified number of iterations and the actual number of iterations used on the *RELAX_ITMAX* worksheet. If the model failed to converge for a given stress period for a previous simulation, the macro increases the ITMAX from 600 to 1,000 and assigns a RELAX value of 1.
- Writes statements to save the head files at the end of the stress period

## 5.3 Running SACFEM2013 – The MicroFEM Batch File

Model calculations can be performed in two manners by MicroFEM. The first is by direct steady-state calculation in the MicroFEM calculation window (see Figure 52). The second is by loading a batch file (*.feb) into the MicroFEM project (either by adding a batch file to the *.fpr file name in a text editor or by opening an *.fpr file through the calculation window [see Figure 53]). The MicroFEM batch file (*.feb) is an ASCII file that can be opened and edited either in the MicroFEM calculation window or in a text editor. The *.feb file contains all commands necessary to perform a given model simulation (loading, calculating, and assigning model input parameters; executing the run statement; managing model output). Refer to the MicroFEM User's Manual or help menu for a list of commands available for use in a *.feb file.

**Note: if storage values of zero are assigned, a steady-state simulation can be executed via a MicroFEM batch file.*

An example batch file, SACFEM_2013.feb, is included in Appendix D. This is the batch file currently used for the baseline condition (no project) SACFEM2013 calibration simulation. As discussed in the preceding section, SACFEM_2013.feb is generated with the pre-processing utility "*PPN_Q_Generator_SACFEM_2013.xlsm*." The following sections describe and explain the syntax used in each portion of the batch file.

FIGURE 52
**MicroFEM Calculation Window, Options Tab**

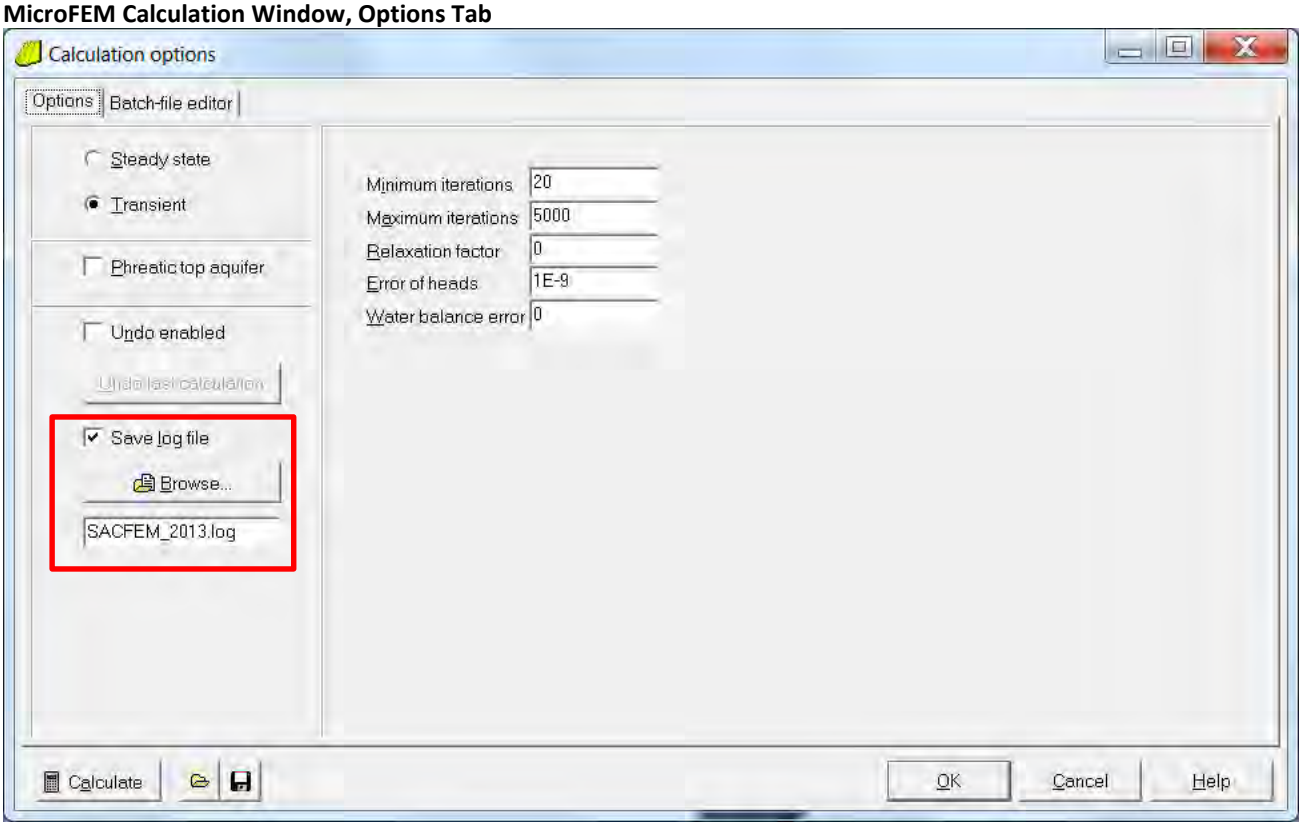
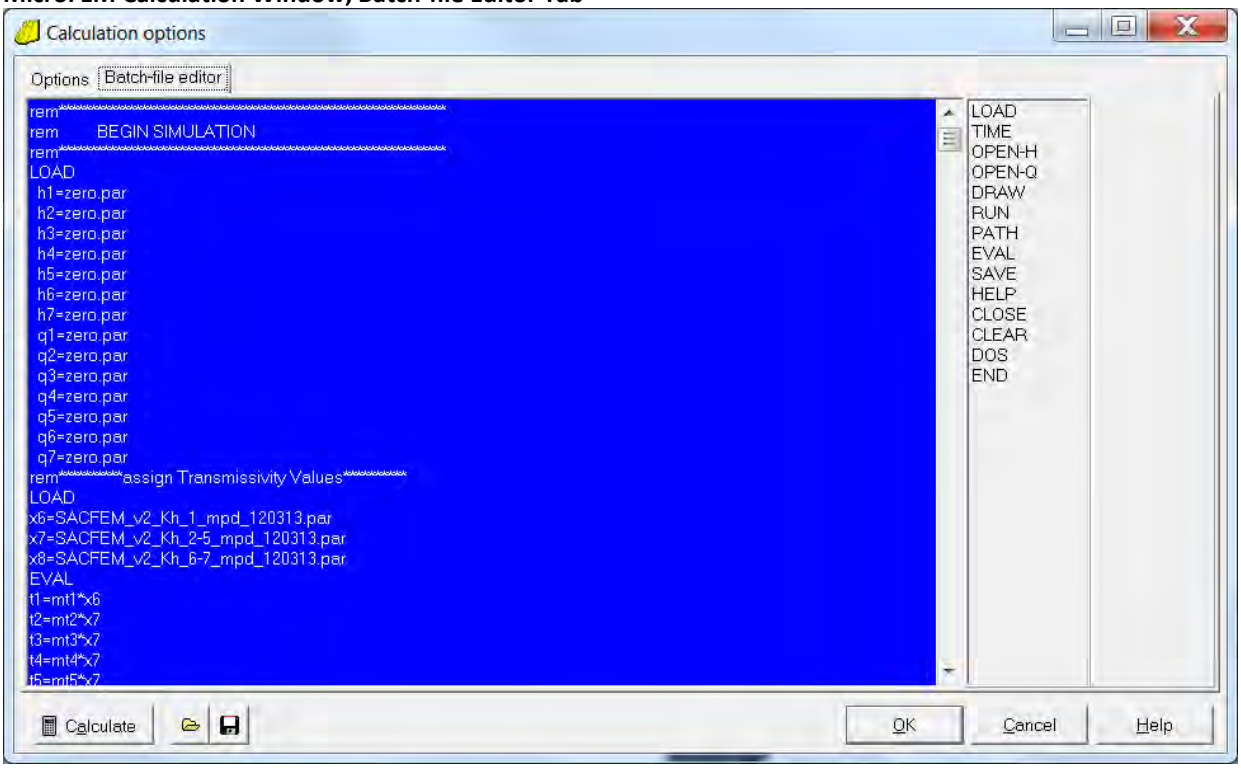



FIGURE 53
**MicroFEM Calculation Window, Batch-file Editor Tab**



## 5.3.1 Non-Looping Batch File

### 5.3.1.1 Assignment of Model Input Parameters

The non-looping portion of SACFE_2013.feb is responsible for assigning initial model parameters and opening of model output files.

*Note: Each line of a *.feb file that begins with "rem" represents remarks (i.e., notes) for the reader. MicroFEM does not read/consider "rem" statements in the model calculation.*

The first section of the non-looping batch file (following the "BEGIN SIMULATION" header) zeros out the initial head and pumping parameters for all nodes/layers. This is done by loading (via the LOAD command) a parameter file, Zero.par, containing a value of zero for every model node into each head and discharge register.

The next section of the batch file (following the rem**********assign Transmissivity Values********** header) calculates the transmissivity values for all model nodes/layers. The first step in the process involves loading parameter files containing horizontal hydraulic conductivity values for each "grouping" of model layers (described in Section 3.2.2) into extra registers. In the case of SACFEM_2013, these are registers x3, x4, and x5. The MicroFEM "Eval" command is then used to directly calculate and assign the transmissivity for each model layer (t1 through t7) by multiplying the model layer thickness (mt1 through mt7) by the horizontal hydraulic conductivity contained in the extra register. For example, the formula to calculate the transmissivity of t1 is as follows:

$$\bar{A}1 = \bar{A}\bar{A}1 \times \bar{A}3 \quad (13)$$

Where:

t1 = transmissivity of model layer 1 ($L^2/T$)
mt1 = thickness of model layer 1 (L)
x3 = extra register containing the horizontal hydraulic conductivity of model layer 1 (L/T)

*Note: The current version of SACFEM2013 assumes that the thickness register has been populated with the appropriate thickness values for each model layer (i.e., SACFEM_2013.thi is loaded into the *.fpr); therefore, thickness values are not directly assigned in the batch file.*

The batch file then saves (using the SAVE command) parameter files for each model layer containing transmissivity values for all model nodes.

As previously discussed, SACFEM2013 does not explicitly simulate aquitards between model layers; however, vertical resistance to groundwater flow across model layer interfaces is simulated using the vertical resistance term. The next portion of the batch file (following the rem**********assign vertical resistance values ********** header) calculates the vertical resistance terms for each model layer (c2 through c7). The first step involves loading a parameter file (SACFEM_v2_KhKv_Ratio_500.par) containing the Kh:Kv values for each model node into extra register x6. The values included in the parameter file are those described in Section 3.2.2. The batch file then calculates the vertical resistance term using Equation 2 and the previously assigned model transmissivity, thickness, and Kh:Kv values. The calculations use a Kh:Kv of 50:1 for model Layer 1 and the anisotropy factors loaded into x6 for all other model layers.

Following assignment of vertical resistance terms, the batch file loads two parameter files (ground surface elevation and streambed elevation) into the extra register. This process loads the data for user review; however, the extra registers are not used for subsequent calculations in the SACFEM2013 simulation.

### 5.3.1.2 Opening Transient Water Budget Files

The final section of the batch file (following the rem**********open ftq files********** header) opens transient head (*.fth) and flux (*.ftq) files that can be used to evaluate model calibration and potential impacts (in the case of a "with project" simulation). Transient head files are used to save time series

(for each stress period) simulated head data for a user-defined set of model nodes. Transient flux files save volumetric flux data for all water budget components for a user-defined set of model nodes. Refer to the MicroFEM User's Manual or Help menu for more information about these files.

The first transient water budget file opened in the batch file is the "all.ftq" file. The first step in the process is to load a label file into the Label 1 register (default register included in the *.fem file) that contains the text "all" at every node within the SACFEM2013 model domain. Next, the transient flux file "all.ftq" is opened using the syntax "open-q all=all.ftq upper=1 lower=7." MicroFEM opens the transient flux file and aggregates the water budget components for every node containing the text "all" in the label register (in this case, every node in the model domain). This file ultimately contains the total volumetric fluxes (i.e., summed for all model nodes) for each of the water budget components for each stress period. MicroFEM saves the volumetric fluxes for each model layer separately. The "upper=1 lower=7" syntax tells MicroFEM to open the transient flux file for model Layers 1 through 7.

The second set of transient water budget files opened in the batch file (following rem**********open ftq files for Water Budget Areas**********) are for sub-areas of the model domain representing the WBAs presented on Figure 25. The first step involves loading the label file *SACFEM_v2_WBAs_121013.lb* into the label 1 register. Each model node has a text string in this label file corresponding to the appropriate water budget area (i.e., all model nodes that are located within the spatial extent of Water Budget Area 2 are assigned the label WBA_2). Next, separate transient water budget files are opened for each group of nodes containing common text strings. Similar to the all.ftq file, the water budget area *.ftq files are opened for all model layers.

The final set of transient water budget files opened in SACFEM_2013.feb (following rem**********open ftq files for streams**********) are for streams simulated in SACFEM2013. A label file, *SACFEM_v2_Streams_FTQ_042314.lb*, is loaded into the label 1 register. This file contains text representing the name of each stream, bypass, and reservoir included in SACFEM2013. The text strings are assigned only to those nodes representing the spatial location of each surface water feature (i.e., non-stream nodes are blank). Separate transient water budget files are then opened for each group of nodes containing common text (i.e., each stream, bypass, or reservoir). FTQ files for surface water features are only opened for model Layer 1, as this is the only model layer that interacts with MicroFEM top system boundary conditions.

As previously described, transient head files save time series simulated groundwater elevation data for a user-defined set of nodes. The portion of the SACFEM2013 batch file following ********open fth for WDL wells******** opens a *.fth file for wells contained in the DWR Water Data Library. A label file containing the unique state well number (SWN) for each well, *SACFEM_v2_WDL_Wells.lb*, is loaded into the label 1 register. Each SWN included in the label file is preceded by the character "^". A single transient head file is then opened for all nodes that contain a "^". Although a single *.fth file is opened, simulated head data are saved and can be read for each individual model node containing a "^" in the label file. As indicated by the "upper=1 lower=7" syntax, head data are saved for all model layers.

Prior to the onset of the transient (looping) portion of the batch file (following ********assign initial heads********), initial head files are loaded into SACFEM2013. This set of initial heads were selected from a previous SACFEM2013 simulation. September 1986 was chosen as the representative stress period for the initial head condition.

### 5.3.2 Looping Batch File

As described in Section 5.2, Model Pre-processing, the looping portion of SACFEM_2013.feb represents the transient model simulation. A similar set of model commands is executed for each of the 492 model stress periods, following:

```
rem*******************************************
rem              BEGIN TRANSIENT SIMULATION
rem*******************************************
```

#### 5.3.2.1 Mountain-Front Recharge

As discussed in Section 3.2.4.2, deep percolation of precipitation within the Sacramento Hydrologic Region in areas outside of the SACFEM2013 model domain is incorporated as a specified-flux boundary condition along the model boundary, mountain-front recharge. The first set of syntax in the *.feb for each stress period of the transient SACFEM2013 simulation (following rem**********assign mountain-front recharge**********) includes calculations to assign the mountain front recharge for each of the 34 polygons presented on Figure 22.

The first step in the process involves loading a label file containing text strings associated with each of the mountain front recharge polygons into the label 1 register, *SACFEM_v2_VoidPolygons2013_v2.lb*. The label file contains text associated with the spatial location of each polygon along the SACFEM2013 model boundary; all other nodes are blank. The batch file then zeros out pumping for all nodes in each model layer by loading a parameter file, Zero.par, containing values of zero for all nodes into each pumping register. This is done to avoid carry-over pumping between model stress periods.

In the next step, the total annual volumetric deep percolation of precipitation (in units of cubic meters) is assigned to all nodes corresponding to each of the mountain-front polygons. This is accomplished using the MicroFEM "EVAL" command to directly assign the deep percolation values to extra register x22. For example, for stress period 1 (October 1969) the syntax EVAL; x22=8071480 label=1 indicates that a value of 8,071,480 $m^3$ is assigned to all nodes containing the text "1" in the label 1 register.

The next section of the *.feb file (following rem**********adjust mountain-front recharge**********) contains syntax to convert the total annual volumetric deep percolation values to daily rates. The batch file firsts loads a parameter file, SACFEM_v2_MtnFront_L_Factor_2013_v2.par, into the x23 register. This parameter file contains a weighting factor for each node of a given polygon to scale the total deep percolation values. For each node in a polygon the weighting factor is calculated as follows:

$$Scaling\ Factor = \frac{Length\ ĀĀ\ Individual\ \ Node}{Total\ \ Length\ ĀĀ\ ĀĀĀNodes\ \ ĀĀMountain\ \ Front\ \ Polygon} \quad (14)$$

The total volumetric values are then converted to daily rates given the following:

$$Daily\ Rate = \frac{Total\ \ Annual\ \ Volume * Month ĀĀDistribution\ \ Factor * Adjustment\ \ Factor}{Days\ \ ĀĀMonth} \quad (15)$$

As previously discussed in Section 3.2.4.2, the "Monthly Distribution Factor" apportions the annual deep percolation values for each month based on monthly distribution of streamflow measured in ungaged sections of Deer Creek (see Table 5). The "adjustment factors" for each mountain-front polygon are multipliers for each polygon developed during the calibration process. An example of the SACFEM_2013.feb syntax is as follows: EVAL; x22=p*0.030*0.50/31 label=1. For this process, MicroFEM takes the p (present value, total annual volumetric flux), multiplies by the monthly distribution factor of 3 percent for October and the calibration adjustment factor of 0.5 for mountain-front polygon 1, and divides by 31 (the number of days in October). As the end of this calculation, the total volumetric deep percolation value is converted to a daily rate, but the total daily rate is assigned to each node of a given polygon.

*Note: when running a batch file that includes performing calculations for subsets of the model domain based on a label file, it is important to have only the label 1 register active (i.e., have no labels loaded into the label 2 through 5 registers). If a label is accidentally loaded twice (that is, the label is present in any of the label 2 through 5 registers and is loaded into label 1 as part of a *.feb file), MicroFEM will perform the calculation multiple times (each time it "sees" the specified text string in any of the label registers).*

*Note: Leap years are not considered in SACFEM; therefore, February stress periods are always 28 days long.*

The final set of syntax in this portion of the *.feb file scales the deep percolation based on the factors described in Equation 14. The syntax included in the *.feb file is "q1=x22*x23*-1." This means that for all nodes in the model, the Layer 1 pumping register is assigned a value representing the total daily deep percolation rate multiplied by the nodal scaling factor. The "-1" indicates that the specified flux is an inflow

value (i.e., in MicroFEM, negative pumping values represent injection and positive values represent extraction).

#### 5.3.2.2 Model Calculation

The final section of the looping batch file contains syntax to conduct the model calculation for each of the 492 monthly stress periods. The first section loads several parameter files specific to each stress period. These include the deep percolation of applied water/precipitation file (*.PPN), the wadi head file (*.wh1), the wadi conductance file (*.wc1), the drain conductance file (*.dc1), and the pumping files for each model layer (*.q).

*Note: For stress period, one these additional parameter files is loaded: model storage file (SACFEM_v2.sto), streambed elevation file (SACFEM_v2_WL1_042314.par, wl1), and drain elevation file (SACFEM_v2_GSE_Combined_mNAVD88_120313.par, dh1). These parameters remain constant throughout the model simulation period.*

The next section of the batch file defines the time discretization for each stress period. For stress period 1, the syntax is as follows:

```
TIME
days=31
steps=1
```

The duration of each stress period is 1 month; therefore, the number of days in a given month is specified (as assigned during model pre-processing described in Section 5.2). A single time step is used in each stress period. The time-step duration is variable, but always equates to the length of the month being simulated.

The next section of the batch file contains the run statement. For stress period 1, the syntax is as follows:

```
RUN
  itmin=50
  itmax=600
  relax=0
  error=0.005
  m3error=1
```

The syntax “itmin” represents the minimum number of iterations, specified as 50 for all stress periods. “Itmax” represents the maximum number of iterations for each stress period. The default value is 600 iterations; however, as discussed in Section 5.2.2.3, a value of 1000 is assigned during model preprocessing if the model failed to converge for a given stress period for a previous simulation. The “relax” is an adjustment factor used by the MicroFEM solver (successive over-relaxation, SOR). The default value of 0 is assigned; however, as with the maximum iterations, a value of 1 is assigned if the model failed to converge for a given stress period during a previous simulation. The “error” term defines the closure criteria for the heads, specified as 0.005 meter for all stress periods, while the “m3error” defines the closure criterion for the model water budget (1 $m^3$/day for all stress periods). Model convergence is only achieved for a given stress period if these error criteria are met.

## 5.4 The MicroFEM LOG File

The *.log file contains the details of a given model simulation. The *.log file is opened by checking a box in the MicroFEM calculation window and specifying a file name (see Figure 52). The *.log file essentially follows the format of the *.feb file for a given simulation, but includes additional information regarding model calculations and summary of model calculation for each stress period. It is important to note that a transient MicroFEM simulation will stop if MicroFEM is unable to load a specified parameter or label file. The MicroFEM *.log file is essential to verify the success of a model simulation.

When calculations are included in a batch file (with the EVAL command), the *.log file will include syntax such as “New values assigned to X nodes”, where X represents the number of nodes to which a given parameter is assigned. If MicroFEM is not successful in implementing a calculation, syntax such as “New values assigned to 0 nodes” or “Cannot Evaluate” will be written to the *.log file, ***but the model simulation will continue with the incorrect parameter values***.

At the end of each stress period, a summary of the stress period calculation is written to the *.log file. This includes the current time (cumulative number of days for the simulation to that point), number of iterations used for the stress period, the maximum change in head for the stress period (in meters), the water budget error for the stress period (in $m^3$/day), the node containing the maximum change in head, and the layer containing the maximum change in head. This summary information should be examined to confirm that the closure criteria were met for each stress period. MicroFEM will continue a simulation regardless of whether the criteria are met and does not write an error message to the *.log file to designate stress periods that failed to converge. A post-processor has been developed to facilitate evaluation of the *.log file and is discussed in the following section.

# 5.5 Model Post-processing

Several transient output files are generated during the SACFEM2013 simulation. Two pre-processors have been developed to process and summarize these data, *RunLogReader_SACFEM_2013.xls* and *Hydrographs_SummaryStatsTool_SACFEM_2013.xlsm*.

## 5.5.1 Run Log Reader

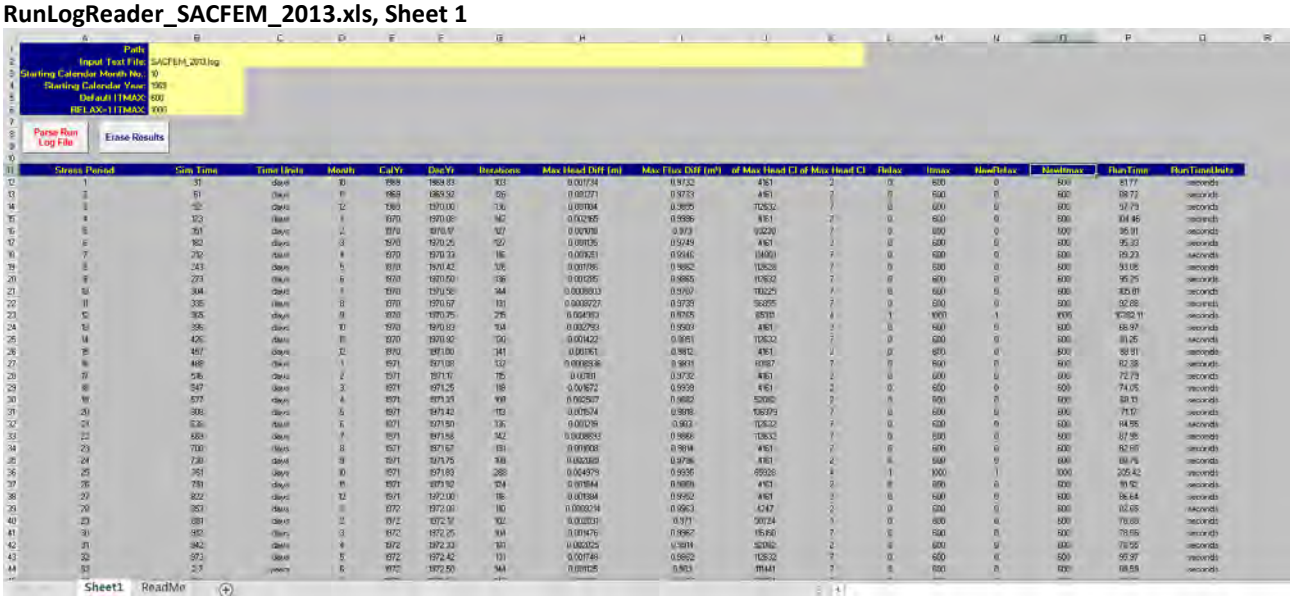
The SACFEM2013 run log reader summarizes the simulation information for each stress period from the *.log file. The user inputs SACFEM2013 file information in the first six rows including: path in *.log file, file name (including extension), starting month (calendar month), starting year (calendar year), default maximum number of iterations, and number of iterations to include if the model fails to converge for a given stress period (see Figure 54). The run log reader contains two macros. The “Erase Results” button clears the summary information from the previous simulation, if present. The “Parse Run Log File” button reads through the SACFEM_2013.log file and searches for the text string below (which is written to the *.log file at the end of each stress period).

*CurrentTime Iterations MaxHeadChange (m) M3Error (m³/d) NodeMaxHeadChange LayerMaxHeadChange*

The macro then writes summary information for each stress period to the “Sheet 1” worksheet (see Figure 54). Finally, the macro compares the number of iterations used to the user-specified default number of maximum iterations. If the number used is greater than or equal to the default, the macro populates the “NewItmax” column with the user-specified value in row 6, and the “NewRelax” column with a 1. The summary information included in “Sheet 1” can be pasted into the “RELAX_ITMAX” of the pre-processing utility “PPN_Q_Generator_SACFEM_2013.xlsm.” As discussed in Section 5.2.2.3, the new itmax and relax values for stress periods that failed to converge will be modified in the *.feb file for the next simulation.

FIGURE 54

**RunLogReader_SACFEM_2013.xls, Sheet 1**




*Note: The number of characters (spaces) in the text string above (that the macro searches the *.log file for) periodically changes with new MicroFEM releases. If the macro fails to run, open the VBA module and the log file, highlight the entire text string from the log file (see Figure 55), and paste into the VBA module (see Figure 56).*

FIGURE 55

**SACFEM2013.log Syntax to Search/Replace**

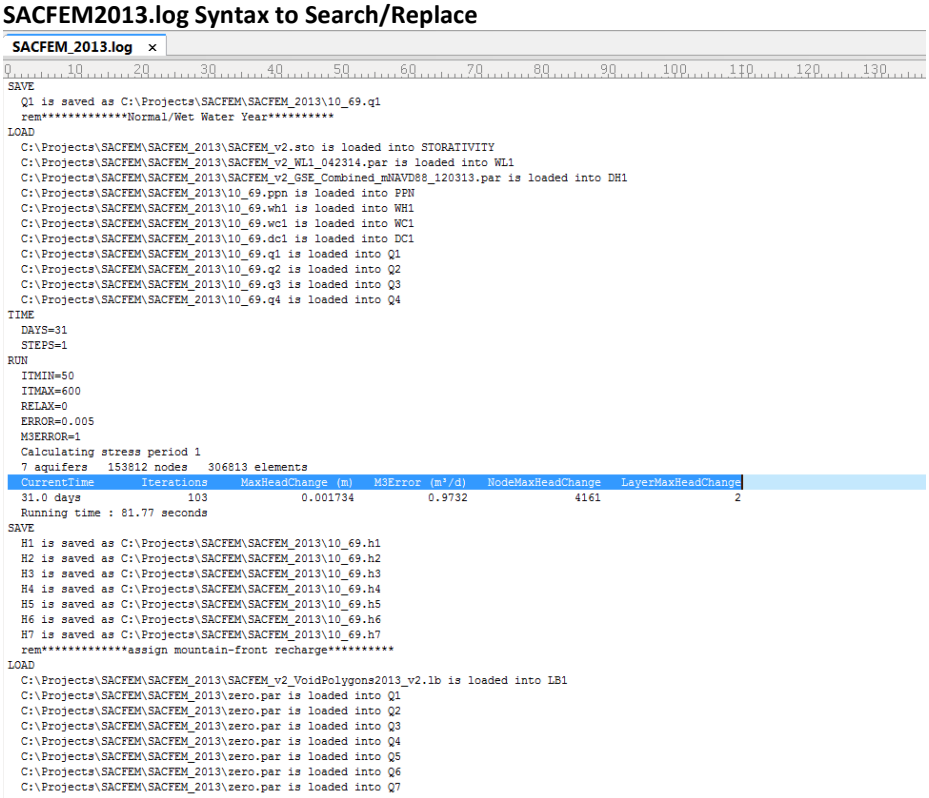


FIGURE 56
**RunLogReader_SACFEM_2013.xls, Visual Basic Code to Search/Replace**

```
Do While Not EOF(1)
  icnt = icnt + 1
  Line Input #1, strLine
  If Mid(strLine, 2, 5) = "RELAX" Then
    sRelax = Val(Trim(Mid(strLine, 8, 15)))
  End If
  If Mid(strLine, 2, 5) = "ITMAX" Then
    iItmax = Val(Trim(Mid(strLine, 8, 15)))
  End If
  If strLine = Chr(9) + "CurrentTime       Iterations     MaxHeadChange (m)    M3Error (m³/d)    NodeMaxHeadChange    LayerMaxHeadChange" Then
    iSP = iSP + 1
    If iMonth < 12 Then
      iMonth = iMonth + 1
    Else
      iYear = iYear + 1
      iMonth = 1
    End If
```

## 5.5.2 Hydrograph and Summary Statistics Utility

As discussed in Section 5.3, transient heads files are opened for all monitoring wells included in the DWR water data library database at the beginning of the SACFEM2013 simulation (WDL_Hydrographs.fth). The post-processing utility "*Hydrographs_SummaryStatsTool_SACFEM_2013.xlsm*" is used to examine simulated-versus-measured groundwater elevation data for SACFEM2013 calibration target wells. Worksheets in this utility include the following:

**ReadMe**: Contains information about the processing utility and disclaimer on use

- **Inputs:** Contains macros to populate and erase data on the "*SimHeads*" worksheet as well as to generate hydrographs.
- **SimHeads:** Worksheet is populated with simulated groundwater elevation data for each SACFEM2013 target well listed on the "*Inputs*" worksheet.
- **ObsHeads:** Contains measured groundwater elevation data for target wells. The date range for the data is limited to the SACFEM2013 simulation period (that is, no data earlier/later than WY1970 and WY2010 can be included). Data should only be included for SACFEM2013 calibration target wells (i.e., the same list of wells included on the "*Inputs*" worksheet and in ReadFTH.inp).
- **NodeNoLayerLookup:** Contains look-up information for SACFEM2013 calibration target wells, including SACFEM2013 model node number, SACFEM2013 model layer number, well coordinates, and ground surface elevation at the well.
- **TemplatePlot:** Worksheet contains the template plot used to format hydrographs. The user can modify the format of the graph (axes, series format, etc.) on this worksheet, and the changes will be propagated to all hydrographs when the "Create Hydrographs" macro is run.
- **Hydrographs:** When the "Create Hydrographs" macro on the "*Inputs*" worksheet is run, this worksheet is populated with hydrographs for all SACFEM2013 calibration target wells.
- **PairedMeasSimHeads:** Contains macros to erase previous simulation results, pair simulated/measured groundwater elevation data for all SACFEM2013 calibration targets, and calculate calibration statistics.
- **C.Scatterplot:** Contains a scatterplot of all data from the "*PairedMeasSimHeads*" worksheets, including calibration statistics for the entire calibration dataset.
- **CalibrationStats_L1……L7:** When the "Compute Calibration Stats" macro is run on the "*PairedMeasSimHeads*" worksheet, these worksheets are populated with calibration statistics for SACFEM2013 target wells for each respective layer.

### 5.5.2.1 ReadFTH

Prior to running any macros in the Excel utility, the *.fth file is converted to a format that is easier for the utility to process. This is done with the utility, ReadFTH.exe. This utility consists of an executable and an input file, which should be located in the same folder as the *.fth file. The input file (ReadFTH.inp) is an ASCII file that can be read/modified via a text editor. The file contains four header rows that include the following information: name of the *.fth file, name of the output file (*.csv file format), starting date of the model simulation, and number of target wells. This information is followed by the list of calibration targets. Each calibration target is listed on its own row with the following information: SACFEM2013 model node number, SACFEM2013 model layer, SWN. This information should be comma-delimited and sorted by ascending SACFEM2013 model node number (see Figure 57). The utility will write the simulated head information for the specified model layer for each well listed in the *.inp file to an Excel *.csv file. This *.csv file is read by the "*Hydrographs_SummaryStatsTool_SACFEM_2013.xlsm*" utility.

*Note: The utility ReadFTH.exe will write the initial heads information to the *.csv output file. The user should open the *.csv file, manually delete the stress period 0 data rows (as this does not represent converged simulated heads to be considered in calibration statistics), and resave the file.*

FIGURE 57
**ReadFTH.inp File**

ReadFTH.inp

```
WDL_Hydrographs.fth     'FTH filename
Target_Hydrographs.csv    'Output CSV filename with FTH results in database flat-file format
10/01/1969              'Starting date of simulation
210                     'No. of sim hydrograph datasets (n) wanted; the next n lines must contain the node, layer, and LOCID sorted by node then layer
584,1,27N03W10B001M
835,2,27N04W35E001M
901,2,27N03W20K001M
1738,2,25N03W10L004M
1738,4,25N03W10L003M
2144,1,25N02W09G001M
2563,1,24N03W17M001M
2854,3,24N02W12P001M
2854,6,24N02W12P002M
2922,3,24N02W30P002M
3505,1,23N01W09E001M
3569,2,23N02W16B001M
3783,2,23N01W14R002M
4004,2,22N02W08B002M
4059,1,23N01E29P001M
4059,2,23N01E29P002M
4303,2,22N03W21F002M
4365,1,22N02W21D001M
4418,1,22N01E09J002M
4447,1,22N02W20Q001M
4486,6,22N02E17E001M
4546,1,22N02W30H004M
4546,2,22N02W30H003M
4546,6,22N02W30H002M
4626,2,22N01W05M001M
4864,2,22N02W36D001M
5055,1,22N01E20K001M
5081,1,21N02W05M004M
5081,2,21N02W05M002M
5081,4,21N02W05M001M
5327,3,22N01E28J003M
5327,6,22N01E28J001M
5327,7,22N01E28J005M
5329,6,22N01E29R001M
5661,2,21N02W09M002M
5960,3,22N01E33N002M
6298,1,22N01E33N001M
6299,2,21N01E05G001M
6631,4,21N01E12K001M
7439,5,21N03W33A004M
7871,2,21N02W31M001M
7931,1,21N01W04N001M
7974,1,17N03E05C001M
```

### 5.5.2.2 Inputs Worksheet

The "Inputs" worksheet of the post-processing utility contains macros to clear simulated data from a previous simulation, read the simulated heads files, and generate hydrographs of simulated and measured data. There are several rows at the top of the worksheet (see Figure 58) where the user defines the following categories of information:

- **FTH-CSV File Path and File**: path to the *.csv file, including the file name
- **Starting Date**: starting date of the simulation
- **Desired Number of Plots Per Row**: number of hydrographs to plot on a given row
- **Desired Plot Width (characters)**: width of each hydrograph

- **Desired Plot Height (characters)**: height of each hydrograph
- **Desired Y-Range on Plots**: y-axis range on hydrographs – if a value is populated in this cell, all hydrographs will have the user-specified range (the macro will select the axis minimum/maximum). If the cell is left blank, all hydrographs will have the exact y-axis value/range as the template plot

Below the user-specified information is a toggle box for the desired output units as well as buttons for each of the macros. The last section of the "*Inputs*" worksheet contains the list of calibration targets, including SWN, SACFEM2013 model layer, and SACFEM2013 model node number. The list should contain the same calibration target wells as ReadFTH.inp and should be sorted in ascending order by SACFEM2013 node number (see Figures 57 and 58).

As previously discussed, three macros are included on the "Inputs" worksheet.

- **ResetSimHeads**: clears the data from the "SimHeads" worksheet.
- **Summarize FTH Results**: reads user-defined *.csv file and writes the simulated groundwater elevation data for all SACFEM2013 calibration target wells listed on the "*Inputs*" worksheet to the "SimHeads" worksheet.
- **Create Hydrographs**: generates hydrographs of simulated and measured groundwater elevations for all SACFEM2013 calibration target wells listed on the "*Inputs*" worksheet. Simulated groundwater elevation data are read from the "*SimHeads*" worksheet, and measured groundwater elevation data are read from the "*ObsHeads*" worksheet. The macro formats the hydrographs consistent with the graph included on the "*TemplatePlot*" worksheet.

*Note: the utility is designed to process data between WY1970 and WY2010. Modifications are required to process data for a different simulation period.*

FIGURE 58
**Hydrographs_SummaryStatsTool_SACFEM_2013.xlsm, Inputs Worksheet**

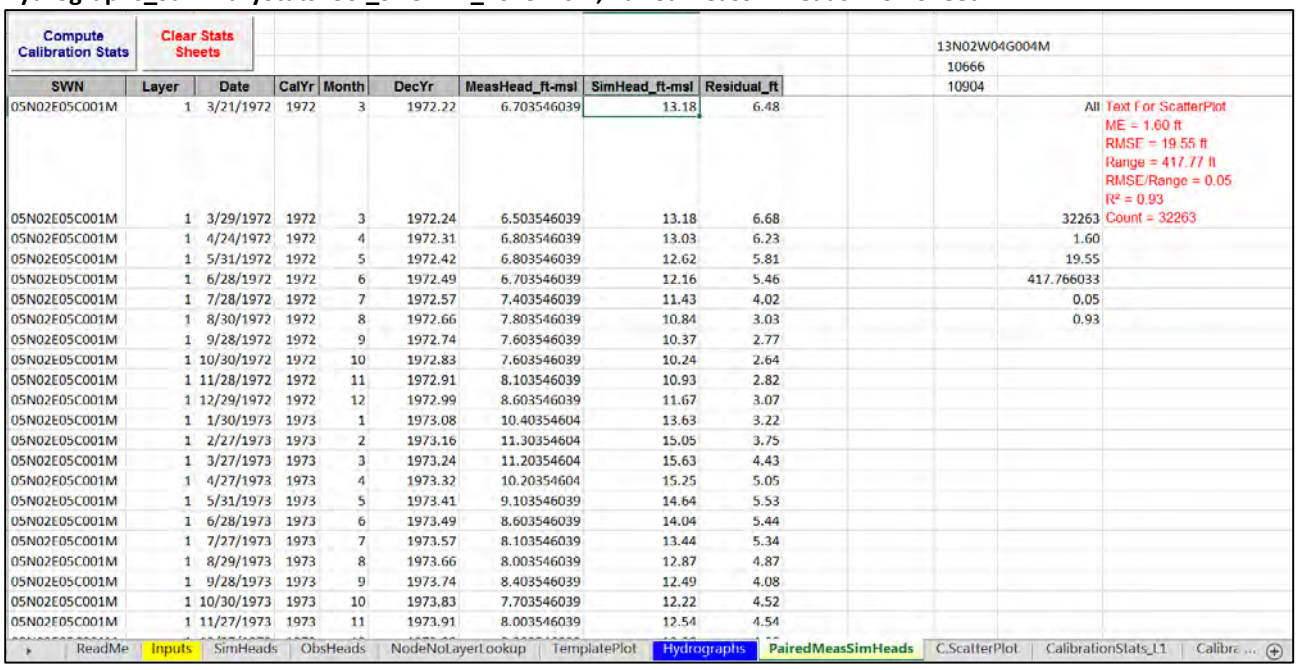



### 5.5.2.3 PairedMeasSimHeads Worksheet

The "*PairedMeasSimHeads*" worksheet of the post-processing utility contains macros to clear data from a previous simulation and to calculate calibration statistics (see Figure 59). The "Clear Stats Sheets" macro clears the data from the "*PairedMeasSimHeads*" worksheet as well as the calibration statistics worksheets for each model layer. The "Compute Calibration Stats" macro performs the following functions:

- For each measured groundwater elevation on the "ObsHeads" worksheet, the macro pairs a quasi-contemporaneous simulated groundwater elevation from the "SimHeads" worksheet. The macro interpolates the simulated groundwater elevation data between stress periods to matches the date of the measured groundwater elevation data. The simulated, measured, and residual error in heads are written to the "*PairedMeasSimHeads*" worksheet for each data point (see Figure 59).
- The macro computes the summary calibration statistics (ME, RMSE, range in measured heads, RMS divided by range in measured heads, $R^2$, and count) for the entire "paired" dataset, which are computed and written to the worksheet.
- The graph on the "*C.Scatterplot*" worksheet automatically updates with the simulated and measured data and the calibration statistics included on the "*PairedMeasSimHeads*" worksheet (see Figure 60).
- For each SACFEM2013 target well listed on the "*Inputs*" worksheet, the macro computes the calibration statistics for the entire "paired" dataset and writes this information to the calibration statistics worksheet corresponding to the model layer for each of the target wells (CalibrationStats_L1 through CalibrationStats_L7).

FIGURE 59
**Hydrographs_SummaryStatsTool_SACFEM_2013.xlsm, PairedMeasSimHeads Worksheet**



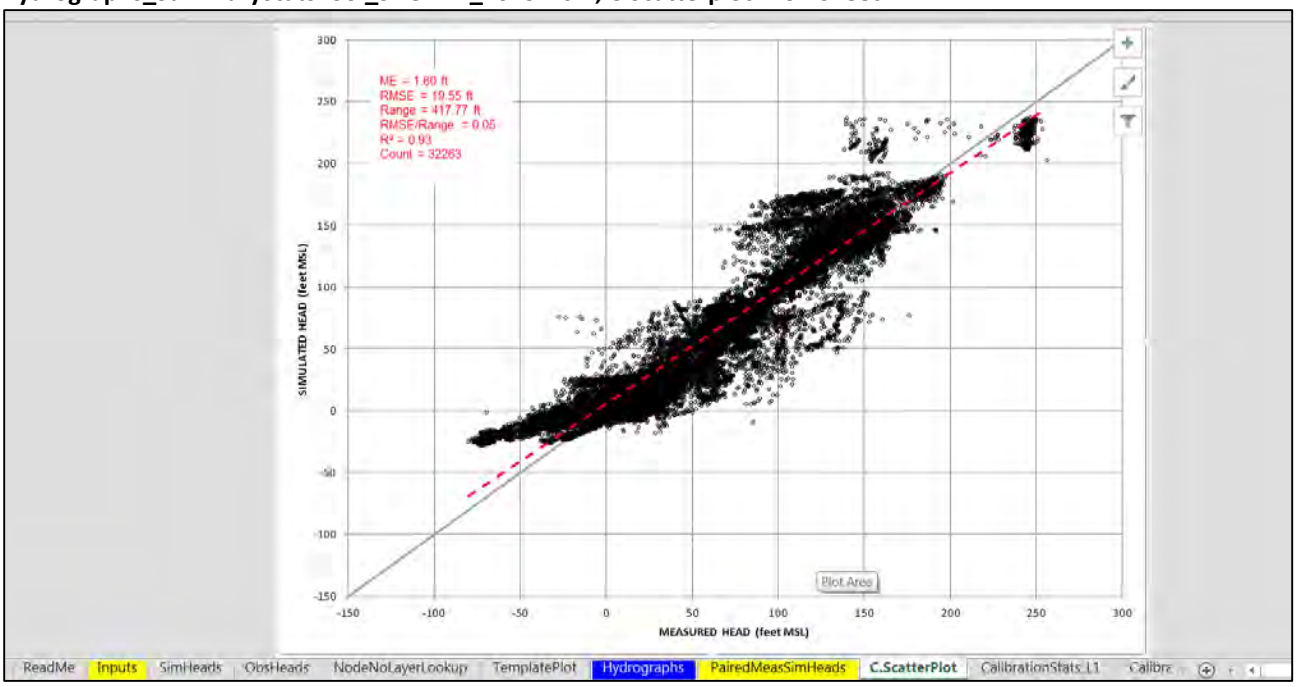
Compute Calibration Stats | Clear Stats Sheets

13N02W04G004M
10666
10904

| SWN | Layer | Date | CalYr | Month | DecYr | MeasHead_ft-msl | SimHead_ft-msl | Residual_ft | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 05N02E05C001M | 1 | 3/21/1972 | 1972 | 3 | 1972.22 | 6.703546039 | 13.18 | 6.48 | All | Text For ScatterPlot<br>ME = 1.60 ft<br>RMSE = 19.55 ft<br>Range = 417.77 ft<br>RMSE/Range = 0.05<br>R² = 0.93 |
| 05N02E05C001M | 1 | 3/29/1972 | 1972 | 3 | 1972.24 | 6.503546039 | 13.18 | 6.68 | 32263 | Count = 32263 |
| 05N02E05C001M | 1 | 4/24/1972 | 1972 | 4 | 1972.31 | 6.803546039 | 13.03 | 6.23 | 1.60 | |
| 05N02E05C001M | 1 | 5/31/1972 | 1972 | 5 | 1972.42 | 6.803546039 | 12.62 | 5.81 | 19.55 | |
| 05N02E05C001M | 1 | 6/28/1972 | 1972 | 6 | 1972.49 | 6.703546039 | 12.16 | 5.46 | 417.766033 | |
| 05N02E05C001M | 1 | 7/28/1972 | 1972 | 7 | 1972.57 | 7.403546039 | 11.43 | 4.02 | 0.05 | |
| 05N02E05C001M | 1 | 8/30/1972 | 1972 | 8 | 1972.66 | 7.803546039 | 10.84 | 3.03 | 0.93 | |
| 05N02E05C001M | 1 | 9/28/1972 | 1972 | 9 | 1972.74 | 7.603546039 | 10.37 | 2.77 | | |
| 05N02E05C001M | 1 | 10/30/1972 | 1972 | 10 | 1972.83 | 7.603546039 | 10.24 | 2.64 | | |
| 05N02E05C001M | 1 | 11/28/1972 | 1972 | 11 | 1972.91 | 8.103546039 | 10.93 | 2.82 | | |
| 05N02E05C001M | 1 | 12/29/1972 | 1972 | 12 | 1972.99 | 8.603546039 | 11.67 | 3.07 | | |
| 05N02E05C001M | 1 | 1/30/1973 | 1973 | 1 | 1973.08 | 10.40354604 | 13.63 | 3.22 | | |
| 05N02E05C001M | 1 | 2/27/1973 | 1973 | 2 | 1973.16 | 11.30354604 | 15.05 | 3.75 | | |
| 05N02E05C001M | 1 | 3/27/1973 | 1973 | 3 | 1973.24 | 11.20354604 | 15.63 | 4.43 | | |
| 05N02E05C001M | 1 | 4/27/1973 | 1973 | 4 | 1973.32 | 10.20354604 | 15.25 | 5.05 | | |
| 05N02E05C001M | 1 | 5/31/1973 | 1973 | 5 | 1973.41 | 9.103546039 | 14.64 | 5.53 | | |
| 05N02E05C001M | 1 | 6/28/1973 | 1973 | 6 | 1973.49 | 8.603546039 | 14.04 | 5.44 | | |
| 05N02E05C001M | 1 | 7/27/1973 | 1973 | 7 | 1973.57 | 8.103546039 | 13.44 | 5.34 | | |
| 05N02E05C001M | 1 | 8/29/1973 | 1973 | 8 | 1973.66 | 8.003546039 | 12.87 | 4.87 | | |
| 05N02E05C001M | 1 | 9/28/1973 | 1973 | 9 | 1973.74 | 8.403546039 | 12.49 | 4.08 | | |
| 05N02E05C001M | 1 | 10/30/1973 | 1973 | 10 | 1973.83 | 7.703546039 | 12.22 | 4.52 | | |
| 05N02E05C001M | 1 | 11/27/1973 | 1973 | 11 | 1973.91 | 8.003546039 | 12.54 | 4.54 | | |

ReadMe | Inputs | SimHeads | ObsHeads | NodeNoLayerLookup | TemplatePlot | Hydrographs | PairedMeasSimHeads | C.ScatterPlot | CalibrationStats_L1 | Calibr ...

FIGURE 60
**Hydrographs_SummaryStatsTool_SACFEM_2013.xlsm, C.Scatterplot Worksheet**




## 5.5.3 Transient Water Budget Files

As discussed in Section 5.3.1, several transient water budget files are opened at the beginning of the SACFEM2013 simulation. These are tab-delimited ASCII 2 files that can be opened in a text editor or copied into a spreadsheet for further analysis. There are several header rows followed by simulated data (in $m^3$/day) for all components of the water balance. The first "block" of data represents the uppermost specified model layer ("upper=" in the open-q statements) and is displayed with header titles for the water balance component (which are in columns). Rows in the *.ftq files represent data for each stress period (in ascending order). Successive "blocks" of data represent additional model layers (i.e., model layers between "upper=" and "lower=" in the open-q statements) and are displayed without column headers. The user is referred to the MicroFEM help menu or user's manual for additional information about transient water budget files.

SECTION 6

# References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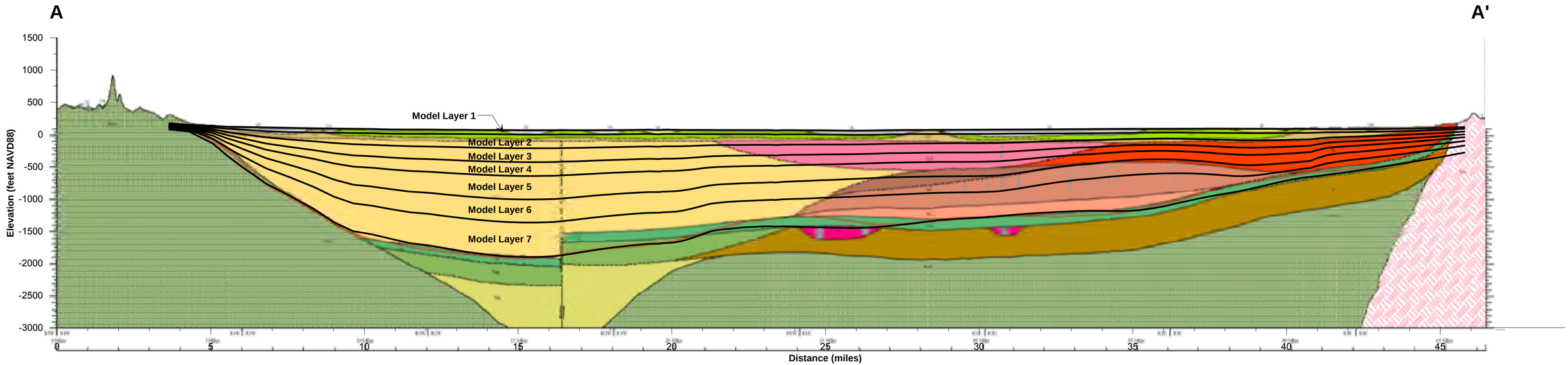



**Qa** **Alluvium** (Holocene)-Includes surficial alluvium and stream channel deposits of unweathered gravel, sand and silt, maximum thickness 80 ft. *(adapted from Helley & Harwood, 1985)*.

**Qb** **Basin Deposits** (Holocene)-Fine-grained silt and clay derived from adjacent mountain ranges, maximum thickness up to 200 ft. *(adapted from Helley & Harwood, 1985)*.

**Qm** **Modesto Formation,** undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated weathered and unweathered gravel, sand, silt and clay; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood , 1985)*.

**Qr** **Riverbank Formation,** undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand and silt; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood, 1985)*.

**Qtl** **Turlock Lake** (Pleistocene)-Weathered and dissected eriosic gravels with minor amounts of resistant metamorphic rock fragments and quartz pebbles, sand and silt; maximum thickness approximately 100 ft. *(adapted from Helley & Harwood, 1985)*.

**Qvb** **Volcanic Basalts,** undifferentiated (Pleistocene)-Younger basalt flows found primarily on the east side of the Sacramento Valley, includes minor exposures of andesite; maximum thickness 100 ft. *(adapted from Helley & Harwood, 1985)*.

**Qtu** **Tuff Breccia** (Plio-Pleistocene)-Tuff breccia forming outer ring surrounding the Sutter Buttes *(adapted from Helley & Harwood, 1985)*.

**Qta** **Volcanic Andesites,** undifferentiated (Plio-Pleistocene)-Younger andesites forming the center of the Sutter Buttes *(adapted from Helley & Harwood, 1985)*.

**Tte** **Tehama Formation** (Plio-Pleistocene)-Includes Red Bluff Formation on west side. Pale green, gray and tan sandstone and siltstone with lenses of pebble and cobble conglomerate; maximum thickness 2,000 ft. *(adapted from Helley & Harwood, 1985)*.

**Ttd** **Tuscan Unit D** (Plio-Pleistocene)-Fragmental flow deposits characterized by monolithic masses containing gray hornblende and basaltic andesites and black pumice, maximum thickness 160 ft. *(adapted from Helley & Harwood, 1985)*.

**Ttc** **Tuscan Unit C** (Plio-Pleistocene)-Includes Red Bluff Formation on east side. Volcanic lahars with some interbedded volcanic conglomerate and sandstone, and reworked sediments; maximum thickness 600 ft. *(adapted from Helley & Harwood, 1985, DWR Bulletin 118-7, 2001, draft report)*.

**Ttb** **Tuscan Unit B** (Pliocene)-Layered, interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone; maximum thickness 600 ft. *(adapted from Helley and Harwood, 1985; DWR Bulletin 118-7, 2001, draft report)*.

**Tta** **Tuscan Unit A** (Pliocene)-Interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone containing metamorphic rock fragments; maximum thickness 400 ft. *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7 (in progress), 2001)*.

**Tla** **Laguna Formation** (Pliocene)-Interbedded alluvial gravel, sand and silt; maximum thickness 450 feet. *(adapted from Helley & Harwood, 1985; Olmsted and Davis, 1961; DWR Bulletin 118-6, 1978)*.

**Tv** **Basalts and Andesites,** undifferentiated (Pliocene)-Older basalts and andesites found on the northeastern portion of the Sacramento Valley and southwest of Winters; maximum thickness up to 230 ft. *(adapted from Helley & Harwood, 1985)*.

**Ts** **Sutter Formation** (Late Miocene to Early Pleistocene)-Volcanic fluvatile sediments with lacustrine deposits; maximum thickness approximately 1,800 ft. *(adapted from Garrison, 1962)*.

**Tn** **Nerely Formation** (Miocene)-Marine to non-marine sediments, tuffaceous andesitic sandstone with interbeds of tuff and tuffaceous shales and occasional conglomerate lenses; max. thickness 500 ft. *(adapted from Redwine, 1972; Wagner and Saucedo, 1990)*.

**Tl** **Lovejoy Basalt** (Miocene)-Black, dense, hard microcrystalline basalt; maximum thickness 65 ft. *(adapted from Helley & Harwood, 1985)*.

**Tupg** **Upper Princeton Valley Fill** (Late Oligocene to Early Miocene)-Non-marine sediments composed of sandstone with interbeds of mudstone and occasional conglomerate and conglomeratic sandstone; maximum thickness 1,400 ft. *(adapted from Redwine, 1972)*.

**Ti** **Ione Formation** (Eocene)-Marine to non-marine deltaic sediments, light colored, commonly white conglomerate, sandstone and siltstone, which is soft and easily eroded; max. thickness 650 ft. *(adapted from DWR Bulletin 118-6, 1978; Creely, 1965)*.

**Tlpg** **Lower Princeton Submarine Valley Fill** (Eocene)-includes Capay Formation. Marine sandstone, conglomerate and interbedded silty shale, maximum thickness 2,400 ft. *(adapted from Redwine, 1972)*

**JKgvs** **Great Valley Sequence** (Late Jurassic to Upper Cretaceous)-Marine clastic sedimentary rock consisting of siltstone, shale, sandstone and conglomerate; maximum thickness 15,000 ft.

**m** **Mixed Rocks** (pre-Cenozoic)-Undivided metasedimentary and metavolcanic rocks of greatly varying types *(adapted from Jennings, 1977)*.

**Mzv** **Volcanic and Metavolcanic Rocks** (Mesozoic)-Undivided volcanic and metavolcanic rocks, andesite rhyolite flow rocks, greenstone and volcanic breccia *(adapted from Jennings, 1977)*.

**um** **Ultramafic Rocks** (Mesozoic)-Primarily composed of serpentine, with peridotite, gabbro and diabase *(adapted from Jennings, 1977)*.

**gb** **Gabbro** (Mesozoic)-Gabbro and dark diotric rocks *(adapted from Jennings, 1977)*.

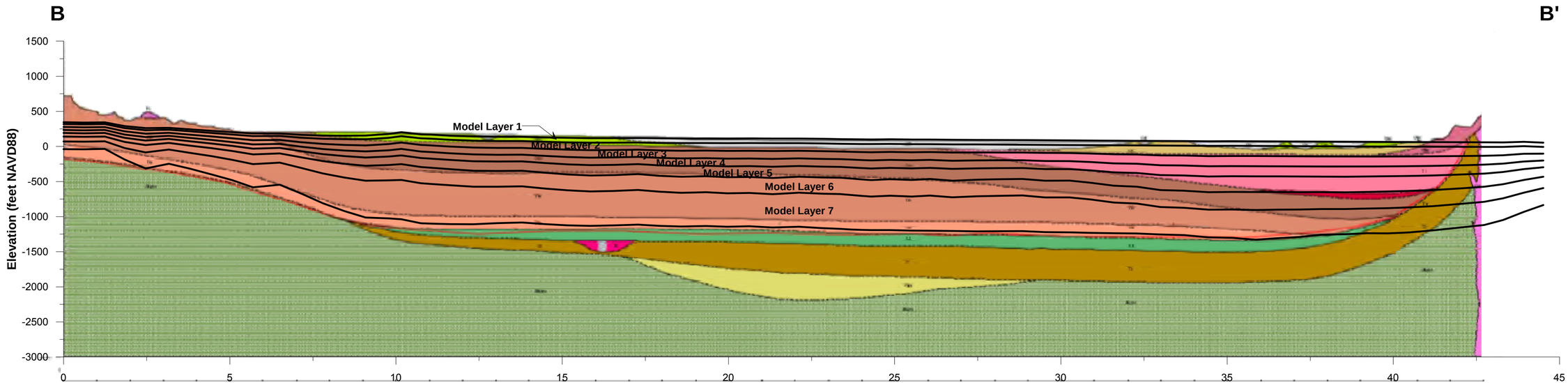
**gr** **Undifferentiated Granitic Plutons** (Mesozoic-Paleozoic)-Undivided granitic plutons and related rocks *(adapted from Jennings, 1977)*.

**Pzs** **Paleozoic Metasedimentary Rocks** (Paleozoic)-Undivided metasedimentary rocks including slate, shale, sandstone, chert, conglomerate, limestone, dolomite, marble, phyllite,schist, hornfels and quartzite *(adapted from Jennings, 1977)*.

**Pzv** **Paleozoic Metavolcanic Rocks** (Paleozoic)-Undivided metavolcanic rocks, primarily flows, breccia, and tuff, including greenstone, diabase and pillow lavas *(adapted from Jennings, 1977)*.

Notes:
1. Modified from DWR (2005)
2. NAVD88 = North American Vertical Datum of 1988

**Figure 10**
**East-West Cross-Section of SACFEM2013 Model Layering**
*SACFEM: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL




**Qa** **Alluvium** (Holocene)-Includes surficial alluvium and stream channel deposits of unweathered gravel, sand and silt, maximum thickness 80 ft. *(adapted from Helley & Harwood, 1985).*

**Qb** **Basin Deposits** (Holocene)-Fine-grained silt and clay derived from adjacent mountain ranges, maximum thickness up to 200 ft. *(adapted from Helley & Harwood, 1985).*

**Qm** **Modesto Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated weathered and unweathered gravel, sand, silt and clay; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood , 1985).*

**Qr** **Riverbank Formation**, undifferentiated (Pleistocene)-Alluvial fan and terrace deposits consisting of unconsolidated to semi-consolidated gravel, sand and silt; maximum thickness approximately 200 ft. *(adapted from Helley & Harwood, 1985).*

**Qtl** **Turlock Lake** (Pleistocene)-Weathered and dissected arkosic gravels with minor amounts of resistant metamorphic rock fragments and quartz pebbles, sand and silt; maximum thickness approximately 100 ft. *(adapted from Helley & Harwood, 1985).*

**Qvb** **Volcanic Basalts**, undifferentiated (Pleistocene)-Younger basalt flows found primarily on the east side of the Sacramento Valley, includes minor exposures of andesite; maximum thickness 100 ft. *(adapted from Helley & Harwood, 1985).*

**Qtm** **Tuff Breccia** (Plio-Pleistocene)-Tuff breccia forming outer ring surrounding the Sutter Buttes *(adapted from Helley & Harwood, 1985).*

**Qtu** **Volcanic Andesites**, undifferentiated (Plio-Pleistocene)-Younger andesites forming the center of the Sutter Buttes *(adapted from Helley & Harwood, 1985).*

**Tte** **Tehama Formation** (Plio-Pleistocene)-Includes Red Bluff Formation on west side. Pale green, gray and tan sandstone and siltstone with lenses of pebble and cobble conglomerate; maximum thickness 2,000 ft. *(adapted from Helley & Harwood, 1985).*

**Ttd** **Tuscan Unit D** (Plio-Pleistocene)-Fragmental flow deposits characterized by monolithic masses containing gray hornblende and basaltic andesites and black pumice, maximum thickness 160 ft. *(adapted from Helley & Harwood, 1985).*

**Ttc** **Tuscan Unit C** (Plio-Pleistocene)-Includes Red Bluff Formation on east side. Volcanic lahars with some interbedded volcanic conglomerate and sandstone, and reworked sediments; maximum thickness 600 ft. *(adapted from Helley & Harwood, 1985, DWR Bulletin 118-7, 2001, draft report).*

**Ttb** **Tuscan Unit B** (Pliocene)-Layered, interbedded lahars, volcanic conglomerate, volcanic sandstone and siltstone; maximum thickness 600 ft. *(adapted from Helley and Harwood, 1985; DWR Bulletin 118-7, 2001, draft report).*

**Tta** **Tuscan Unit A** (Pliocene)-Interbedded lahars, volcanic conglomerate, volcanic sandstone, and siltstone containing metamorphic rock fragments; maximum thickness 400 ft. *(adapted from Helley & Harwood, 1985; DWR Bulletin 118-7 (in progress), 2001).*

**Tla** **Laguna Formation** (Pliocene)-Interbedded alluvial gravel, sand and silt; maximum thickness 450 feet. *(adapted from Helley & Harwood, 1985; Olmsted and Davis, 1961; DWR Bulletin 118-6, 1978).*

**Tv** **Basalts and Andesites**, undifferentiated (Pliocene)-Older basalts and andesites found on the northeastern portion of the Sacramento Valley and southwest of Winters; maximum thickness up to 230 ft. *(adapted from Helley & Harwood, 1985).*

**Ts** **Sutter Formation** (Late Miocene to Early Pleistocene)-Volcanic fluvatile sediments with lacustrine deposits; maximum thickness approximately 1,800 ft. *(adapted from Garrison, 1962).*

**Tn** **Neroly Formation** (Miocene)-Marine to non-marine sediments, tuffaceous andesitic sandstone with interbeds of tuff and tuffaceous shales and occasional conglomerate lenses; max. thickness 500 ft. *(adapted from Redwine, 1972; Wagner and Saucedo, 1990).*

**Tl** **Lovejoy Basalt** (Miocene)-Black, dense, hard microcrystalline basalt; maximum thickness 65 ft. *(adapted from Helley & Harwood, 1985).*

**Tupg** **Upper Princeton Valley Fill** (Late Oligocene to Early Miocene)-Non-marine sediments composed of sandstone with interbeds of mudstone and occasional conglomerate and conglomerate sandstone; maximum thickness 1,400 ft. *(adapted from Redwine, 1972).*

**Ti** **Ione Formation** (Eocene)-Marine to non-marine deltaic sediments, light colored, commonly white conglomerate, sandstone and siltstone, which is soft and easily eroded; max. thickness 650 ft. *(adapted from DWR Bulletin 118-6, 1978; Creely, 1965).*

**Tlpg** **Lower Princeton Submarine Valley Fill** (Eocene)-includes Capay Formation. Marine sandstone, conglomerate and interbedded silty shale, maximum thickness 2,400 ft. *(adapted from Redwine, 1972)*

**JKgvs** **Great Valley Sequence** (Late Jurassic to Upper Cretaceous)-Marine clastic sedimentary rock consisting of siltstone, shale, sandstone and conglomerate; maximum thickness 15,000 ft.

**m** **Mixed Rocks** (pre-Cenozoic)-Undivided metasedimentary and metavolcanic rocks of greatly varying types *(adapted from Jennings, 1977).*

**Mzv** **Volcanic and Metavolcanic Rocks** (Mesozoic)-Undivided volcanic and metavolcanic rocks, andesite rhyolite flow rocks, greenstone and volcanic breccia *(adapted from Jennings, 1977).*

**um** **Ultramafic Rocks** (Mesozoic)-Primarily composed of serpentine, with peridotite, gabbro and diabase *(adapted from Jennings, 1977).*

**gb** **Gabbro** (Mesozoic)-Gabbro and dark diotric rocks *(adapted from Jennings, 1977).*

**gr** **Undifferentiated Granitic Plutons** (Mesozoic-Paleozoic)-Undivided granitic plutons and related rocks *(adapted from Jennings, 1977).*

**Pz** **Paleozoic Metasedimentary Rocks** (Paleozoic)-Undivided metasedimentary rocks including slate, shale, sandstone, chert, conglomerate, limestone, dolomite, marble, phyllite,schist, hornfels and quartzite *(adapted from Jennings, 1977).*

**Pzv** **Paleozoic Metavolcanic Rocks** (Paleozoic)-Undivided metavolcanic rocks, primarily flows, breccia, and tuff, including greenstone, diabase and pillow lavas *(adapted from Jennings, 1977).*

Notes:
1. Modified from DWR (2005)
2. NAVD88 = North American Vertical Datum of 1988

**Figure 11**
**North-South Cross-Section of SACFEM2013 Model Layering**
*SACFEM: Sacramento Valley Finite Element Groundwater Flow Model*
USER'S MANUAL

# Appendix A
# Historical Surface Water Diversion Data and IDC Applied Water Demand Comparisons

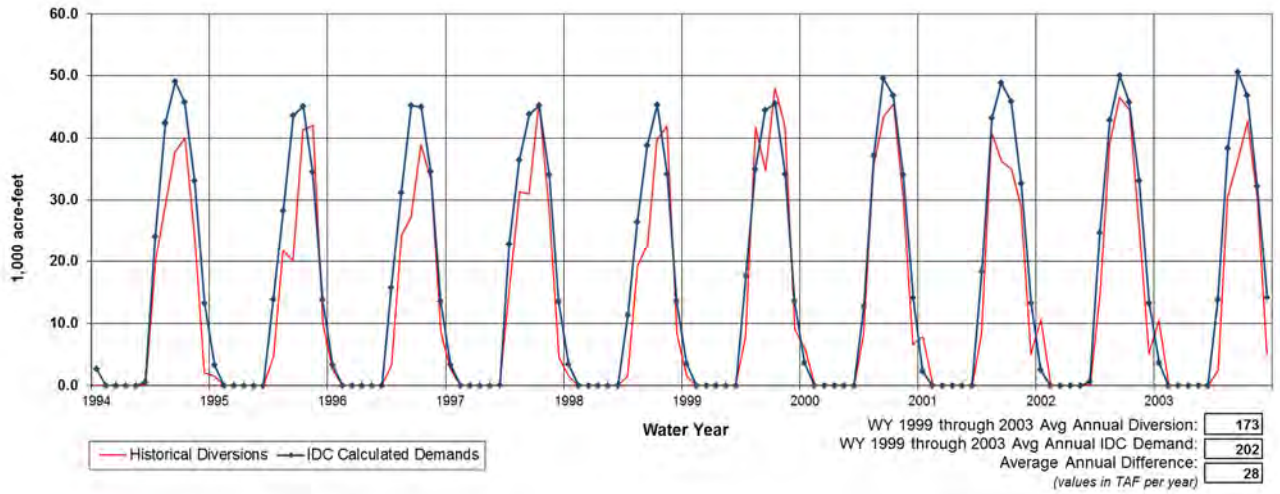



**Figure A-1 Annual Historical Diversions and IDC Calculated Demands for RD 108 and River Garden Farms**

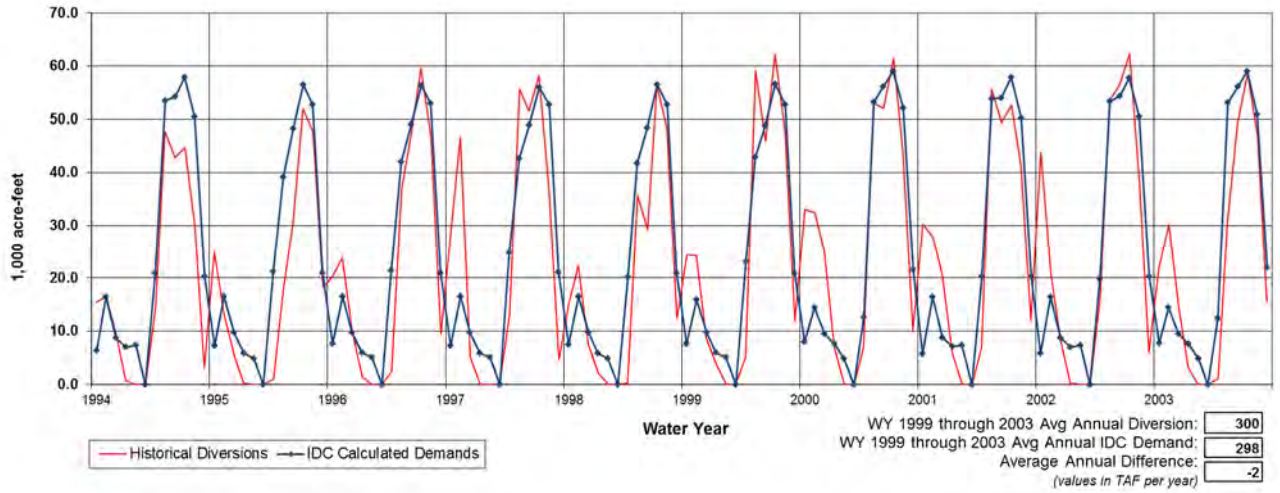



**Figure A-2 Annual Historical Diversions and IDC Calculated Demands for Western Canal**

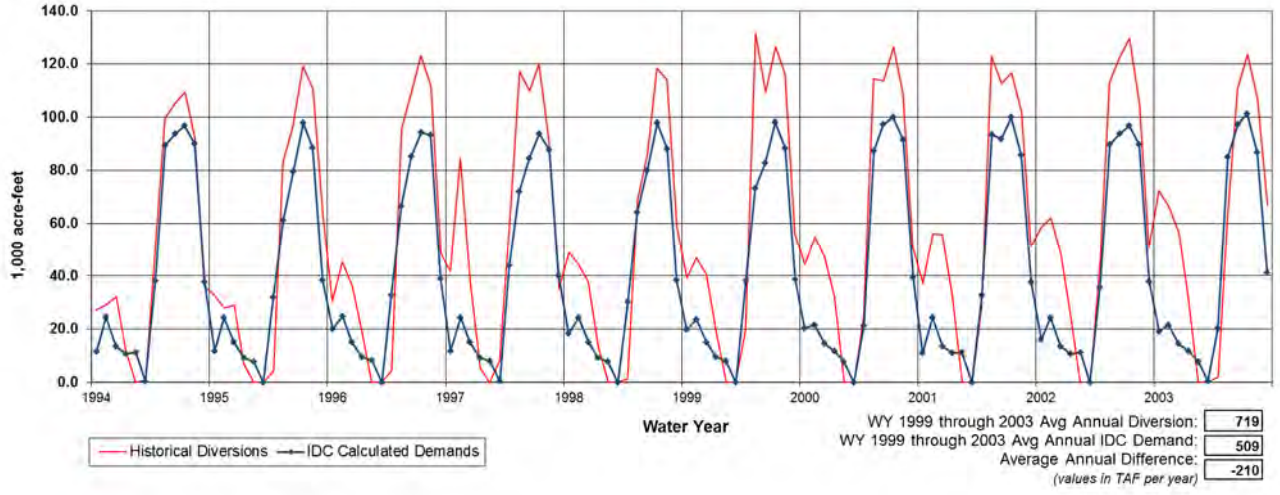



**Figure A-3 Annual Historical Diversions and IDC Calculated Demands for Joint Water District**

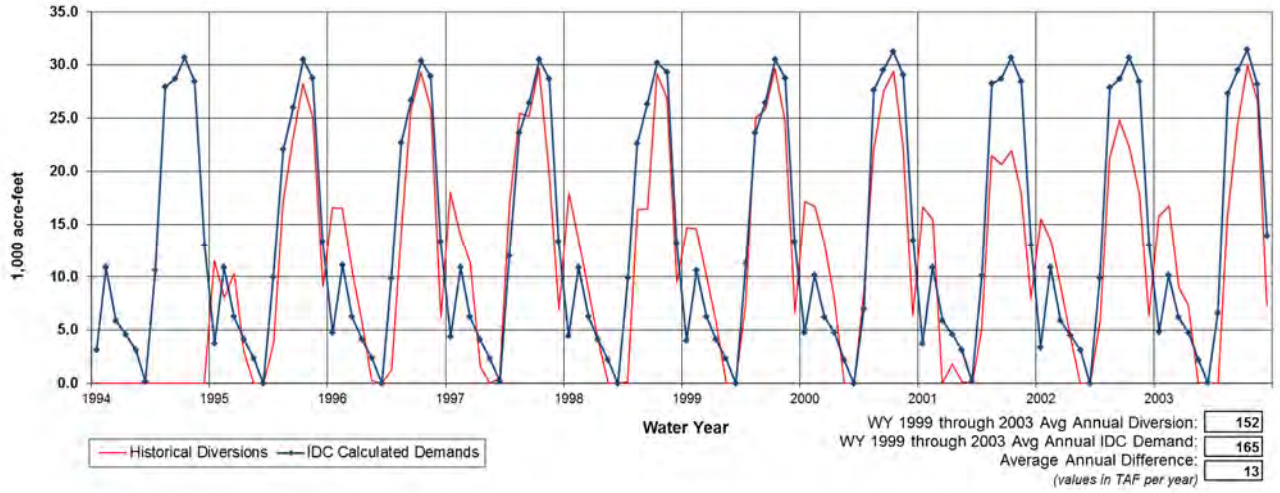



**Figure A-4 Annual Historical Diversions and IDC Calculated Demands for YCWA**

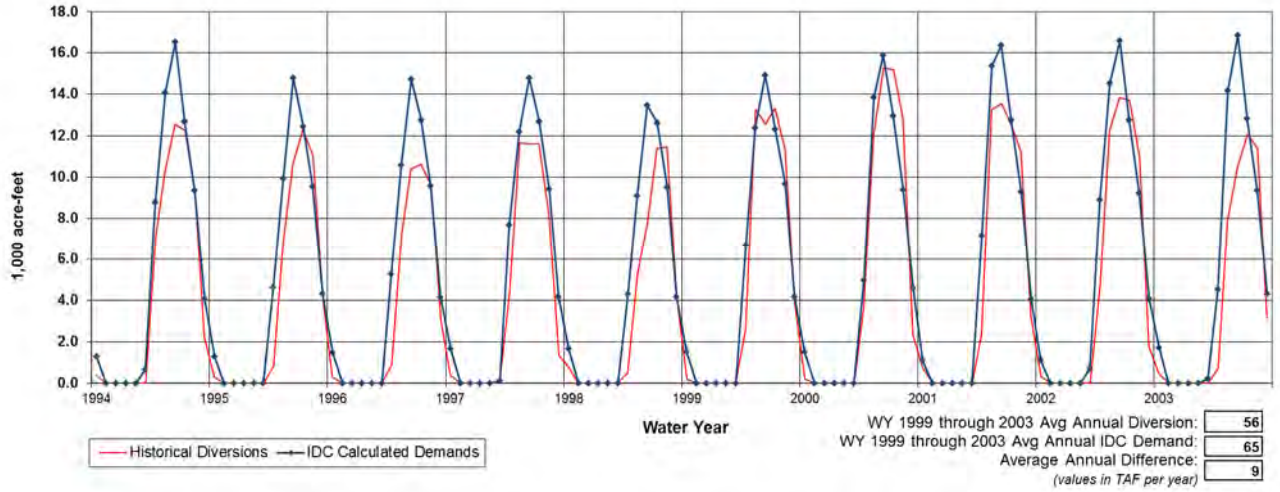



**Figure A-5 Annual Historical Diversions and IDC Calculated Demands for Meridian, Newhall, Tisdale, and Short Form Contractors in WBA 18**

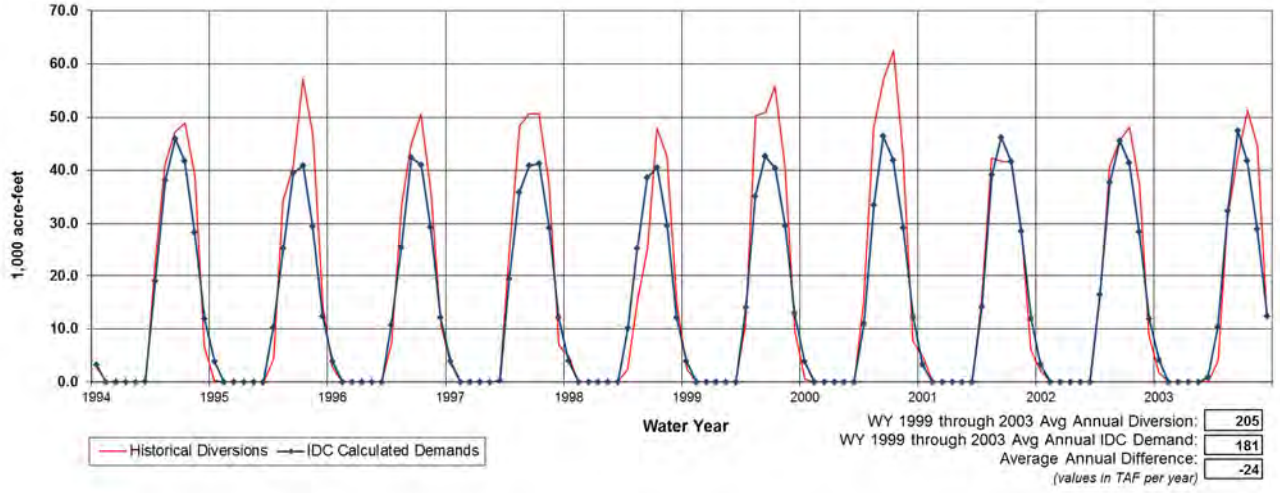



**Figure A-6 Annual Historical Diversions and IDC Calculated Demands for Sutter Mutual**

# Appendix B
# Summary of Quantitative Calibration Targets

APPENDIX B

**Summary of Quantitative Calibration Targets by Well**

*SACFEM2013: Sacramento Valley Finite Element Groundwater Model; User's Manual*

| State Well Number | SACFEM 2013 Model Layer | Earliest Year with Measured Data | Latest Year with Measured Data | Minimum Measured Groundwater Elevation (feet NAVD88) | Maximum Measured Groundwater Elevation (feet NAVD88) | Range in Measured Groundwater Elevation (feet) | Number of Measurements | Mean Error (feet) | Root Mean Squared Error (feet) |
|---|---|---|---|---|---|---|---|---|---|
| 05N02E05C001M | 1 | 1972.22 | 1999.76 | 2.2 | 14.3 | 12.1 | 318.0 | -0.3 | 4.9 |
| 05N05E04C001M | 2 | 1969.9 | 2002.35 | -55.5 | -22.5 | 33.0 | 335.0 | 30.2 | 30.7 |
| 05N05E10C003M | 2 | 1969.87 | 2010.57 | -42.5 | -10.6 | 31.9 | 94.0 | 19.7 | 21.1 |
| 06N01E24L003M | 2 | 1970.24 | 2010.25 | 14.4 | 33.0 | 18.6 | 75.0 | -1.4 | 4.9 |
| 06N02E02M003M | 2 | 1970.24 | 2010.24 | -8.3 | 24.3 | 32.6 | 72.0 | -8.6 | 14.6 |
| 06N05E01C001M | 1 | 1969.9 | 2006.7 | -80.1 | -42.8 | 37.3 | 425.0 | 43.9 | 44.3 |
| 07N01E08N002M | 2 | 1972.64 | 1994.63 | 64.6 | 87.5 | 22.9 | 235.0 | -24.5 | 25.0 |
| 07N01E11K001M | 4 | 1994.09 | 1998.42 | -17.5 | 51.9 | 69.4 | 51.0 | -26.4 | 33.0 |
| 07N01E25J001M | 3 | 1991.6 | 1999.25 | -69.3 | 33.4 | 102.7 | 77.0 | -10.4 | 19.8 |
| 07N05E26C001M | 4 | 1970.21 | 2008.9 | -63.9 | -31.0 | 32.9 | 75.0 | 31.5 | 32.0 |
| 07N05E32D001M | 5 | 1978.79 | 1991.2 | -51.3 | -27.1 | 24.2 | 26.0 | 26.1 | 26.4 |
| 07N06E23P001M | 2 | 1969.9 | 1998.94 | -38.1 | 1.4 | 39.5 | 317.0 | -0.8 | 4.8 |
| 08N03E04R001M | 2 | 1970.28 | 2010.67 | -35.8 | 17.9 | 53.7 | 414.0 | 8.2 | 10.0 |
| 08N04E24M001M | 1 | 1969.9 | 2001.41 | -12.6 | 3.0 | 15.6 | 142.0 | 13.9 | 14.1 |
| 08N05E07P001M | 2 | 1970.21 | 2010.7 | -5.5 | 5.7 | 11.2 | 349.0 | 3.3 | 3.6 |
| 08N06E21N002M | 2 | 1969.81 | 2004.17 | -28.4 | 1.6 | 30.0 | 122.0 | 3.7 | 6.9 |
| 08N06E25J002M | 2 | 1970.21 | 2010.57 | -14.7 | 85.5 | 100.2 | 79.0 | -13.8 | 19.2 |
| 08N07E18E002M | 3 | 1984.2 | 2010.58 | -28.9 | 28.7 | 57.6 | 51.0 | -8.7 | 15.8 |
| 09N02E16N001M | 2 | 1969.9 | 2010.67 | -27.0 | 48.1 | 75.1 | 461.0 | -2.5 | 11.0 |
| 09N04E01R001M | 1 | 1970.82 | 2010.31 | -18.5 | 13.1 | 31.6 | 70.0 | 0.4 | 4.6 |
| 09N04E22E001M | 2 | 1969.9 | 2007.83 | 2.9 | 15.1 | 12.2 | 162.0 | 1.9 | 2.8 |
| 09N05E14B001M | 3 | 1980.77 | 2010.57 | -49.6 | -20.8 | 28.8 | 61.0 | 24.0 | 24.7 |
| 09N05E25J001M | 2 | 1977.5 | 2010.7 | -45.7 | -7.4 | 38.3 | 346.0 | 18.3 | 19.4 |
| 09N05E28K001M | 2 | 1970.21 | 2010.57 | -37.4 | -4.8 | 32.6 | 81.0 | 20.4 | 21.4 |
| 10N01E26E003M | 2 | 1970.26 | 2010.32 | -20.2 | 55.5 | 75.7 | 86.0 | 15.7 | 19.5 |
| 10N01E33L002M | 2 | 1972.55 | 2010.3 | 2.0 | 74.6 | 72.6 | 88.0 | -0.3 | 13.6 |
| 10N02E08E001M | 2 | 1970.84 | 2010.32 | -20.2 | 51.5 | 71.7 | 82.0 | 5.9 | 12.2 |
| 10N04E27R002M | 5 | 1996.77 | 2010.67 | -32.5 | -16.0 | 16.5 | 110.0 | 26.1 | 26.3 |
| 10N04E27R003M | 4 | 1996.77 | 2010.67 | -6.1 | 7.1 | 13.2 | 111.0 | -0.6 | 2.2 |
| 10N04E27R004M | 2 | 1996.77 | 2010.67 | 6.7 | 18.2 | 11.5 | 111.0 | -10.9 | 11.3 |

APPENDIX B

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| State Well Number | SACFEM 2013 Model Layer | Earliest Year with Measured Data | Latest Year with Measured Data | Minimum Measured Groundwater Elevation (feet NAVD88) | Maximum Measured Groundwater Elevation (feet NAVD88) | Range in Measured Groundwater Elevation (feet) | Number of Measurements | Mean Error (feet) | Root Mean Squared Error (feet) |
|---|---|---|---|---|---|---|---|---|---|
| 10N04E31M001M | 5 | 1997.19 | 2010.67 | -18.5 | -9.9 | 8.6 | 109.0 | 22.8 | 23.0 |
| 10N04E31M002M | 4 | 1997.52 | 2010.67 | -8.4 | 4.9 | 13.3 | 106.0 | 9.5 | 9.7 |
| 10N04E31M003M | 3 | 1997.52 | 2010.67 | 2.4 | 15.1 | 12.7 | 106.0 | 1.9 | 2.9 |
| 10N04E31M004M | 2 | 1997.52 | 2010.67 | 5.2 | 13.7 | 8.5 | 106.0 | 2.0 | 2.7 |
| 10N05E05E001M | 2 | 1970.21 | 2010.57 | -39.2 | -13.2 | 26.0 | 80.0 | 18.6 | 19.4 |
| 10N05E22G001M | 3 | 1969.87 | 1995.36 | -43.1 | 4.4 | 47.5 | 283.0 | 9.9 | 12.8 |
| 10N06E05H001M | 2 | 1969.9 | 2010.7 | -17.7 | 28.2 | 45.9 | 450.0 | -3.2 | 8.2 |
| 11N01E03E001M | 2 | 1970.21 | 2010.25 | -21.7 | 37.1 | 58.8 | 118.0 | -1.6 | 10.8 |
| 11N02E20K004M | 2 | 1970.23 | 2010.67 | -20.1 | 37.3 | 57.4 | 405.0 | -5.4 | 8.6 |
| 11N03E15C001M | 1 | 1970.22 | 2010.67 | 7.5 | 32.2 | 24.7 | 123.0 | 3.7 | 5.5 |
| 11N03E20H003M | 2 | 1970.23 | 2010.55 | 14.0 | 29.3 | 15.3 | 83.0 | 2.5 | 4.7 |
| 11N04E04N001M | 7 | 1994.02 | 2010.71 | -8.6 | 15.1 | 23.7 | 209.0 | -2.2 | 4.2 |
| 11N04E04N002M | 3 | 1994.1 | 2010.71 | 4.4 | 27.2 | 22.8 | 208.0 | -13.2 | 13.6 |
| 11N04E04N003M | 2 | 1994.1 | 2010.71 | 11.6 | 28.7 | 17.1 | 208.0 | -11.2 | 11.5 |
| 11N06E15C004M | 1 | 1970.23 | 2008.77 | 33.3 | 62.7 | 29.4 | 147.0 | -40.6 | 42.2 |
| 12N01E06D002M | 5 | 1997.77 | 2010.73 | -7.0 | 28.7 | 35.8 | 95.0 | 10.4 | 12.2 |
| 12N01E06D003M | 4 | 1997.77 | 2010.73 | -29.3 | 29.2 | 58.5 | 94.0 | 15.7 | 20.6 |
| 12N01E06D004M | 3 | 1997.77 | 2010.73 | -11.6 | 29.6 | 41.2 | 95.0 | 8.5 | 11.4 |
| 12N01E16A001M | 5 | 1997.77 | 2010.73 | -14.9 | 28.4 | 43.3 | 85.0 | 11.0 | 13.6 |
| 12N01E16A002M | 3 | 1997.77 | 2010.73 | -15.1 | 29.9 | 45.1 | 86.0 | 16.0 | 20.5 |
| 12N01E26A001M | 4 | 1996.85 | 2010.73 | -18.6 | 21.1 | 39.7 | 103.0 | 19.6 | 21.7 |
| 12N01E26A002M | 3 | 1996.85 | 2010.73 | -21.5 | 23.0 | 44.5 | 104.0 | 21.0 | 24.0 |
| 12N01E26A003M | 2 | 1996.85 | 2010.73 | -0.3 | 22.6 | 22.9 | 104.0 | 14.1 | 15.3 |
| 12N02E23K001M | 6 | 1969.78 | 2009.95 | 15.5 | 20.9 | 5.4 | 93.0 | 4.1 | 4.7 |
| 12N04E03N002M | 7 | 1996.77 | 2010.67 | -6.5 | 44.7 | 51.2 | 113.0 | -13.8 | 16.1 |
| 12N04E03N003M | 6 | 1996.77 | 2010.67 | -1.5 | 41.3 | 42.8 | 112.0 | -11.1 | 13.7 |
| 12N04E03N004M | 2 | 1996.77 | 2010.67 | 10.1 | 45.0 | 34.9 | 113.0 | -18.7 | 19.7 |
| 12N04E05R004M | 1 | 1970.22 | 2010.71 | -0.3 | 37.7 | 38.0 | 398.0 | -9.0 | 10.5 |
| 12N04E26J002M | 7 | 1996.77 | 2010.67 | -17.8 | 24.4 | 42.2 | 114.0 | -5.3 | 9.1 |
| 12N04E26J003M | 5 | 1996.77 | 2010.67 | -17.5 | 24.6 | 42.1 | 113.0 | -7.2 | 9.9 |

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|---|---|---|---|---|---|---|---|---|---|
| 12N04E26J004M | 2 | 1996.77 | 2010.67 | 2.6 | 38.3 | 35.8 | 114.0 | -21.4 | 22.6 |
| 12N05E01D002M | 2 | 1970.21 | 2010.57 | 49.6 | 77.3 | 27.7 | 91.0 | -32.6 | 35.2 |
| 12N05E06R001M | 1 | 1970.21 | 2010.57 | -7.5 | 52.5 | 60.0 | 86.0 | -22.4 | 24.8 |
| 12N05E12Q001M | 1 | 1969.83 | 2007.68 | 22.8 | 73.0 | 50.2 | 446.0 | -24.7 | 31.4 |
| 12N05E17A002M | 1 | 1970.21 | 2010.7 | -1.9 | 41.4 | 43.3 | 402.0 | -13.9 | 16.9 |
| 12N06E27D002M | 3 | 1969.9 | 2003.83 | 39.4 | 95.0 | 55.6 | 160.0 | -6.6 | 22.3 |
| 13N01E11A001M | 2 | 1970.19 | 2010.59 | 18.7 | 31.8 | 13.1 | 98.0 | 5.2 | 6.0 |
| 13N01E12J002M | 2 | 1970.22 | 2010.67 | 23.8 | 32.8 | 9.0 | 135.0 | 6.3 | 6.9 |
| 13N01E32K001M | 4 | 1997.77 | 2010.73 | -24.7 | 23.3 | 48.0 | 94.0 | 23.7 | 27.0 |
| 13N01E32K002M | 3 | 1997.77 | 2010.73 | -13.1 | 20.4 | 33.5 | 94.0 | 20.4 | 21.9 |
| 13N02W04G001M | 3 | 1969.81 | 2010.59 | 38.1 | 120.0 | 81.9 | 449.0 | -17.5 | 32.4 |
| 13N02W04G004M | 1 | 1978.45 | 2010.59 | 97.3 | 148.0 | 50.7 | 239.0 | -51.3 | 53.7 |
| 13N02W15J001M | 2 | 1975.25 | 2010.59 | 31.0 | 111.9 | 80.9 | 215.0 | -27.8 | 34.8 |
| 13N02W22H001M | 1 | 1970.21 | 2010.27 | 106.8 | 176.0 | 69.2 | 77.0 | -61.3 | 63.3 |
| 13N04E07L001M | 3 | 1996.3 | 2010.72 | 26.1 | 39.7 | 13.6 | 115.0 | -2.3 | 3.1 |
| 13N04E23A002M | 1 | 1970.22 | 2010.57 | 15.0 | 57.9 | 42.9 | 99.0 | -8.6 | 12.5 |
| 13N04E36E001M | 1 | 1969.79 | 1995.47 | -25.9 | 43.4 | 69.3 | 199.0 | -10.0 | 16.0 |
| 13N05E06R004M | 4 | 1996.3 | 2010.72 | 27.5 | 61.9 | 34.4 | 116.0 | 3.2 | 6.3 |
| 14N01W03L002M | 3 | 1970.19 | 1983.76 | -21.1 | 40.8 | 61.9 | 84.0 | -10.8 | 16.6 |
| 14N01W04K003M | 1 | 1970.19 | 2010.59 | 25.8 | 36.2 | 10.4 | 96.0 | -26.0 | 28.2 |
| 14N02W16N002M | 1 | 1969.81 | 1988.19 | 46.5 | 87.8 | 41.3 | 142.0 | 13.3 | 16.1 |
| 14N02W29J001M | 5 | 1970.82 | 2010.59 | 57.5 | 107.2 | 49.7 | 225.0 | -33.2 | 38.2 |
| 14N03E05C001M | 1 | 1970.21 | 2004.8 | 3.1 | 42.5 | 39.4 | 66.0 | -5.0 | 7.6 |
| 14N03E17A003M | 2 | 1970.23 | 2010.58 | 2.0 | 38.1 | 36.1 | 345.0 | -0.8 | 4.2 |
| 14N03W11A001M | 4 | 1970.21 | 2010.59 | 48.5 | 107.6 | 59.1 | 95.0 | -5.1 | 16.3 |
| 14N04E30N003M | 2 | 1995.74 | 2010.72 | 4.7 | 33.4 | 28.7 | 152.0 | 4.0 | 6.6 |
| 15N01E16R001M | 3 | 1969.78 | 2003.22 | 29.7 | 40.3 | 10.6 | 72.0 | -2.7 | 6.4 |
| 15N01W05G001M | 1 | 1976.19 | 2010.59 | 26.2 | 47.6 | 21.4 | 88.0 | -6.7 | 9.0 |
| 15N02E35D001M | 3 | 1970.24 | 2010.57 | 31.5 | 44.7 | 13.2 | 87.0 | -11.8 | 13.5 |
| 15N03E05D002M | 2 | 1970.22 | 2004.21 | 30.7 | 58.7 | 28.0 | 63.0 | -14.8 | 15.6 |

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|---|---|---|---|---|---|---|---|---|---|
| 15N03E15H004M | 2 | 1970.22 | 2010.67 | 32.0 | 46.7 | 14.7 | 137.0 | 0.7 | 2.4 |
| 15N04E13A001M | 2 | 1970.8 | 2010.59 | 13.4 | 88.1 | 74.6 | 90.0 | 21.4 | 28.2 |
| 15N04E16G002M | 3 | 1996.29 | 2010.72 | 31.1 | 59.1 | 28.0 | 114.0 | 4.8 | 5.9 |
| 15N04E27A001M | 4 | 1970.23 | 2006.28 | -13.5 | 61.4 | 74.9 | 82.0 | 28.4 | 34.2 |
| 16N01W20F001M | 1 | 1970.19 | 2010.59 | 24.7 | 55.7 | 31.0 | 114.0 | 16.1 | 17.1 |
| 16N02E26Q001M | 1 | 1970.22 | 2010.58 | 39.3 | 60.9 | 21.6 | 91.0 | -17.4 | 18.5 |
| 16N02W25B002M | 2 | 1969.88 | 2010.59 | 28.1 | 51.4 | 23.3 | 335.0 | -3.8 | 5.6 |
| 16N03E21D002M | 1 | 1970.22 | 2010.58 | 44.6 | 69.1 | 24.5 | 115.0 | -16.4 | 17.0 |
| 16N03W07Q001M | 1 | 1975.25 | 2010.59 | 105.7 | 111.3 | 5.6 | 90.0 | -11.4 | 11.7 |
| 16N03W35N002M | 4 | 1970.19 | 2010.22 | 60.6 | 70.5 | 9.9 | 97.0 | 0.8 | 5.0 |
| 16N04E17R002M | 2 | 1988.84 | 2010.69 | 37.1 | 79.4 | 42.3 | 122.0 | -2.2 | 8.0 |
| 16N04E22B001M | 3 | 1995.74 | 2010.72 | 41.9 | 85.1 | 43.2 | 154.0 | 10.0 | 13.2 |
| 17N01E10A001M | 2 | 1970.22 | 2010.59 | 28.1 | 60.7 | 32.6 | 124.0 | 4.9 | 7.1 |
| 17N01E17F001M | 2 | 1992.89 | 2010.59 | 51.9 | 59.8 | 7.9 | 69.0 | 5.8 | 8.2 |
| 17N01E17F002M | 3 | 1992.89 | 2010.59 | 51.9 | 62.6 | 10.7 | 69.0 | 3.5 | 5.8 |
| 17N01E17F003M | 5 | 1992.89 | 2010.59 | 51.6 | 62.3 | 10.7 | 69.0 | 3.1 | 5.0 |
| 17N02E14A001M | 1 | 1970.22 | 2010.69 | 56.2 | 84.2 | 28.0 | 140.0 | -16.6 | 18.3 |
| 17N02W09H002M | 5 | 2004.06 | 2010.59 | 24.4 | 68.7 | 44.4 | 64.0 | 10.9 | 16.5 |
| 17N02W09H003M | 4 | 2004.06 | 2010.59 | 11.1 | 68.0 | 56.9 | 63.0 | 11.8 | 21.0 |
| 17N02W09H004M | 2 | 2004.06 | 2010.59 | 53.4 | 67.3 | 13.9 | 64.0 | 2.2 | 4.2 |
| 17N03E03D001M | 1 | 1970.22 | 2010.59 | 61.9 | 89.8 | 27.9 | 139.0 | 3.4 | 5.2 |
| 17N03E05C001M | 1 | 1970.22 | 2002.79 | 75.6 | 95.6 | 20.0 | 105.0 | -13.0 | 13.7 |
| 17N03E16N001M | 2 | 1970.22 | 2010.69 | 66.4 | 82.6 | 16.2 | 141.0 | -15.8 | 16.7 |
| 17N03W08R001M | 2 | 1975.25 | 2010.59 | 86.6 | 98.1 | 11.5 | 139.0 | 4.1 | 5.0 |
| 17N03W10C001M | 1 | 1970.19 | 2010.59 | 85.9 | 93.3 | 7.4 | 226.0 | -4.8 | 5.5 |
| 17N04E30R001M | 4 | 1970.21 | 2010.69 | -26.4 | 82.4 | 108.8 | 129.0 | 4.2 | 10.6 |
| 18N01E13M001M | 2 | 1970.23 | 2002.79 | 61.1 | 75.5 | 14.4 | 90.0 | 1.9 | 4.7 |
| 18N01E17D001M | 1 | 1970.21 | 2001.56 | 63.8 | 71.6 | 7.8 | 80.0 | 5.5 | 11.6 |
| 18N01W17G001M | 1 | 1970.21 | 2010.22 | 50.4 | 79.4 | 29.0 | 137.0 | 13.3 | 14.7 |
| 18N01W22L001M | 2 | 1970.21 | 2009.81 | 32.0 | 70.2 | 38.2 | 136.0 | 5.5 | 11.5 |

APPENDIX B

**Summary of Quantitative Calibration Targets by Well**

*SACFEM2013: Sacramento Valley Finite Element Groundwater Model; User's Manual*

| State Well Number | SACFEM 2013 Model Layer | Earliest Year with Measured Data | Latest Year with Measured Data | Minimum Measured Groundwater Elevation (feet NAVD88) | Maximum Measured Groundwater Elevation (feet NAVD88) | Range in Measured Groundwater Elevation (feet) | Number of Measurements | Mean Error (feet) | Root Mean Squared Error (feet) |
|---|---|---|---|---|---|---|---|---|---|
| 18N01W35K001M | 1 | 1970.19 | 2001.78 | 58.4 | 62.2 | 3.8 | 86.0 | 7.2 | 11.9 |
| 18N02E16F001M | 1 | 1970.76 | 2010.59 | 74.2 | 79.1 | 4.9 | 138.0 | 4.3 | 7.1 |
| 18N02E32Q002M | 1 | 1970.23 | 2002.79 | 69.3 | 74.8 | 5.5 | 267.0 | -2.3 | 6.2 |
| 18N02W18D001M | 6 | 2007.33 | 2010.59 | 77.1 | 81.7 | 4.6 | 17.0 | 4.8 | 5.1 |
| 18N02W18D002M | 5 | 2007.33 | 2010.59 | 73.7 | 78.5 | 4.8 | 17.0 | 7.9 | 7.9 |
| 18N02W18D003M | 4 | 2007.33 | 2010.59 | 74.3 | 78.6 | 4.3 | 18.0 | 6.7 | 6.8 |
| 18N02W18D004M | 2 | 2007.33 | 2010.59 | 40.5 | 77.4 | 36.9 | 17.0 | 24.2 | 27.8 |
| 18N02W18K001M | 2 | 1975.25 | 2010.59 | -27.8 | 78.2 | 106.0 | 63.0 | 13.1 | 32.0 |
| 18N02W36B001M | 1 | 1970.19 | 2010.59 | 60.5 | 73.2 | 12.7 | 100.0 | 0.8 | 3.3 |
| 18N03E05K001M | 1 | 1970.22 | 2002.79 | 89.3 | 106.3 | 17.0 | 104.0 | 9.9 | 10.3 |
| 18N03E18F001M | 5 | 1970.22 | 2010.59 | 86.2 | 98.6 | 12.4 | 139.0 | -4.8 | 6.3 |
| 18N03E21G001M | 1 | 1970.22 | 2010.59 | 80.5 | 96.9 | 16.4 | 140.0 | -0.2 | 3.5 |
| 18N03W10L001M | 1 | 1969.88 | 2010.59 | 89.5 | 95.6 | 6.1 | 222.0 | 1.1 | 3.1 |
| 18N04E16C001M | 3 | 1970.22 | 2010.59 | 93.3 | 136.3 | 43.0 | 135.0 | -11.3 | 16.5 |
| 18N04W12A001M | 1 | 1970.21 | 2010.22 | 98.9 | 129.0 | 30.1 | 124.0 | -7.1 | 12.4 |
| 18N04W23F001M | 7 | 1970.21 | 2010.59 | 128.0 | 149.0 | 21.0 | 130.0 | 7.8 | 11.9 |
| 19N01E09Q001M | 2 | 1991.66 | 2010.59 | 48.1 | 92.6 | 44.5 | 93.0 | 5.1 | 10.0 |
| 19N01E27Q001M | 4 | 1978.39 | 2010.59 | 60.1 | 86.8 | 26.7 | 172.0 | -1.3 | 5.0 |
| 19N01W15D001M | 1 | 1970.21 | 2010.59 | 66.8 | 89.7 | 22.9 | 142.0 | 9.7 | 12.8 |
| 19N02W13J001M | 1 | 1969.88 | 2010.59 | 73.6 | 88.3 | 14.7 | 223.0 | 6.2 | 7.3 |
| 19N02W29Q001M | 2 | 1970.21 | 2010.59 | 77.5 | 92.4 | 14.9 | 130.0 | -2.5 | 4.3 |
| 19N02W36H001M | 1 | 1970.21 | 2010.59 | 70.6 | 83.9 | 13.3 | 130.0 | -1.1 | 3.9 |
| 19N03W26P001M | 3 | 1974.19 | 2010.59 | 91.6 | 102.3 | 10.7 | 122.0 | -3.1 | 4.7 |
| 19N04W12E001M | 4 | 1969.88 | 2010.59 | 63.5 | 170.0 | 106.5 | 355.0 | -5.6 | 25.6 |
| 20N01E10C002M | 2 | 1973.26 | 2010.59 | 70.3 | 126.8 | 56.5 | 130.0 | 0.0 | 9.2 |
| 20N01E18L001M | 6 | 2000.12 | 2010.59 | 99.8 | 113.8 | 13.9 | 102.0 | -3.8 | 4.3 |
| 20N01E18L002M | 5 | 2001.89 | 2010.59 | 100.8 | 108.0 | 7.1 | 75.0 | -2.1 | 2.9 |
| 20N01E18L003M | 2 | 2001.89 | 2010.59 | 103.5 | 108.1 | 4.5 | 74.0 | -3.1 | 3.7 |
| 20N01E35C001M | 1 | 1970.23 | 2010.59 | 93.8 | 101.0 | 7.2 | 137.0 | 4.2 | 4.6 |
| 20N02E06Q001M | 4 | 1970.23 | 2010.59 | 97.6 | 134.3 | 36.7 | 141.0 | 6.7 | 8.9 |

APPENDIX B

**Summary of Quantitative Calibration Targets by Well**

*SACFEM2013: Sacramento Valley Finite Element Groundwater Model; User's Manual*

| State Well Number | SACFEM 2013 Model Layer | Earliest Year with Measured Data | Latest Year with Measured Data | Minimum Measured Groundwater Elevation (feet NAVD88) | Maximum Measured Groundwater Elevation (feet NAVD88) | Range in Measured Groundwater Elevation (feet) | Number of Measurements | Mean Error (feet) | Root Mean Squared Error (feet) |
|---|---|---|---|---|---|---|---|---|---|
| 20N02E07H001M | 3 | 1990.84 | 1997.84 | 91.1 | 128.7 | 37.6 | 99.0 | 4.6 | 6.2 |
| 20N02E24C001M | 2 | 2000.01 | 2010.59 | 105.8 | 130.6 | 24.8 | 81.0 | 15.5 | 16.0 |
| 20N02E24C002M | 5 | 2000.01 | 2010.59 | 105.9 | 130.6 | 24.7 | 84.0 | 16.2 | 16.6 |
| 20N02E24C003M | 7 | 2000.01 | 2010.59 | 105.6 | 130.7 | 25.1 | 85.0 | 18.1 | 18.5 |
| 20N02E28N001M | 1 | 1969.89 | 2010.59 | 112.8 | 121.6 | 8.8 | 400.0 | -5.4 | 7.0 |
| 20N02W02J001M | 1 | 1970.21 | 2010.59 | 114.8 | 125.6 | 10.8 | 131.0 | 1.5 | 3.9 |
| 20N02W11A001M | 1 | 1976.88 | 2010.59 | 110.4 | 124.6 | 14.2 | 633.0 | -1.7 | 4.5 |
| 20N02W11A002M | 2 | 1978.24 | 2010.59 | 91.2 | 121.4 | 30.2 | 313.0 | 0.2 | 4.2 |
| 20N02W11A003M | 4 | 1978.24 | 2010.59 | 75.1 | 123.1 | 48.0 | 320.0 | 3.7 | 6.5 |
| 20N02W29G001M | 1 | 1969.88 | 2010.59 | 110.4 | 116.7 | 6.3 | 161.0 | -2.3 | 4.5 |
| 21N01E05G001M | 2 | 1969.98 | 1997.56 | 113.5 | 144.9 | 31.4 | 116.0 | -3.3 | 4.3 |
| 21N01E12K001M | 4 | 1970.23 | 2010.52 | 81.1 | 165.2 | 84.1 | 108.0 | 15.7 | 21.7 |
| 21N01E27D001M | 1 | 1970.23 | 2010.59 | 87.0 | 132.1 | 45.2 | 169.0 | 0.1 | 9.1 |
| 21N01W04N001M | 1 | 1970.21 | 2010.59 | 106.6 | 129.2 | 22.6 | 152.0 | 9.1 | 9.6 |
| 21N01W23J001M | 1 | 1970.23 | 2010.59 | 104.2 | 120.2 | 16.0 | 168.0 | 0.5 | 3.1 |
| 21N01W24B001M | 6 | 1995.29 | 2010.59 | 96.0 | 127.4 | 31.4 | 122.0 | 1.0 | 4.9 |
| 21N02E26F001M | 7 | 1970.23 | 2008.19 | 102.0 | 146.7 | 44.7 | 119.0 | 27.0 | 29.9 |
| 21N02W05M001M | 4 | 2002.41 | 2010.59 | 117.3 | 167.8 | 50.5 | 95.0 | -3.6 | 6.4 |
| 21N02W05M002M | 2 | 2002.41 | 2010.59 | 133.5 | 181.1 | 47.6 | 96.0 | -11.8 | 13.3 |
| 21N02W05M004M | 1 | 2002.41 | 2006.89 | 159.1 | 178.4 | 19.3 | 63.0 | -12.1 | 12.6 |
| 21N02W09M002M | 2 | 1970.21 | 2010.23 | 118.3 | 172.0 | 53.7 | 128.0 | -8.7 | 12.8 |
| 21N02W23G001M | 2 | 1970.21 | 2010.59 | 107.4 | 147.9 | 40.5 | 149.0 | -5.5 | 7.9 |
| 21N02W31M001M | 2 | 1970.21 | 2010.23 | 94.7 | 155.5 | 60.8 | 126.0 | -8.4 | 13.4 |
| 21N03W31R002M | 3 | 1969.81 | 2008.19 | 68.2 | 166.1 | 97.9 | 488.0 | 30.0 | 40.2 |
| 21N03W31R004M | 2 | 1969.81 | 2008.19 | 76.3 | 166.9 | 90.6 | 480.0 | 32.3 | 42.6 |
| 21N03W31R005M | 1 | 1969.81 | 2008.19 | 92.4 | 166.0 | 73.6 | 482.0 | 30.3 | 39.4 |
| 21N03W33A004M | 5 | 1970.21 | 2010.27 | 99.3 | 169.0 | 69.7 | 75.0 | 9.3 | 22.0 |
| 22N01E09J002M | 1 | 1970.23 | 2002.79 | 133.8 | 165.4 | 31.6 | 91.0 | -1.8 | 13.8 |
| 22N01E20K001M | 1 | 1969.89 | 2010.59 | 112.5 | 154.9 | 42.4 | 229.0 | -3.2 | 9.4 |
| 22N01E28J001M | 6 | 1972.24 | 2010.59 | 115.0 | 162.2 | 47.2 | 326.0 | -1.5 | 10.5 |

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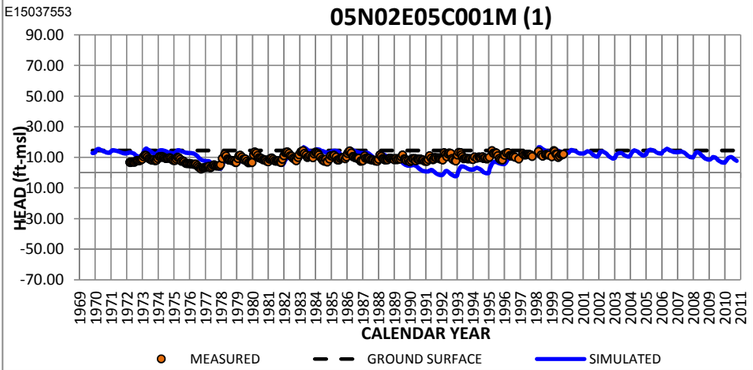
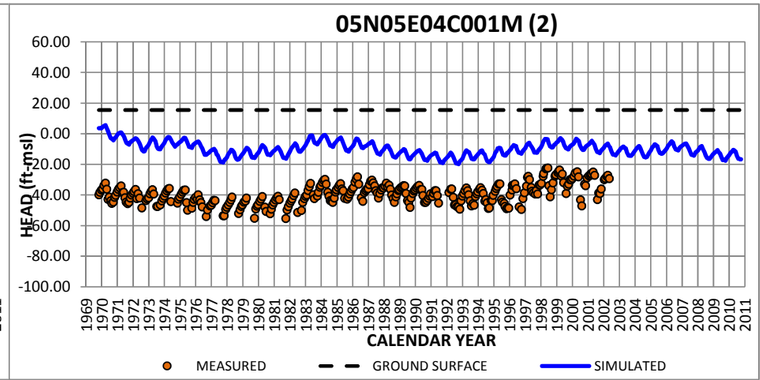
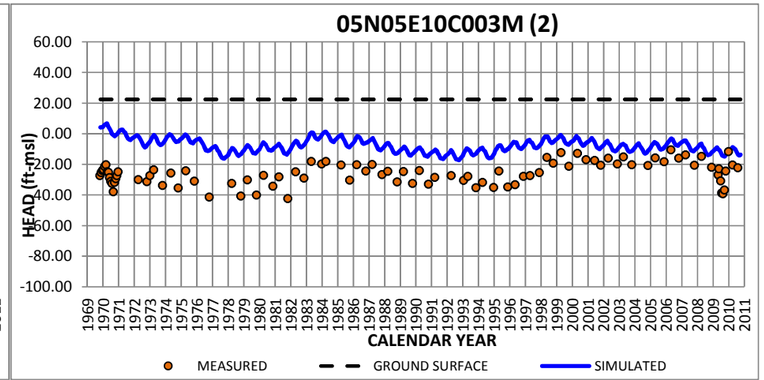
|---|---|---|---|---|---|---|---|---|---|
| 22N01E28J003M | 3 | 1971.99 | 2010.59 | 122.1 | 164.4 | 42.3 | 329.0 | -2.8 | 7.5 |
| 22N01E28J005M | 7 | 1971.99 | 2010.59 | 116.1 | 160.2 | 44.1 | 330.0 | 3.7 | 12.0 |
| 22N01E29R001M | 6 | 1970.23 | 2010.59 | 106.5 | 156.4 | 49.9 | 137.0 | -5.4 | 10.3 |
| 22N01E33N001M | 1 | 1994.28 | 1997.54 | 121.4 | 150.5 | 29.1 | 19.0 | -0.5 | 10.1 |
| 22N01E33N002M | 3 | 1994.28 | 1997.54 | 105.8 | 143.4 | 37.6 | 19.0 | 2.6 | 4.8 |
| 22N01W05M001M | 2 | 1970.23 | 2010.59 | 115.4 | 148.3 | 32.9 | 117.0 | 3.4 | 6.4 |
| 22N02E17E001M | 6 | 1971.19 | 2003.57 | 138.5 | 256.0 | 117.5 | 140.0 | 57.1 | 60.4 |
| 22N02W08B002M | 2 | 1969.88 | 2010.59 | 117.1 | 201.6 | 84.5 | 211.0 | 9.4 | 17.5 |
| 22N02W20Q001M | 1 | 1973.8 | 2010.59 | 165.4 | 198.2 | 32.8 | 146.0 | -8.0 | 9.4 |
| 22N02W21D001M | 1 | 1970.21 | 2010.59 | 145.8 | 191.2 | 45.4 | 122.0 | 3.3 | 8.7 |
| 22N02W30H002M | 6 | 2004.39 | 2010.59 | 86.3 | 140.8 | 54.5 | 48.0 | 46.7 | 48.3 |
| 22N02W30H003M | 2 | 2004.39 | 2010.59 | 144.5 | 193.1 | 48.6 | 47.0 | 0.3 | 8.9 |
| 22N02W30H004M | 1 | 2004.39 | 2010.59 | 183.5 | 195.5 | 12.0 | 46.0 | -11.2 | 11.4 |
| 22N02W36D001M | 2 | 1970.21 | 2010.59 | 128.3 | 162.0 | 33.7 | 150.0 | -2.8 | 6.2 |
| 22N03W21F002M | 2 | 1977.49 | 2010.59 | 223.1 | 253.9 | 30.8 | 321.0 | -19.2 | 20.2 |
| 23N01E29P001M | 1 | 1969.89 | 1990.18 | 141.3 | 192.0 | 50.7 | 129.0 | -12.7 | 19.7 |
| 23N01E29P002M | 2 | 1991.18 | 2010.59 | 129.8 | 164.9 | 35.1 | 97.0 | 33.9 | 35.2 |
| 23N01W09E001M | 1 | 1970.23 | 2010.59 | 131.9 | 170.1 | 38.2 | 293.0 | 20.0 | 21.7 |
| 23N01W14R002M | 2 | 1986.17 | 2010.59 | 137.9 | 171.1 | 33.2 | 116.0 | 26.6 | 27.3 |
| 23N02W16B001M | 2 | 1970.22 | 2010.22 | 114.5 | 170.8 | 56.3 | 93.0 | 31.9 | 33.5 |
| 24N02W12P001M | 3 | 1999.99 | 2010.59 | 194.4 | 202.9 | 8.6 | 62.0 | 13.1 | 13.6 |
| 24N02W12P002M | 6 | 1999.99 | 2010.59 | 194.6 | 202.9 | 8.3 | 62.0 | 21.5 | 21.6 |
| 24N02W30P002M | 3 | 1993.21 | 2010.22 | 111.9 | 196.0 | 84.1 | 56.0 | 33.9 | 38.1 |
| 24N03W17M001M | 1 | 1973.18 | 2010.59 | 236.0 | 286.4 | 50.4 | 144.0 | 5.4 | 11.3 |
| 25N02W09G001M | 1 | 1973.19 | 2010.59 | 219.0 | 234.4 | 15.4 | 176.0 | 6.9 | 7.7 |
| 25N03W10L003M | 4 | 1969.89 | 2010.59 | 179.7 | 248.5 | 68.8 | 344.0 | 19.6 | 23.1 |
| 25N03W10L004M | 2 | 1969.89 | 2010.59 | 236.6 | 269.1 | 32.5 | 321.0 | -10.8 | 12.0 |
| 27N03W10B001M | 1 | 1970.55 | 2010.59 | 243.1 | 269.3 | 26.2 | 331.0 | 6.5 | 7.1 |
| 27N03W20K001M | 2 | 1969.84 | 1975.25 | 249.6 | 257.4 | 7.8 | 34.0 | 7.0 | 7.5 |
| 27N04W35E001M | 2 | 1970.23 | 2010.59 | 297.3 | 337.7 | 40.4 | 133.0 | -21.9 | 23.9 |

# Appendix C
# Simulated and Measured Groundwater Hydrographs

E15037553


05N02E05C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


05N05E04C001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED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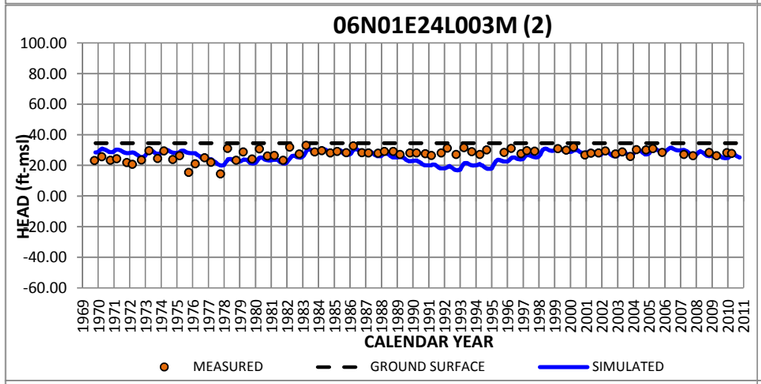
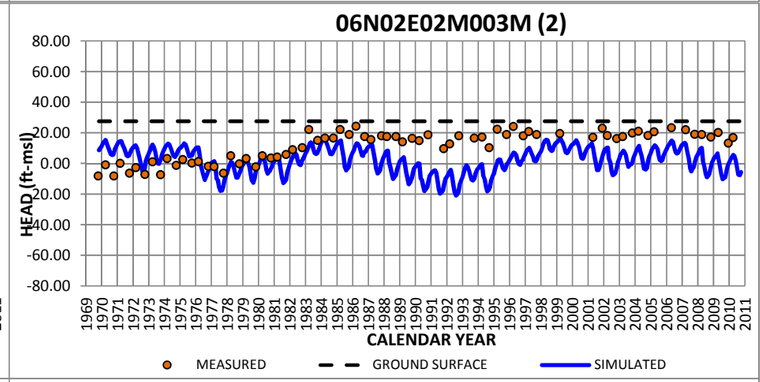
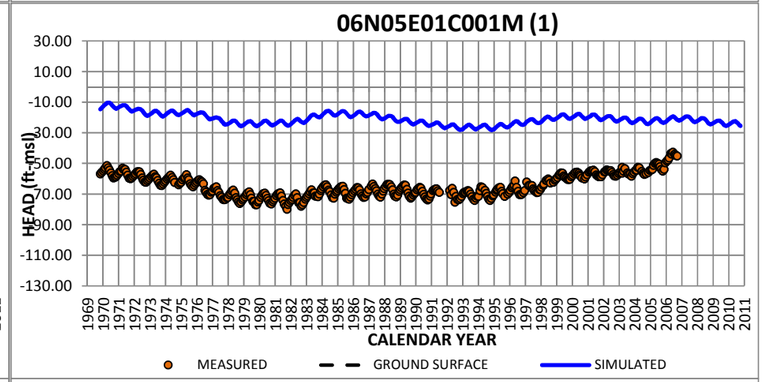
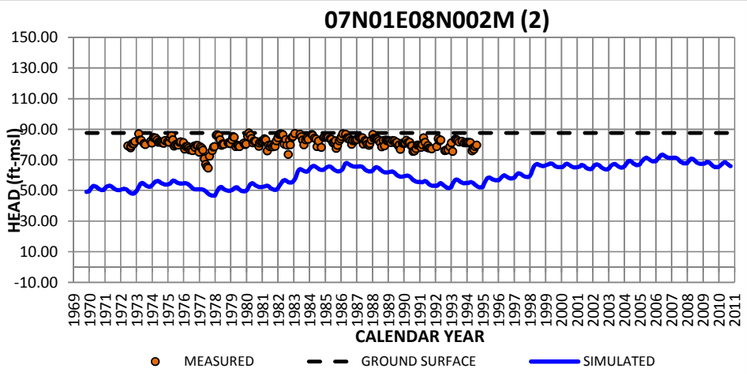
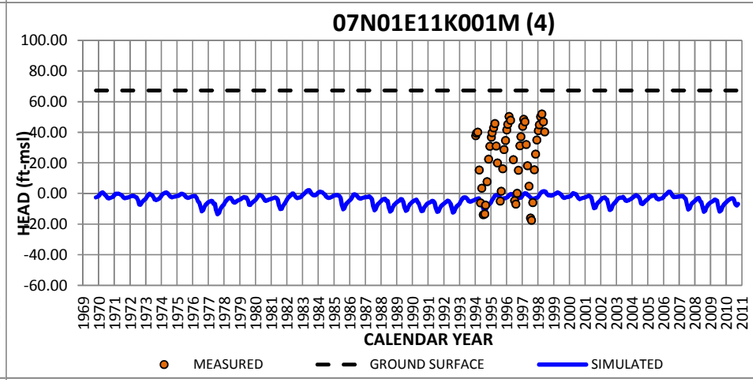
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

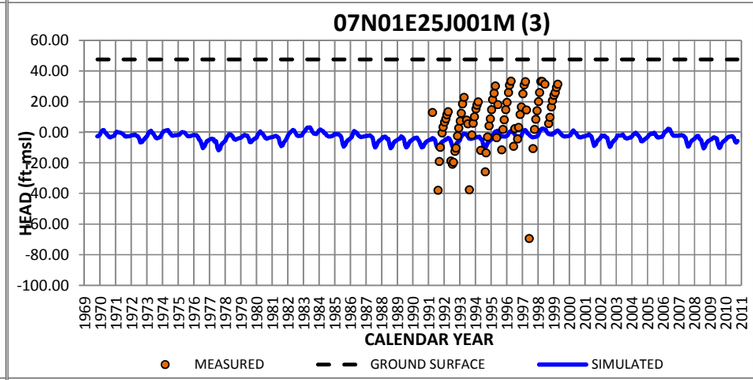

06N01E24L003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

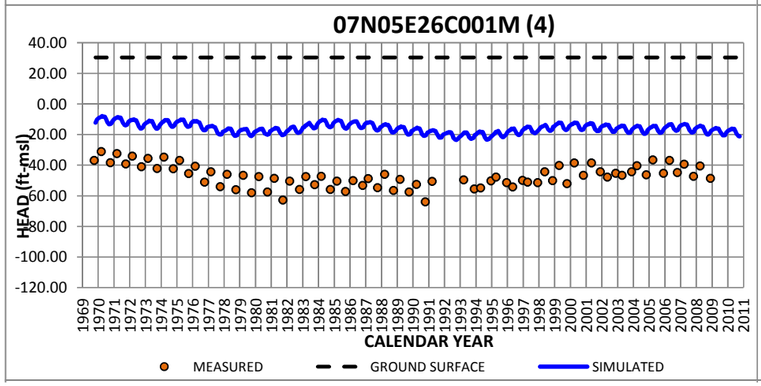

06N02E02M003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

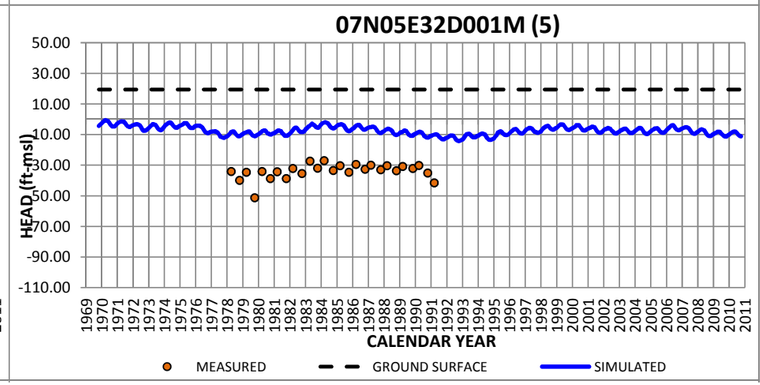

06N05E01C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


07N01E08N002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


07N01E11K001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


07N01E25J001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


07N05E26C001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED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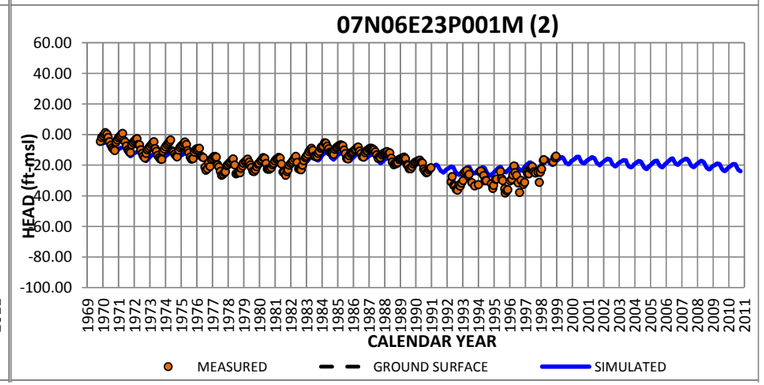
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED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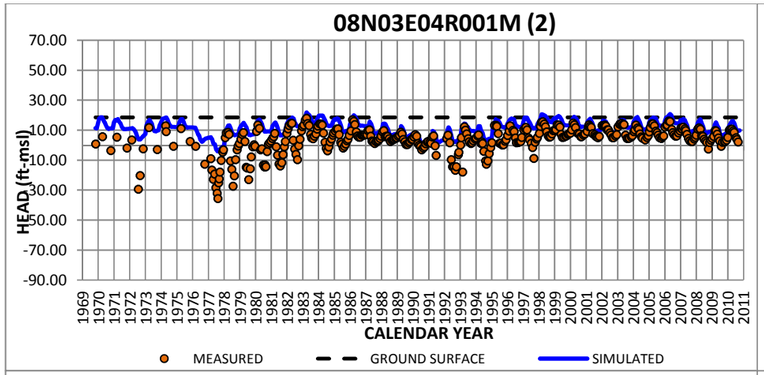
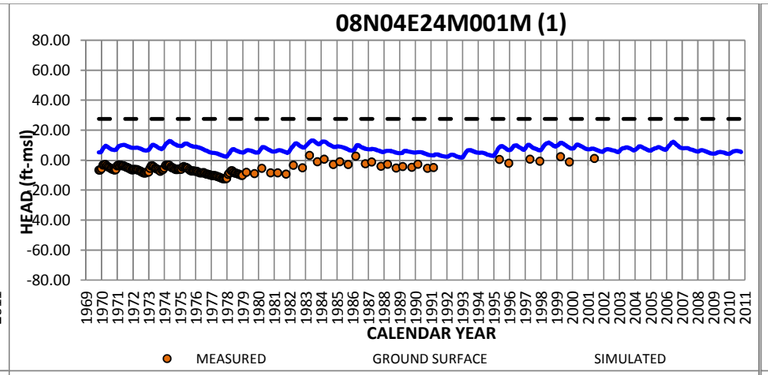
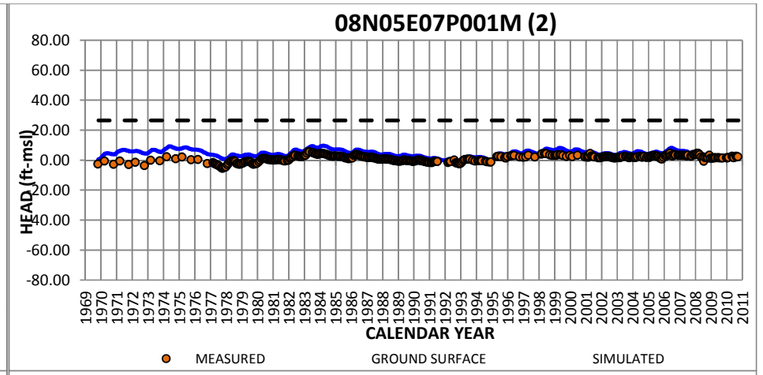
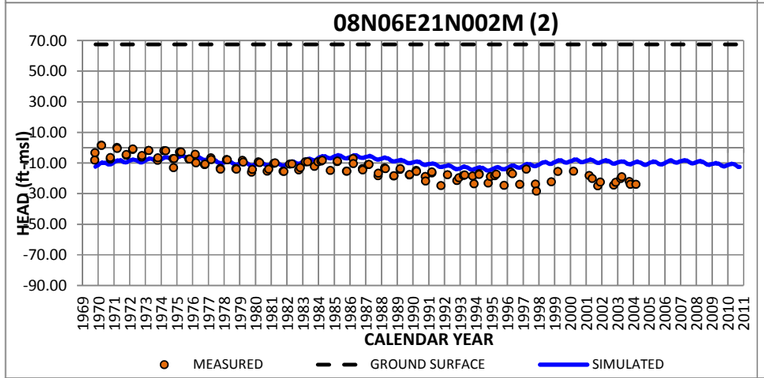
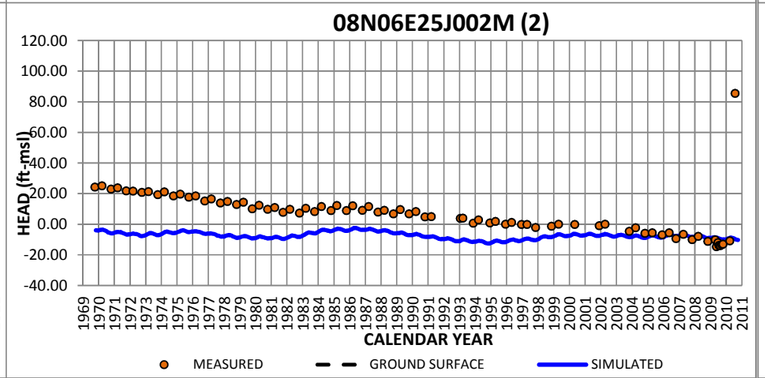
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

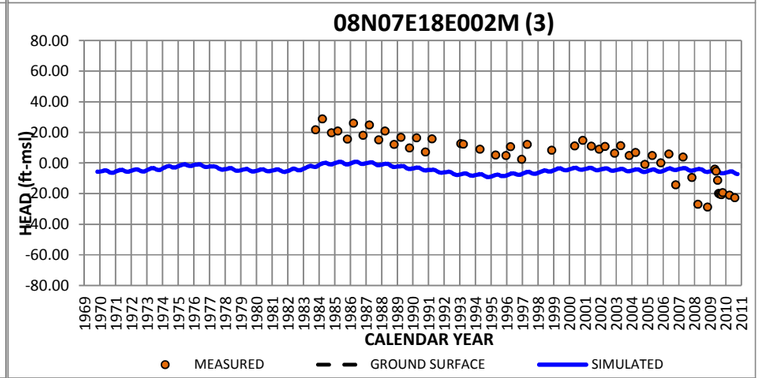

08N03E04R001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

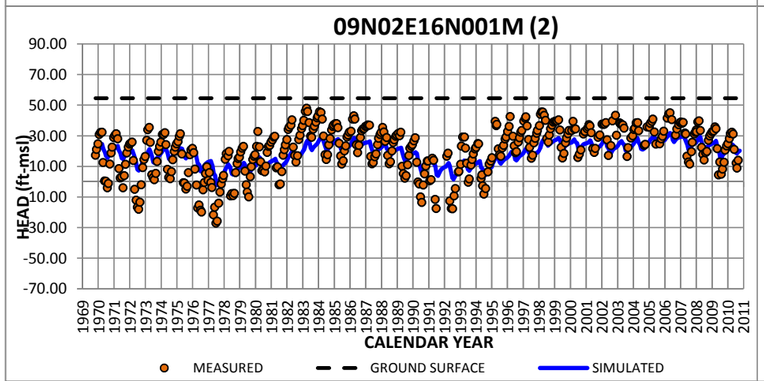

08N04E24M001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

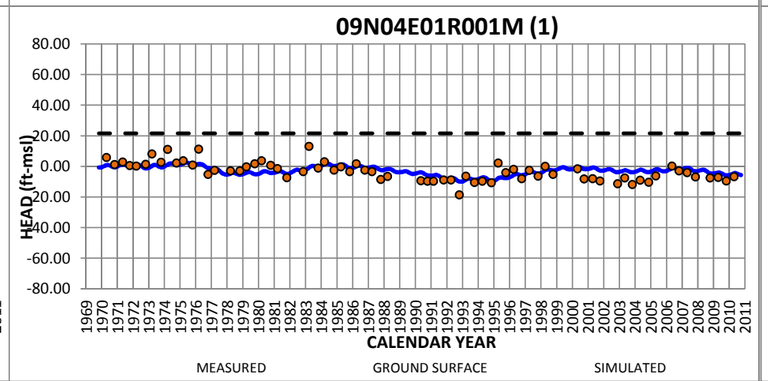

08N05E07P001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

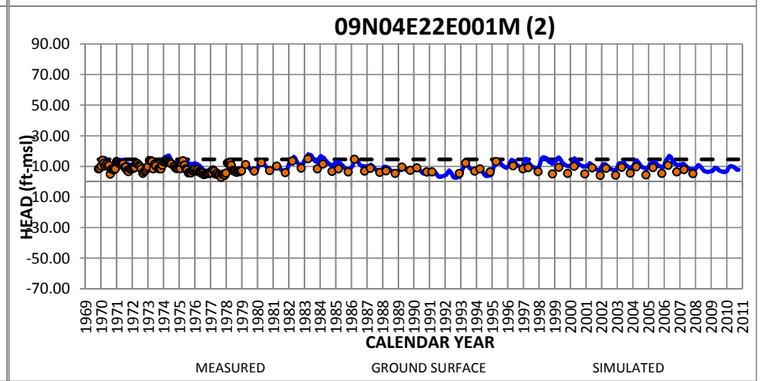

08N06E21N002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

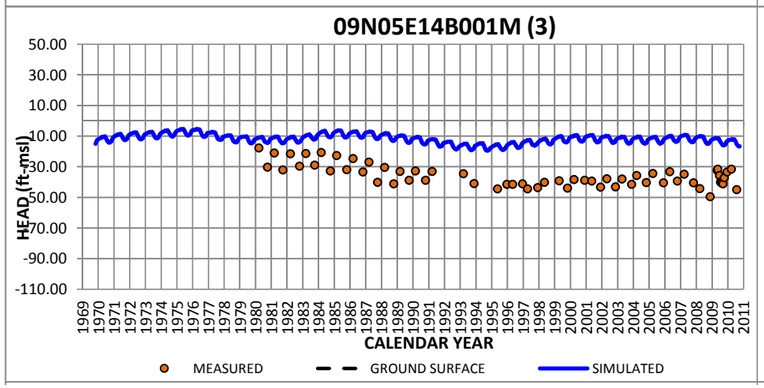

08N06E25J002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

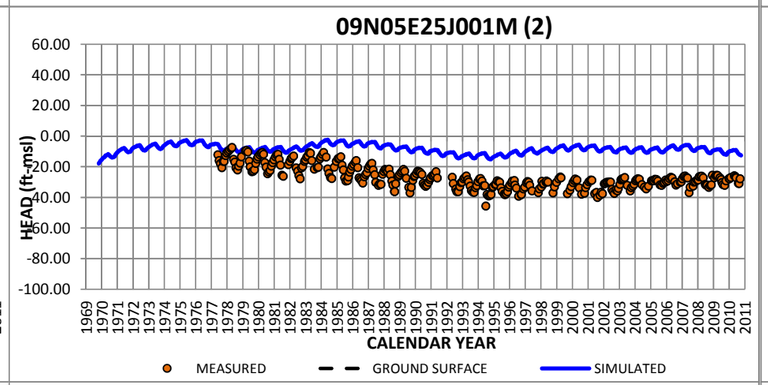

08N07E18E002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

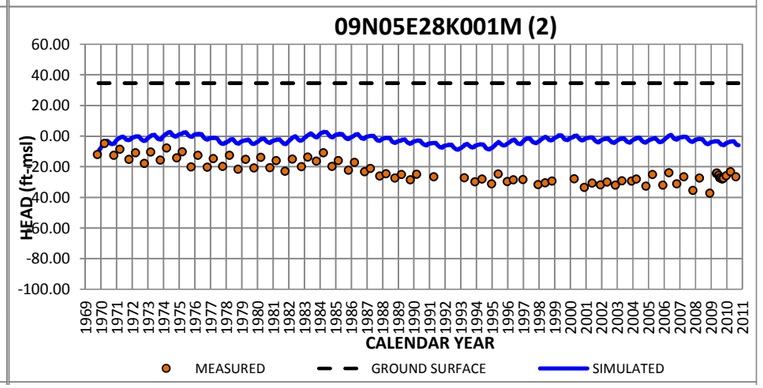

09N02E16N001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

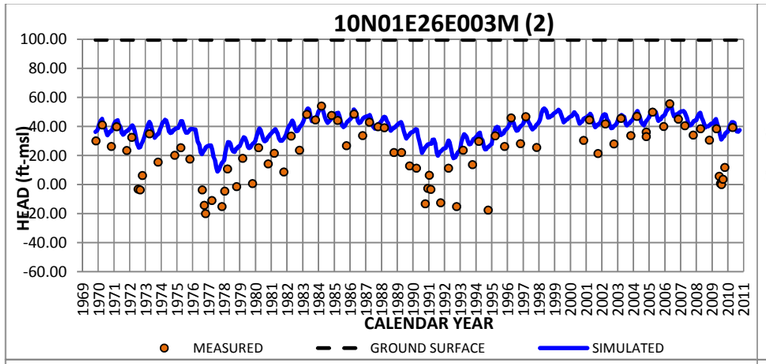

09N04E01R001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

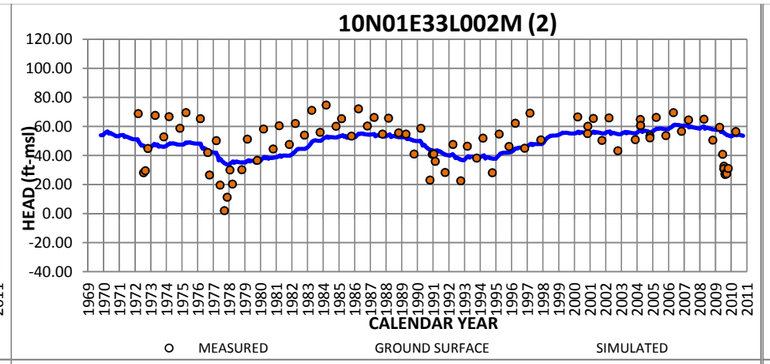

09N04E22E001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

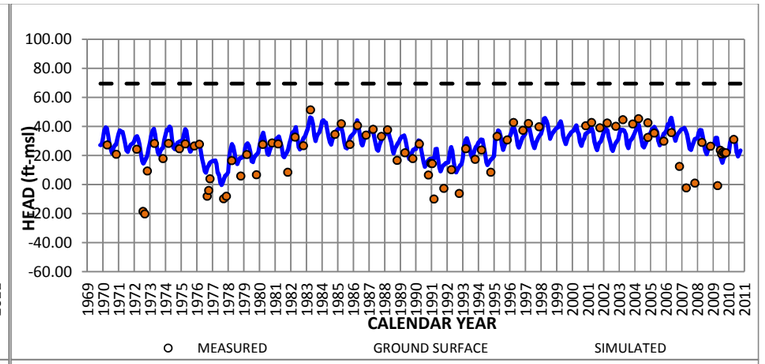

09N05E14B001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

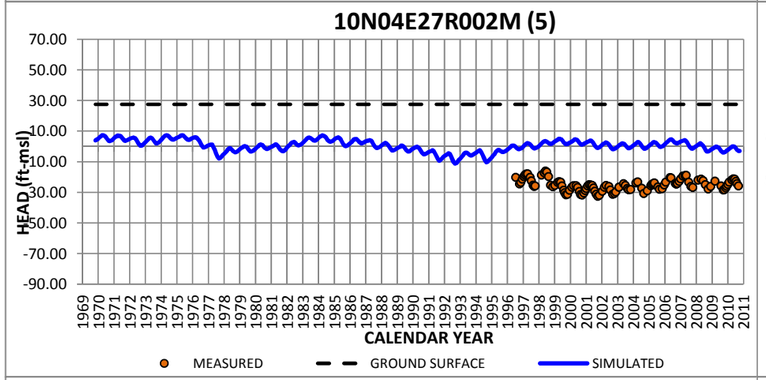

09N05E25J001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

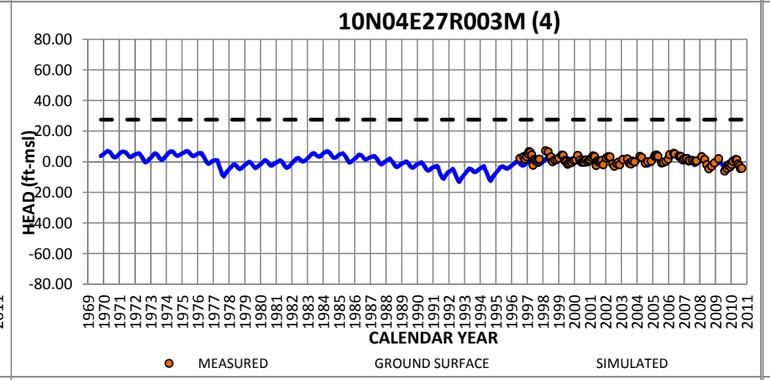

09N05E28K001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

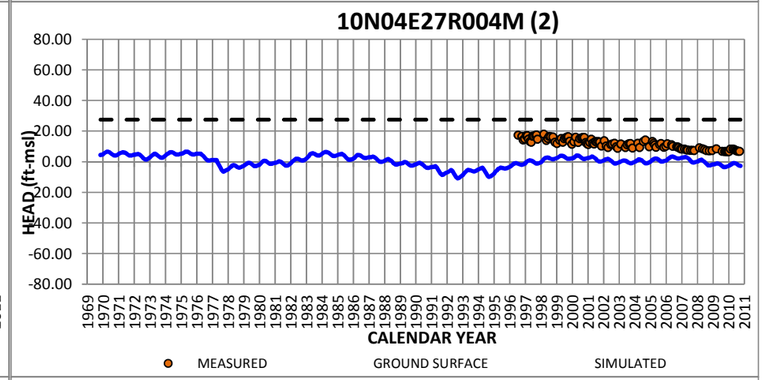

10N01E26E003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

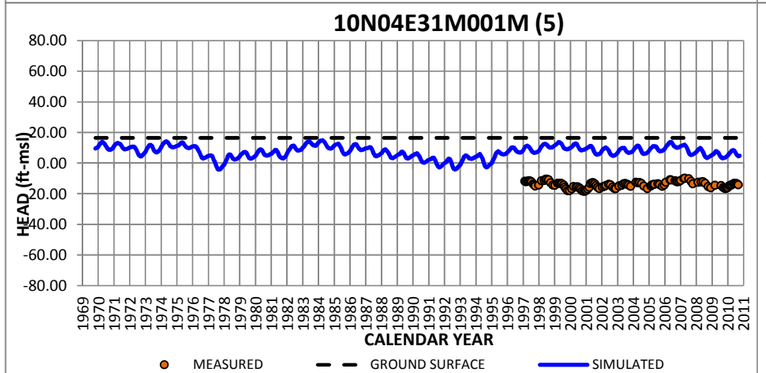

10N01E33L002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

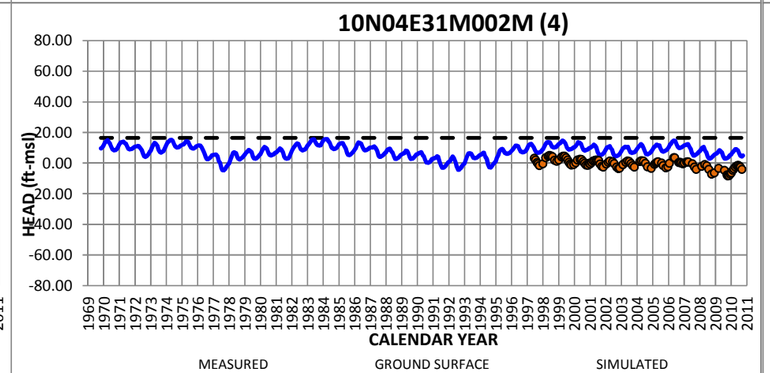

HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

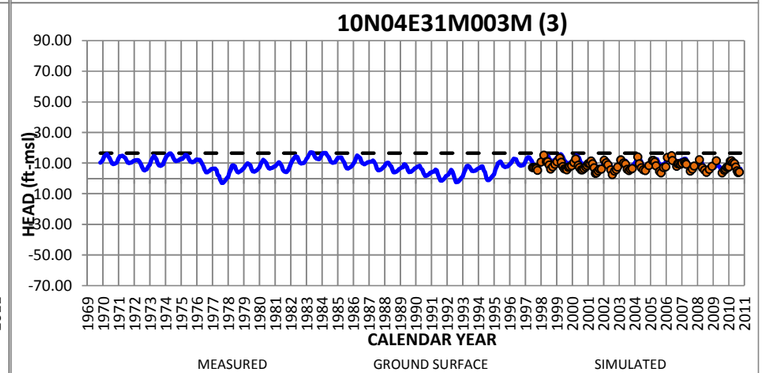

10N04E27R002M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

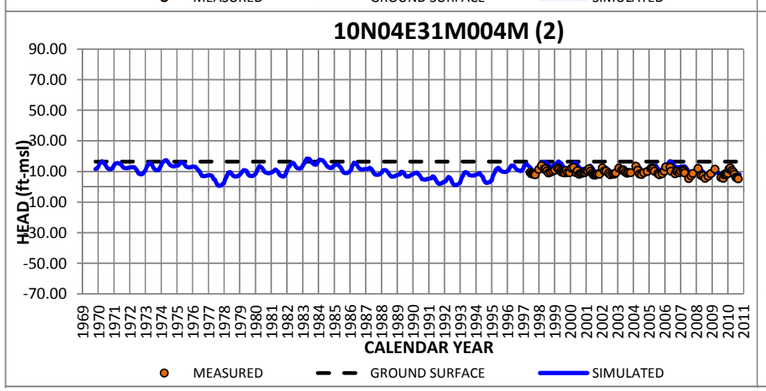

10N04E27R003M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

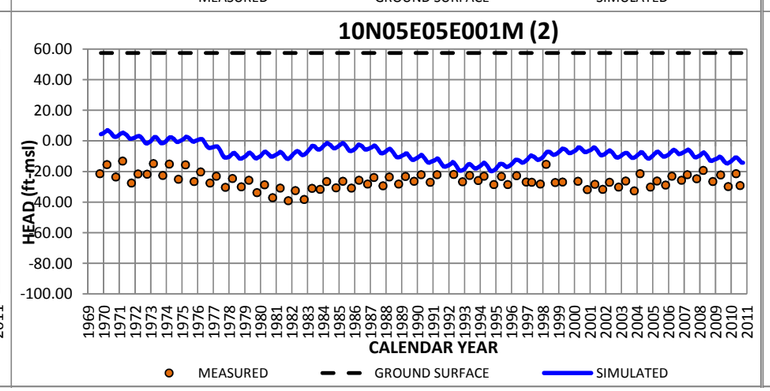

10N04E27R004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

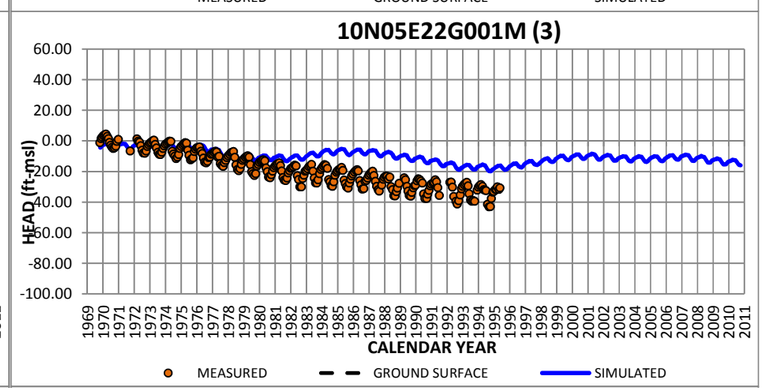

10N04E31M001M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

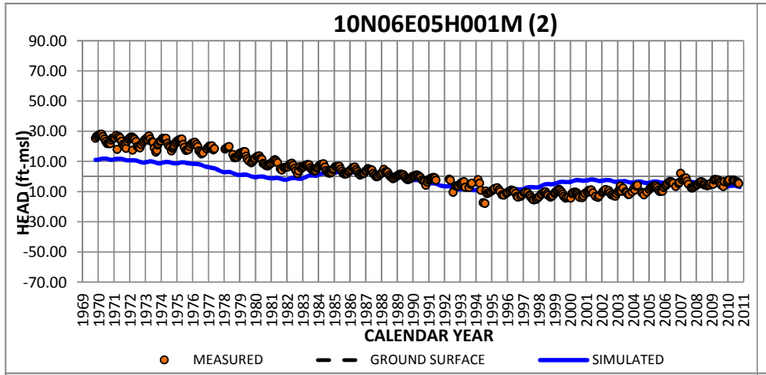

10N04E31M002M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

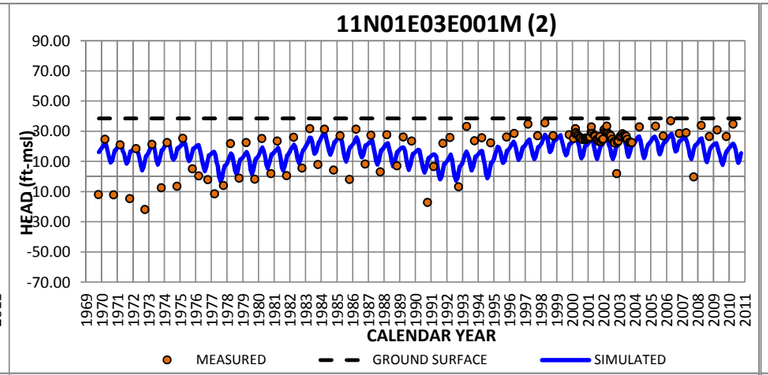

10N04E31M003M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

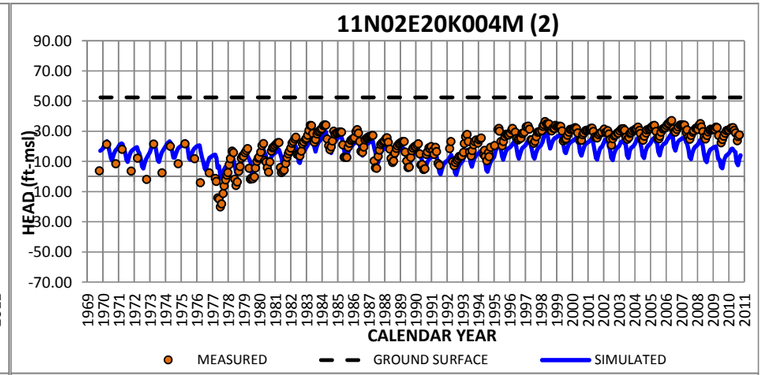

10N04E31M004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

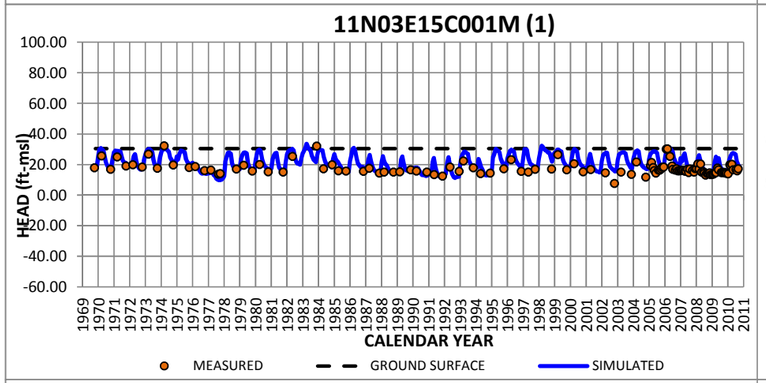

10N05E05E001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

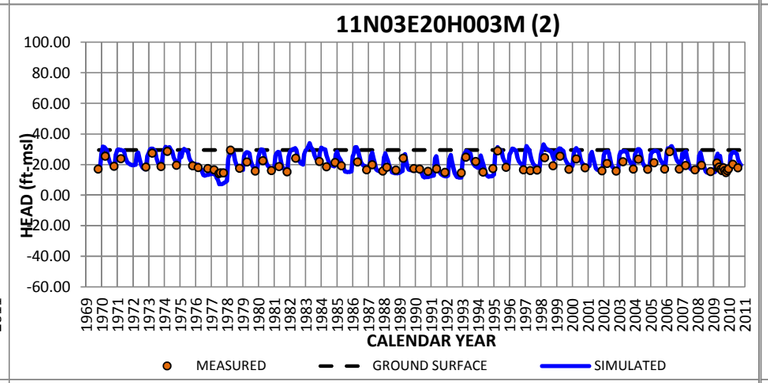

10N05E22G001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

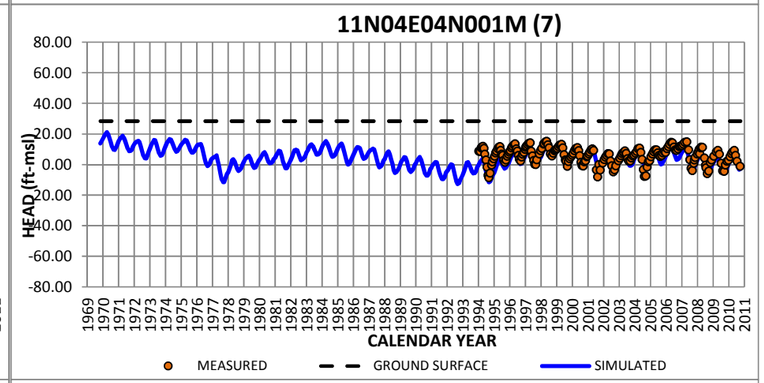

10N06E05H001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

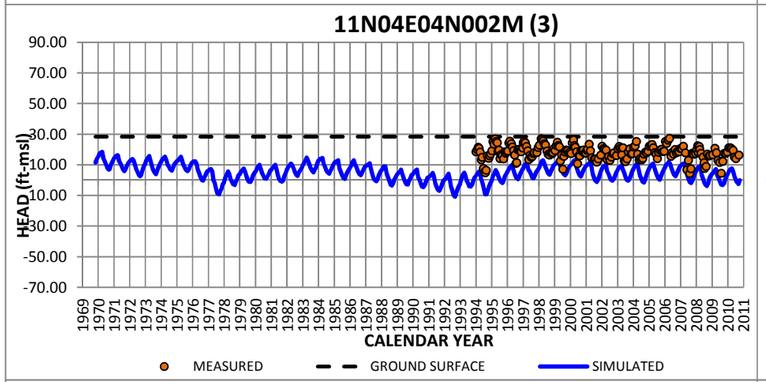

11N01E03E001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

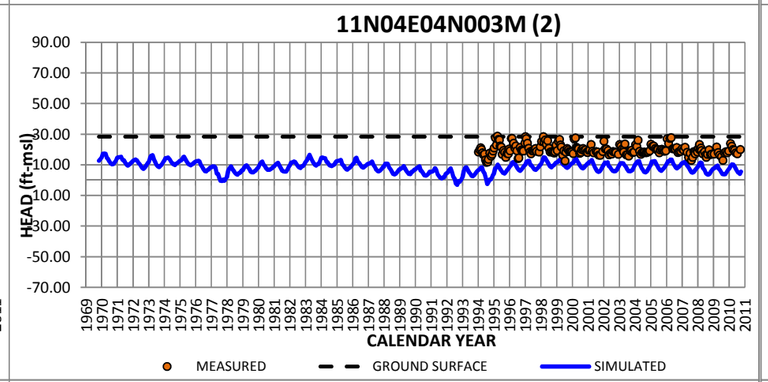

11N02E20K004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

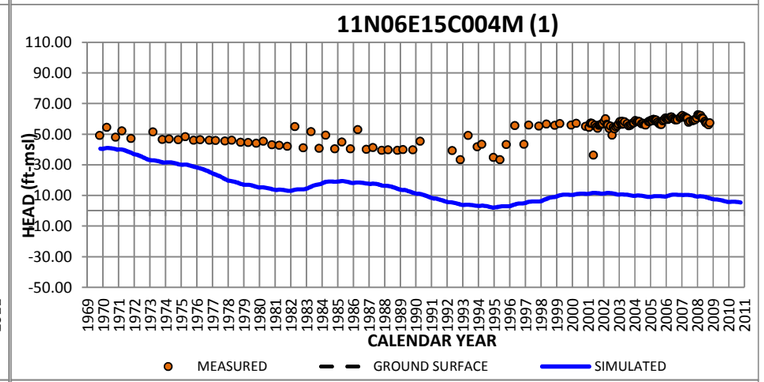

11N03E15C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

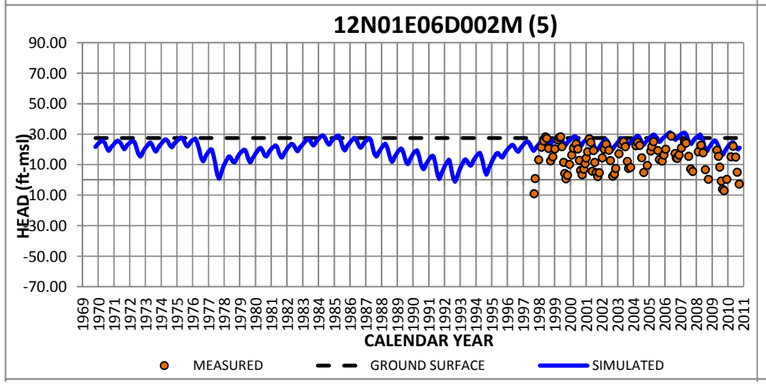

11N03E20H003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

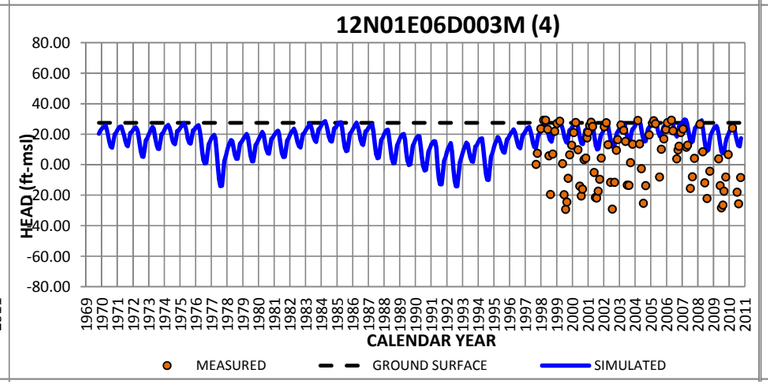

11N04E04N001M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

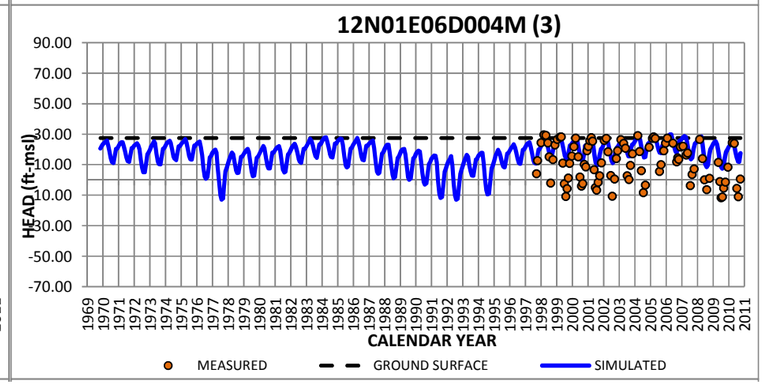

11N04E04N002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

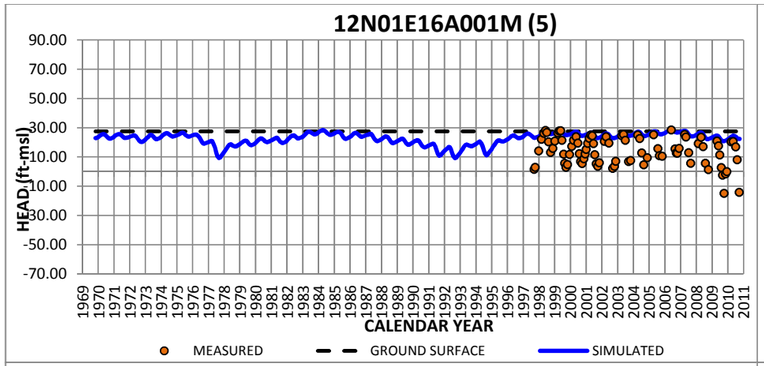

11N04E04N003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

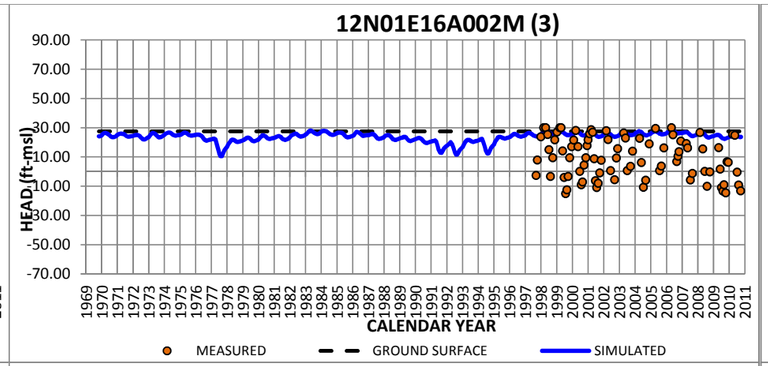

11N06E15C004M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

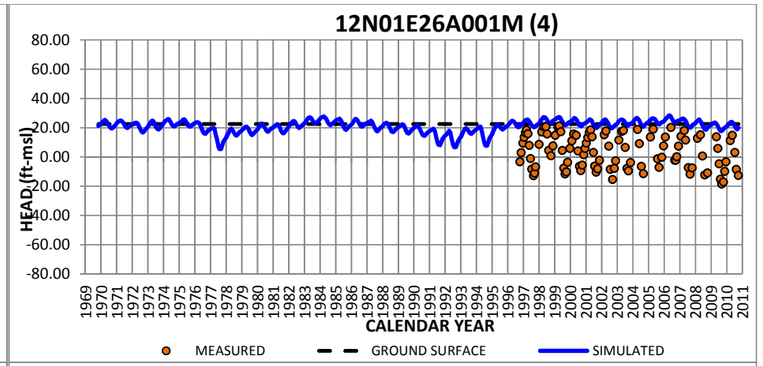

12N01E06D002M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

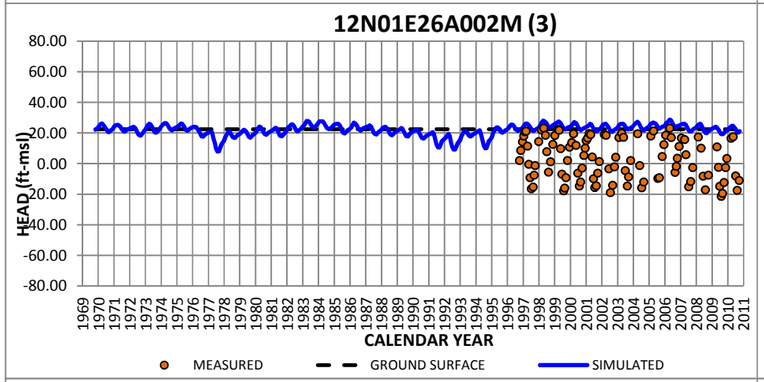

12N01E06D003M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

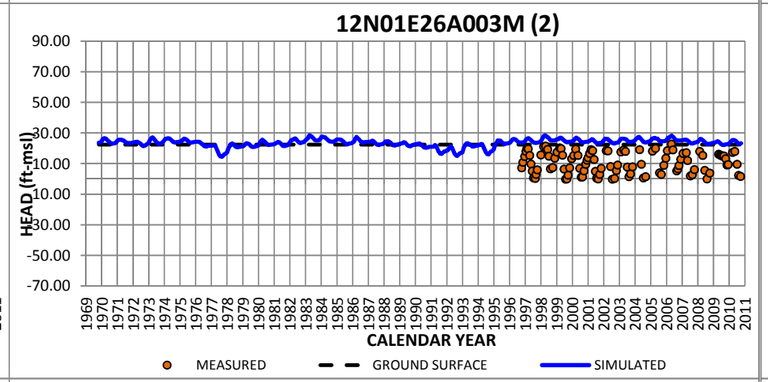

12N01E06D004M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

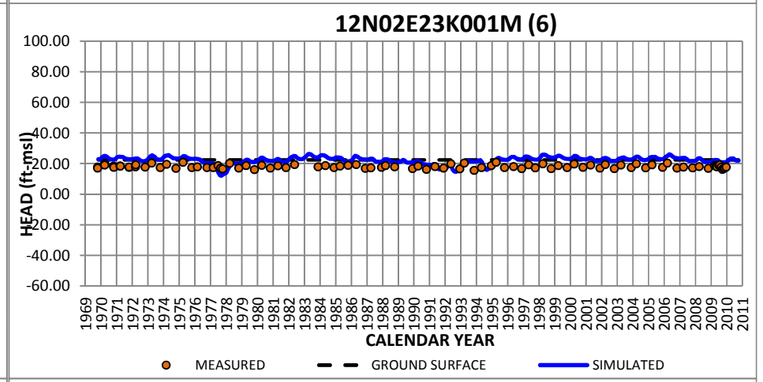

12N01E16A001M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

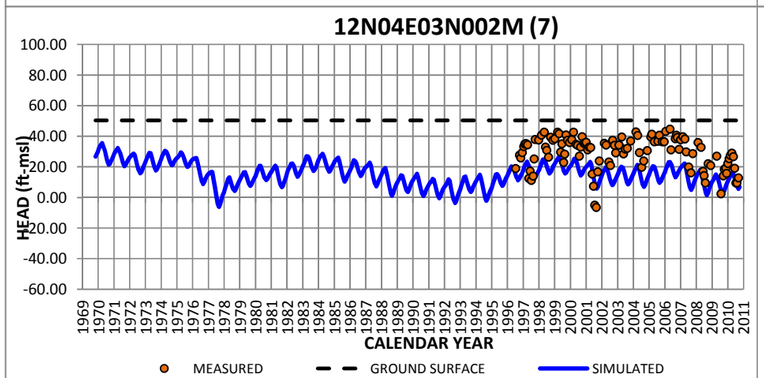

12N01E16A002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

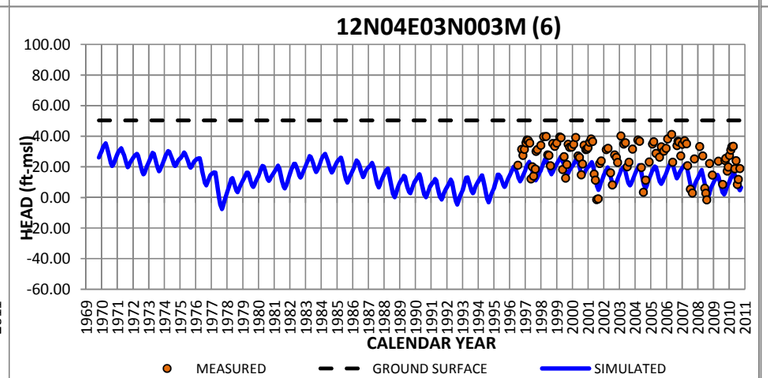

12N01E26A001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

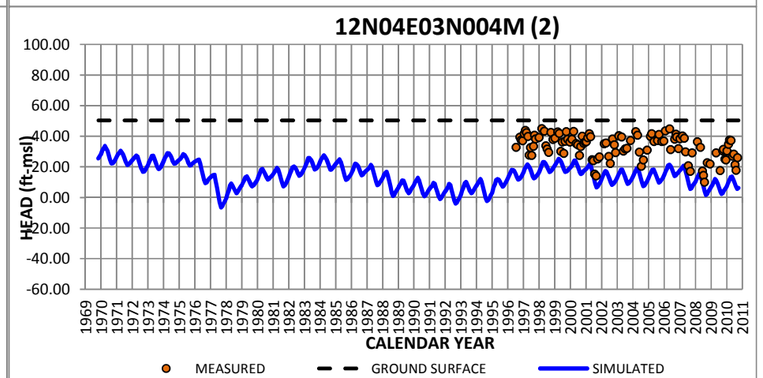

12N01E26A002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

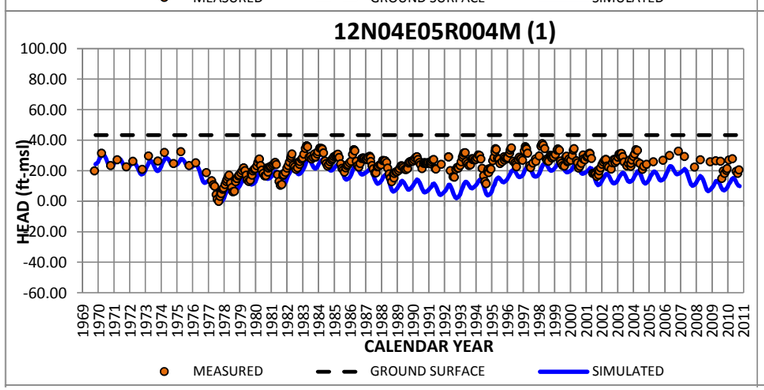

12N01E26A003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

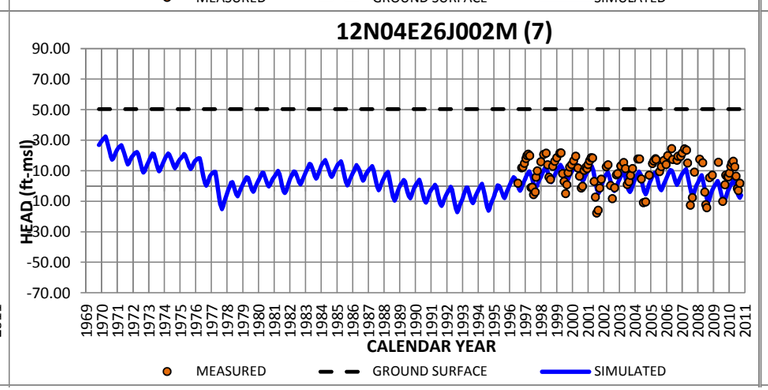

12N02E23K001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

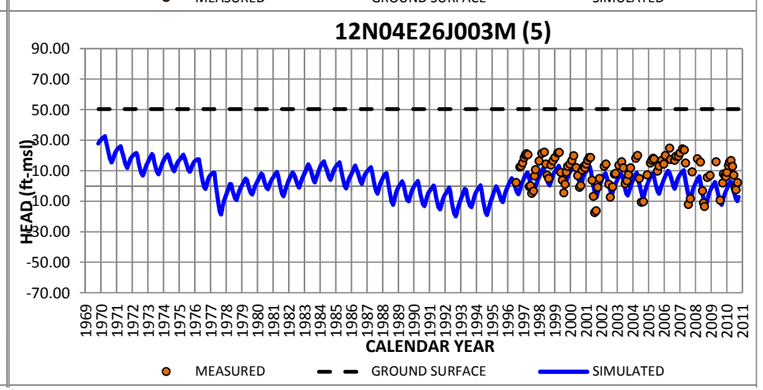

12N04E03N002M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

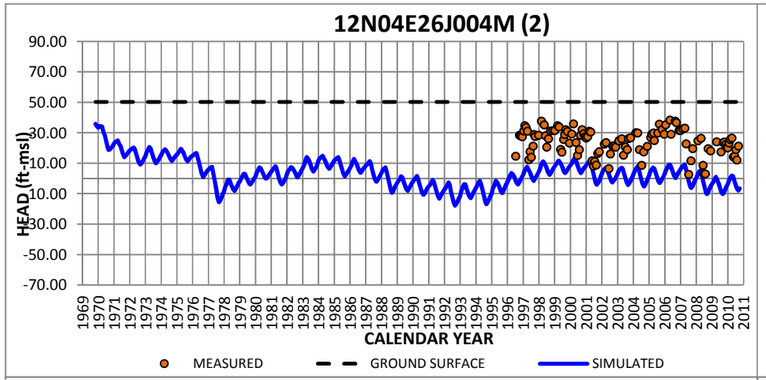

12N04E03N003M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

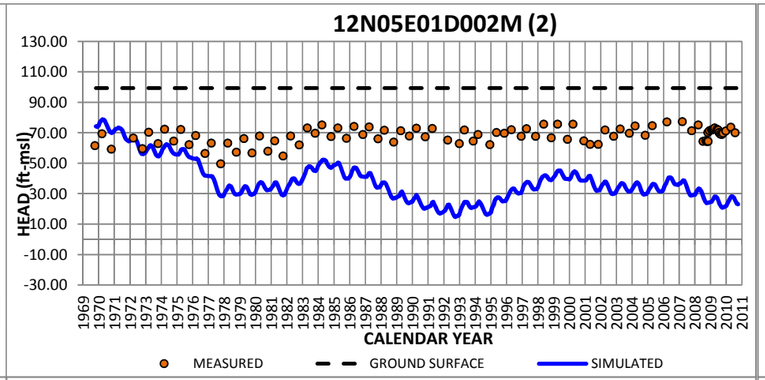

12N04E03N004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

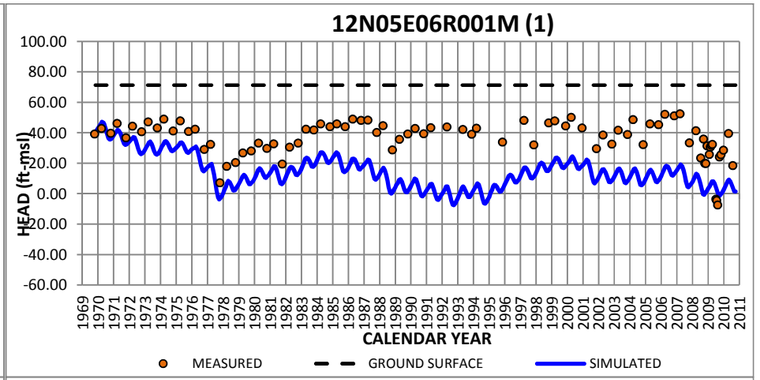

12N04E05R004M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

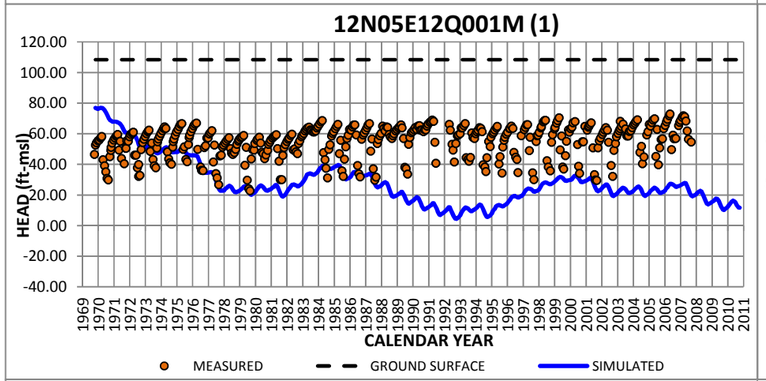

12N04E26J002M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

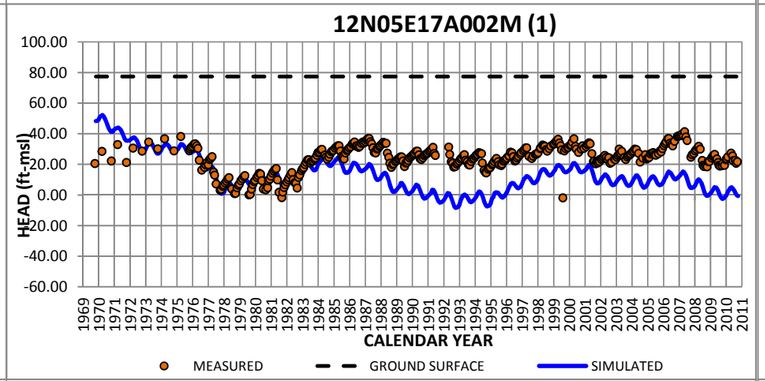

12N04E26J003M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

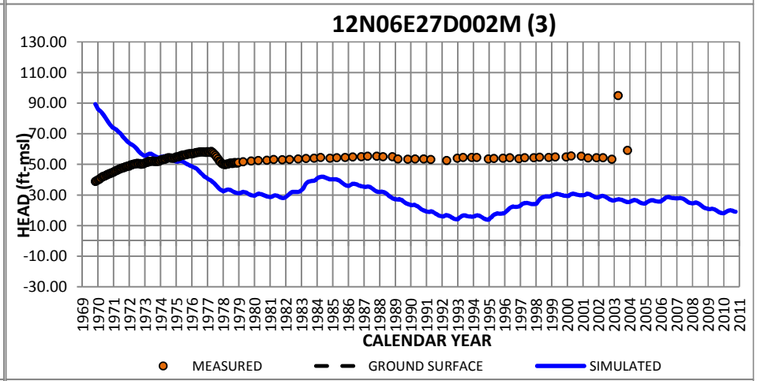

12N04E26J004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

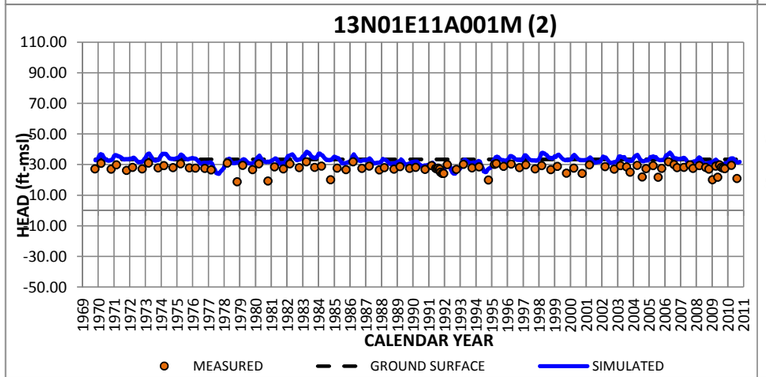

12N05E01D002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

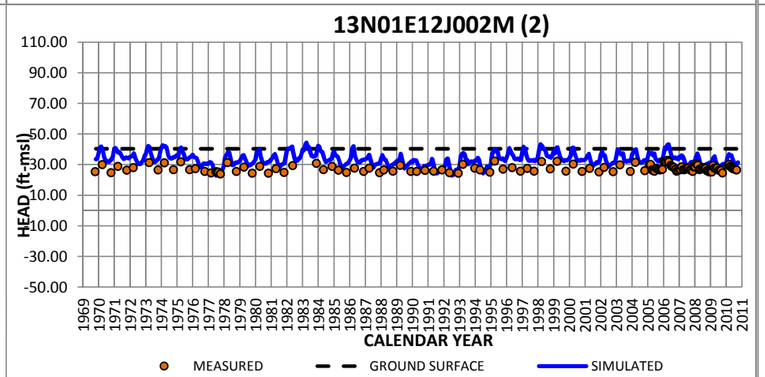

12N05E06R001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

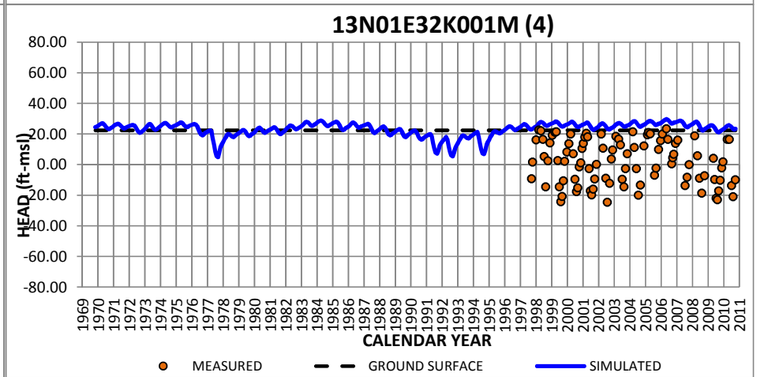

12N05E12Q001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

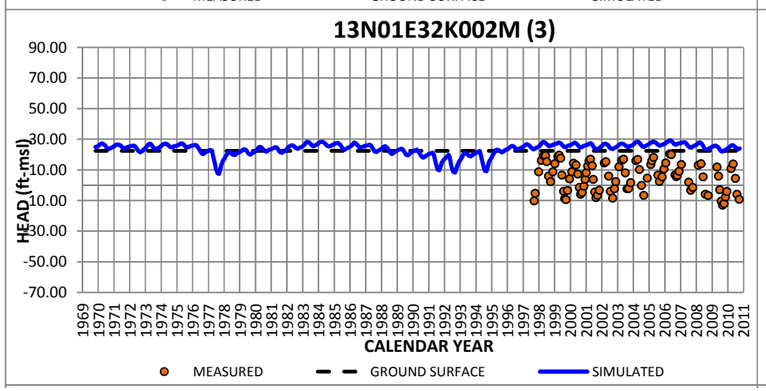

12N05E17A002M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

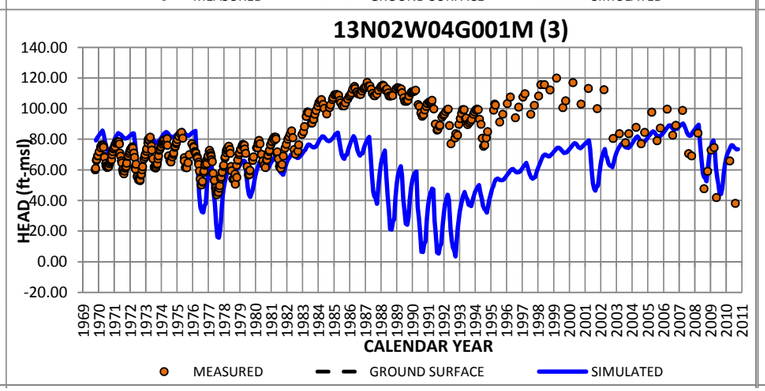

12N06E27D002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

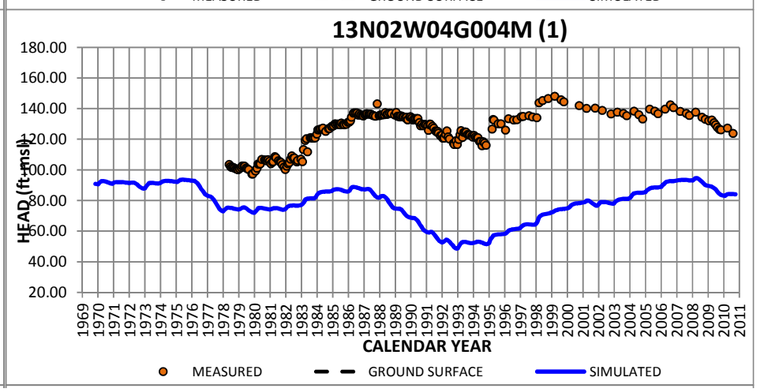

13N01E11A001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

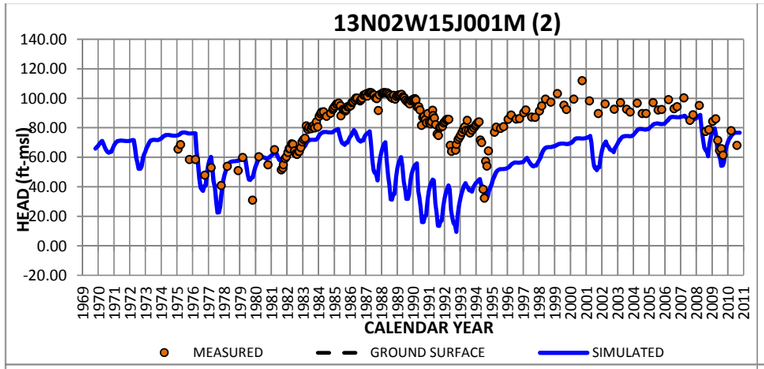

13N01E12J002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

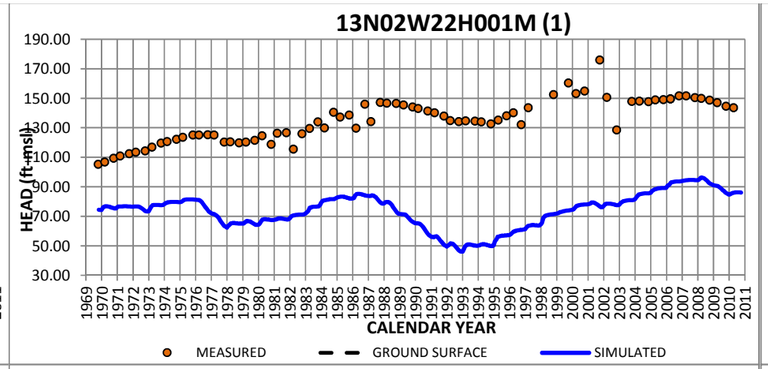

13N01E32K001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

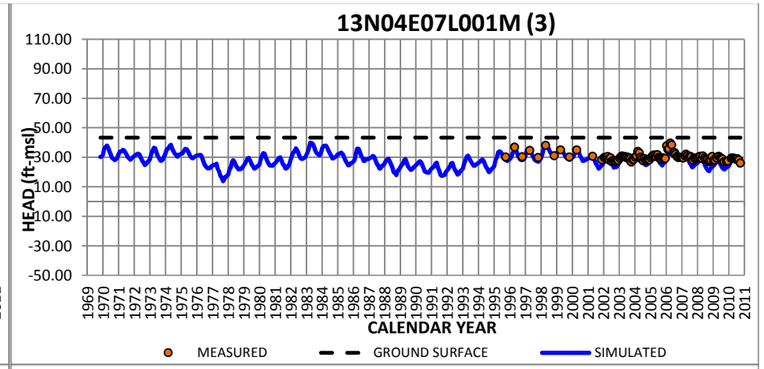

13N01E32K002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

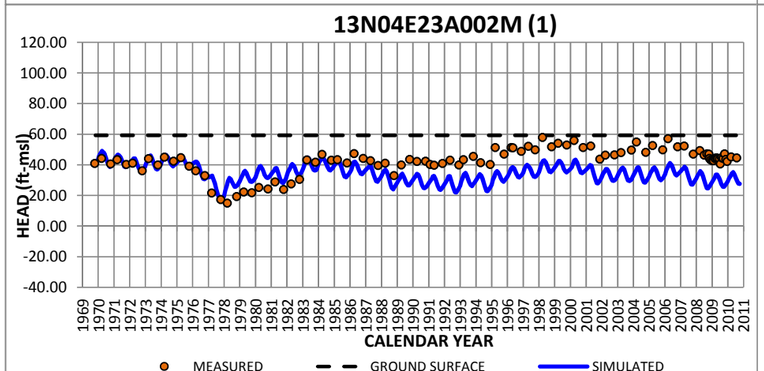

13N02W04G001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

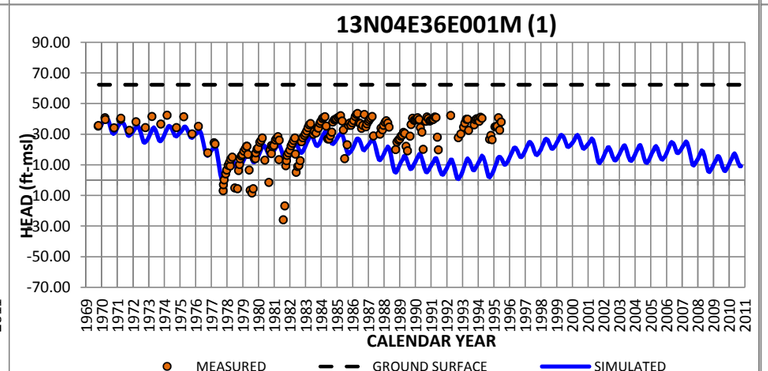

13N02W04G004M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

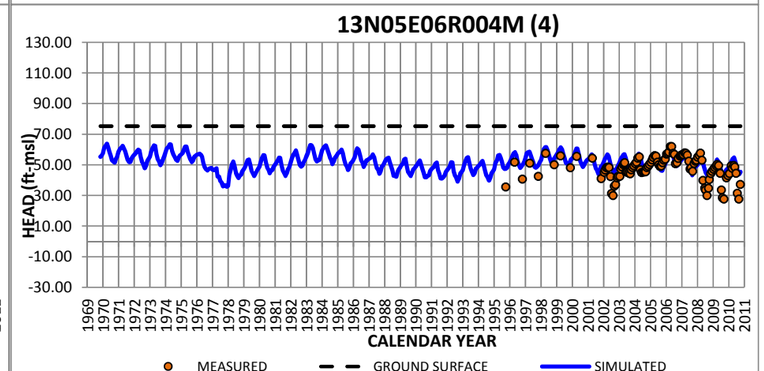

13N02W15J001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

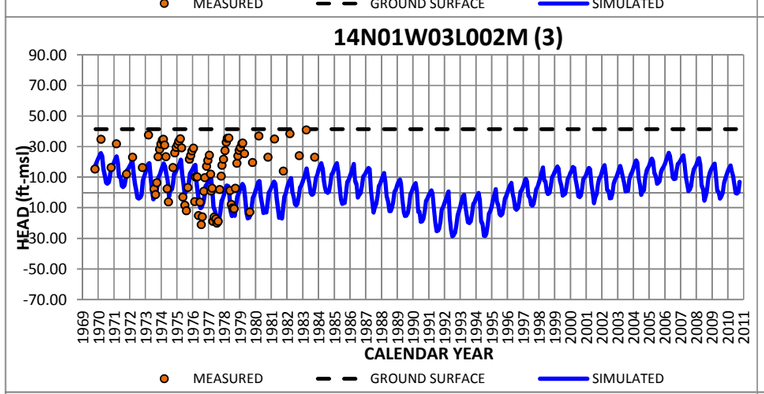

13N02W22H001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

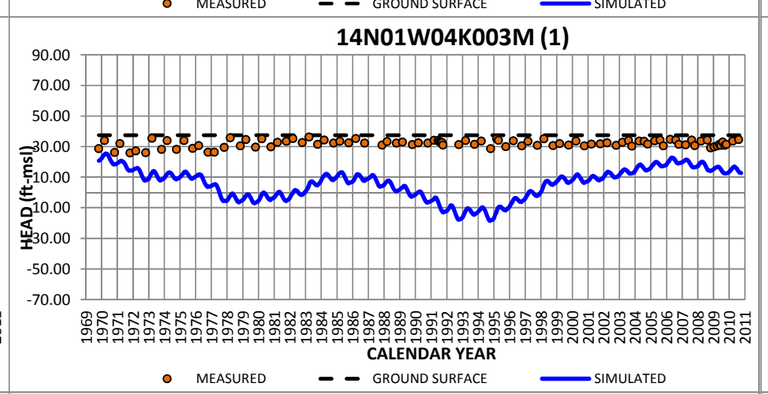

13N04E07L001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

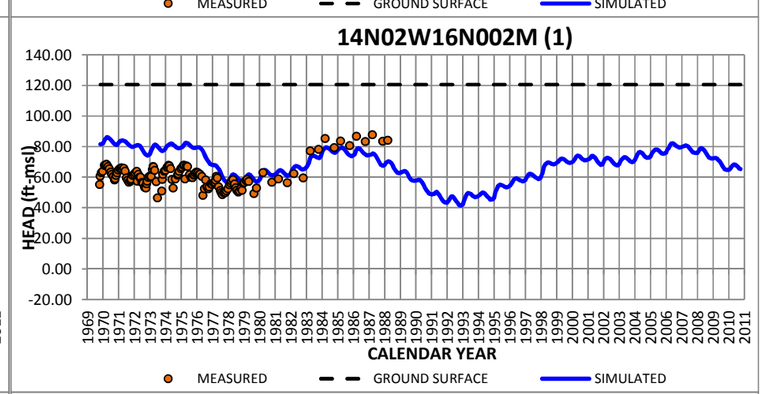

13N04E23A002M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

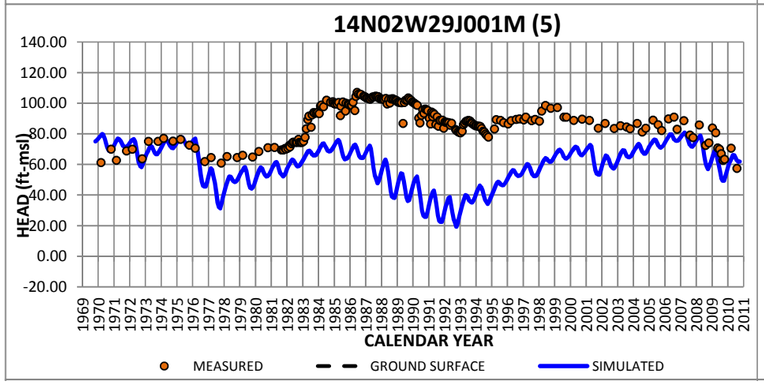

13N04E36E001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

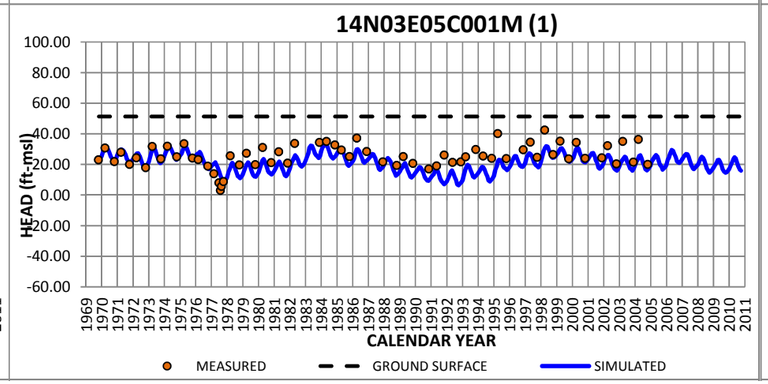

13N05E06R004M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

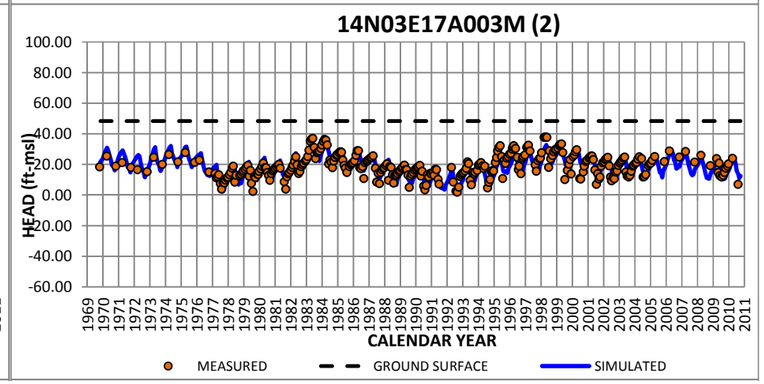

14N01W03L002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

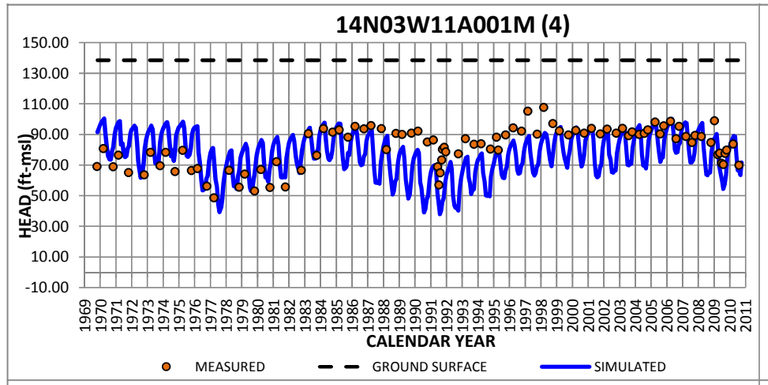

14N01W04K003M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

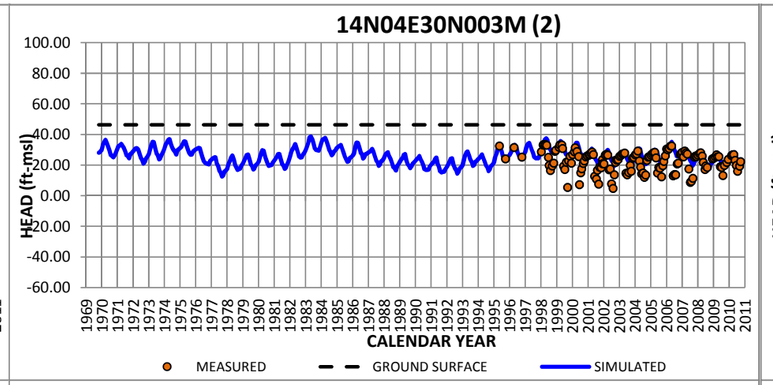

14N02W16N002M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

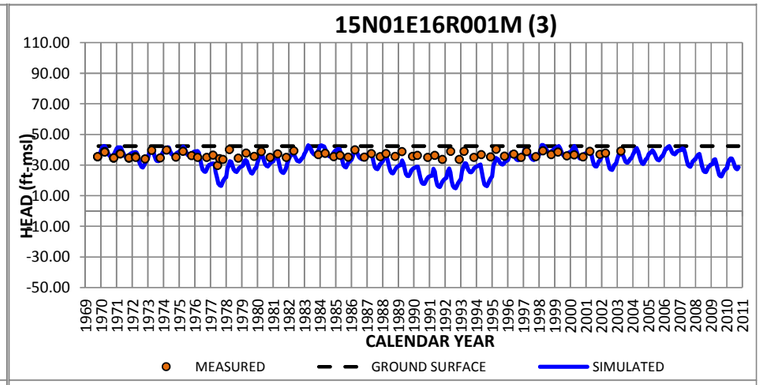

14N02W29J001M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

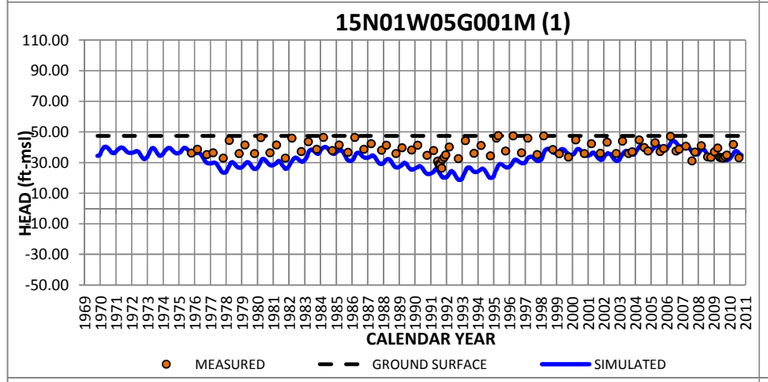

14N03E05C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

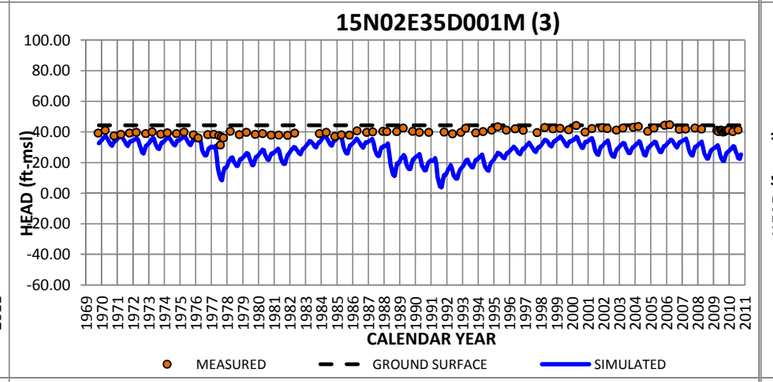

14N03E17A003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

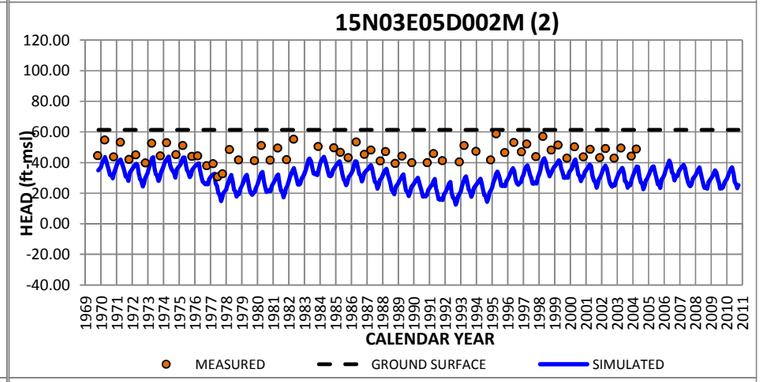

14N03W11A001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

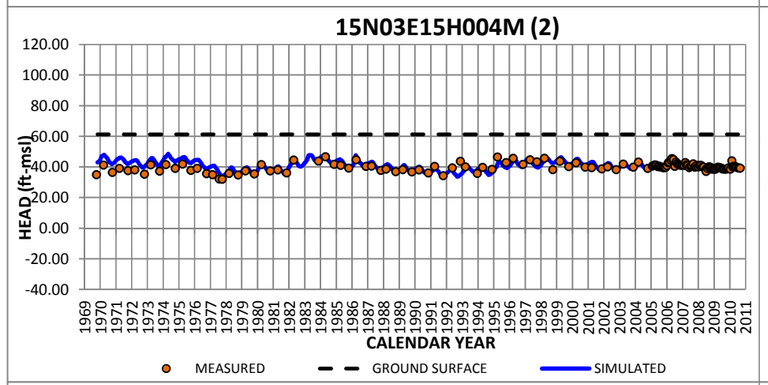

14N04E30N003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

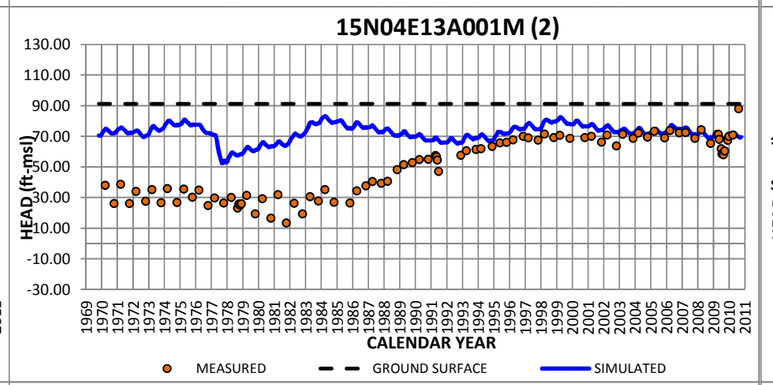

15N01E16R001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

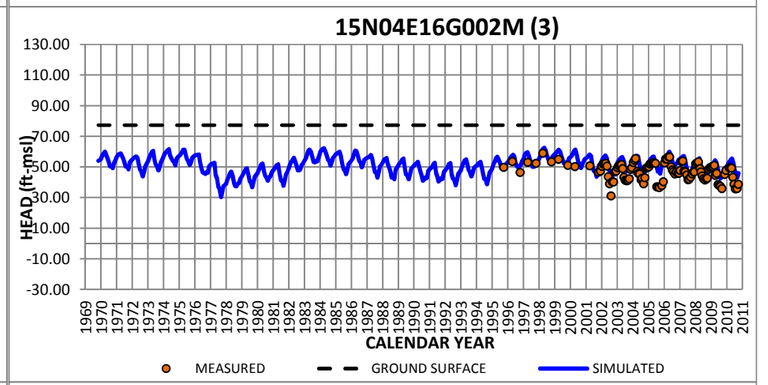

15N01W05G001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

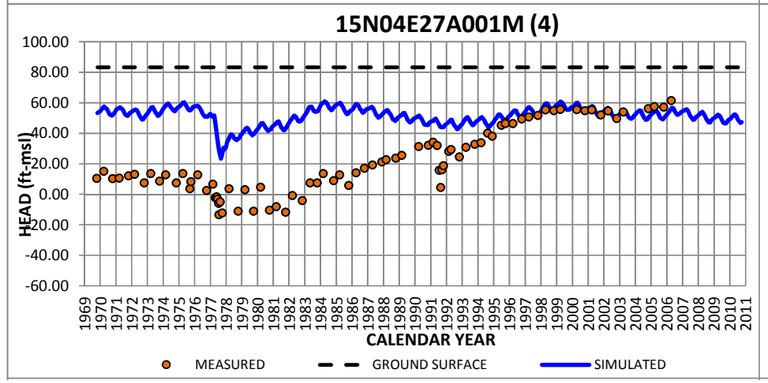

15N02E35D001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

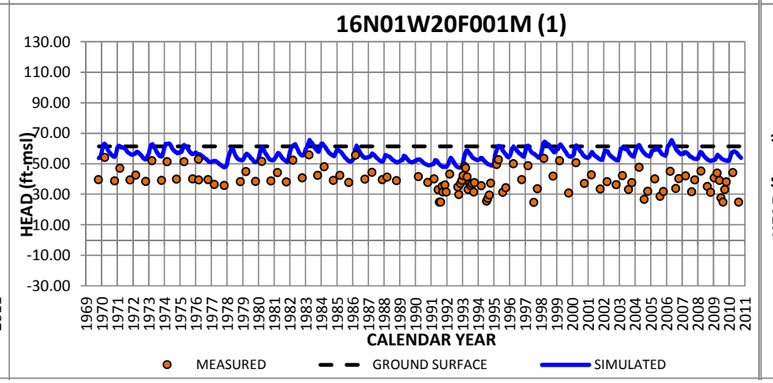

15N03E05D002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

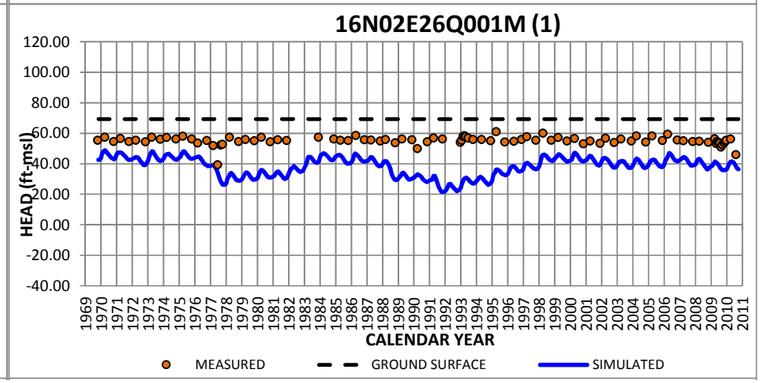

15N03E15H004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

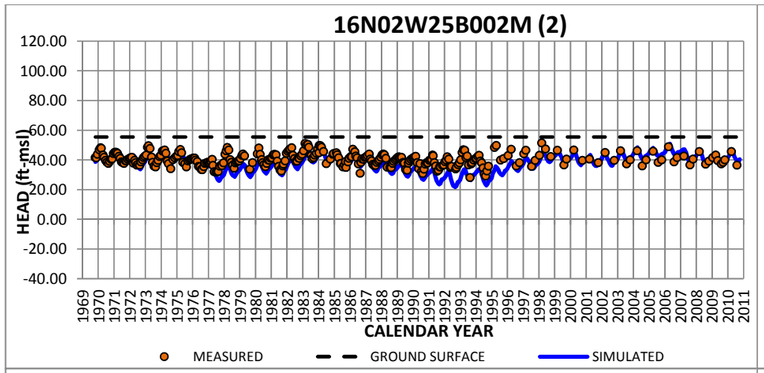

15N04E13A001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

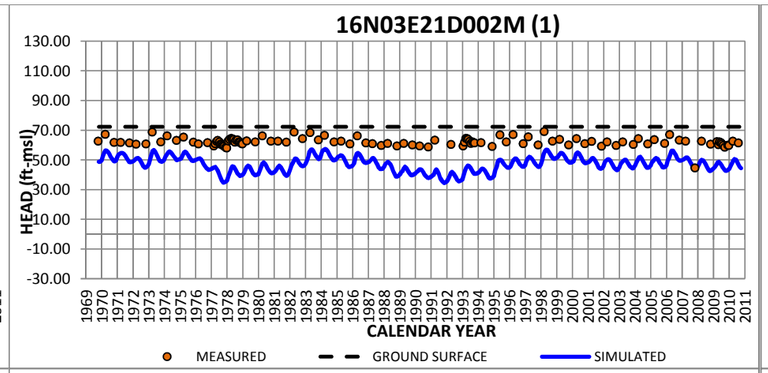

15N04E16G002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

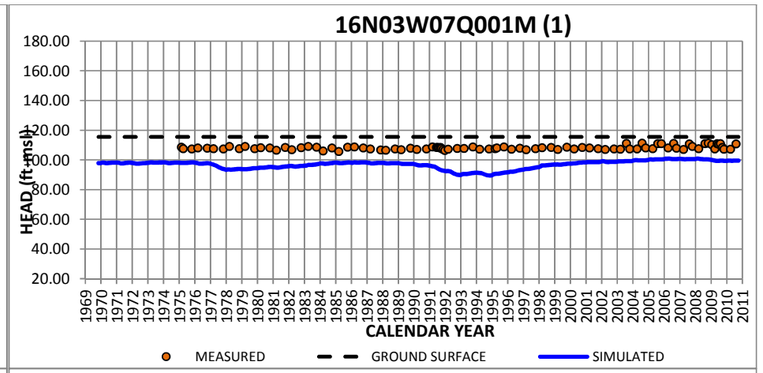

15N04E27A001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

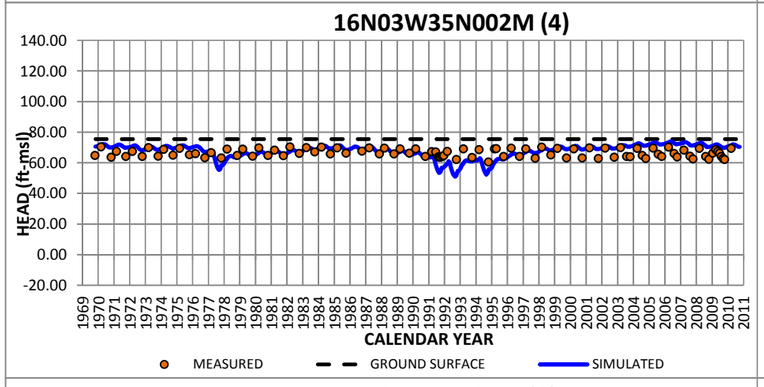

16N01W20F001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

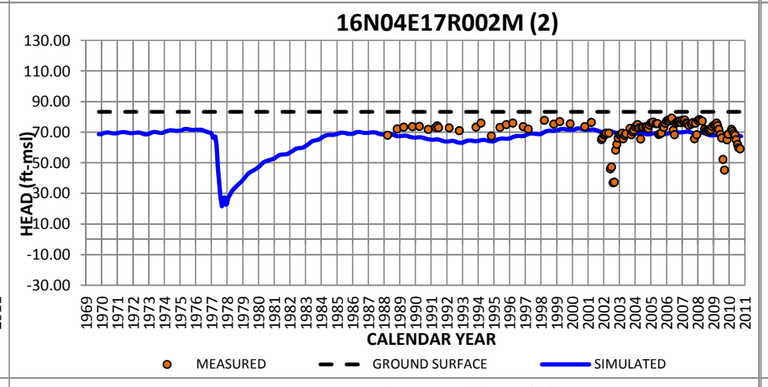

16N02E26Q001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

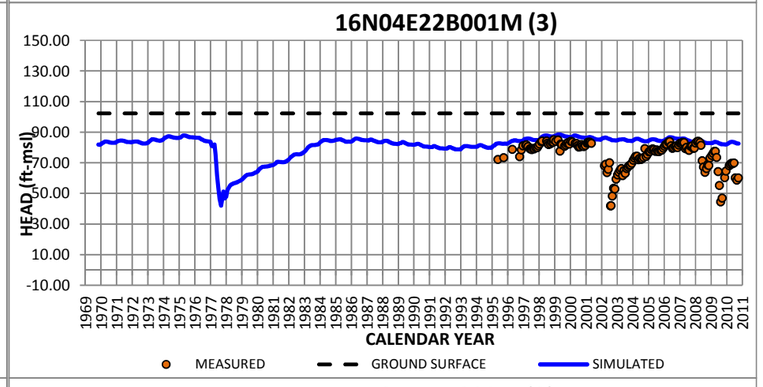

16N02W25B002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

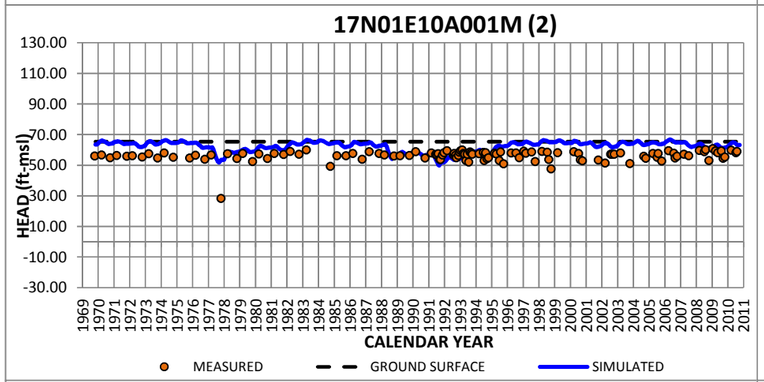

16N03E21D002M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

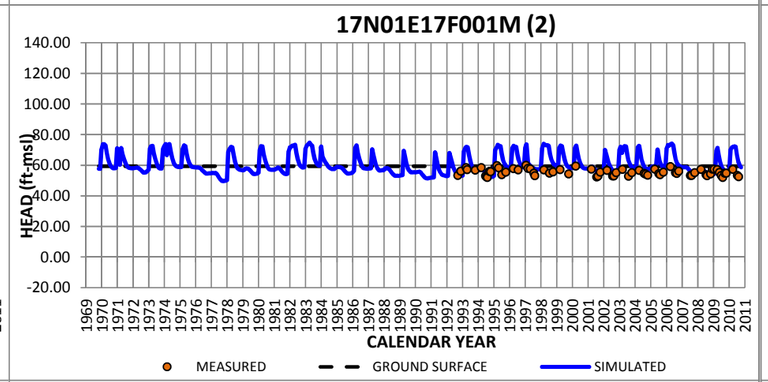

16N03W07Q001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

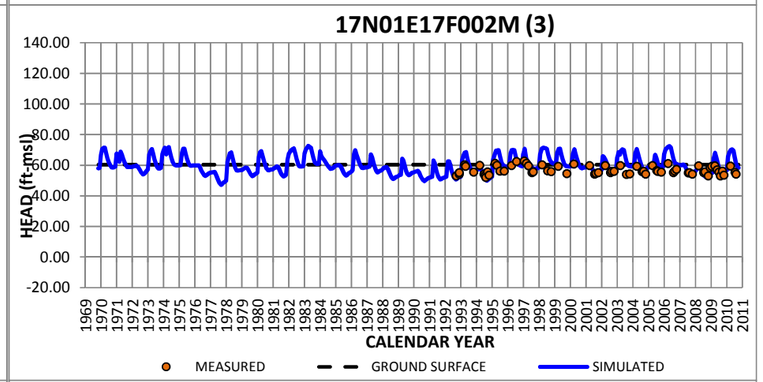

16N03W35N002M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

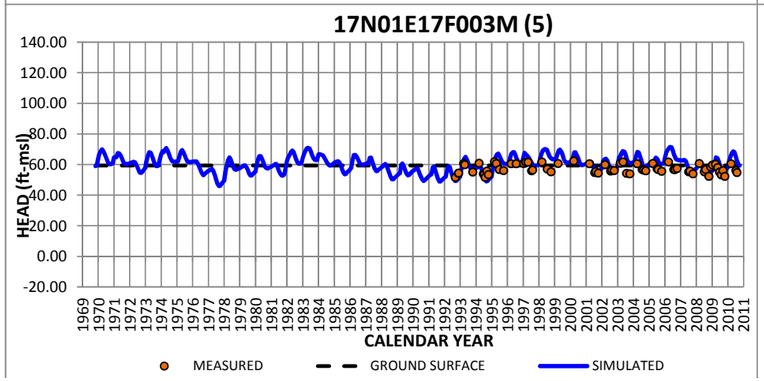

16N04E17R002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

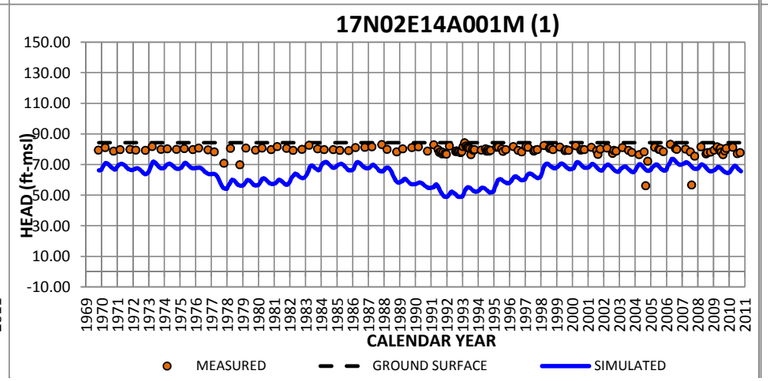

16N04E22B001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

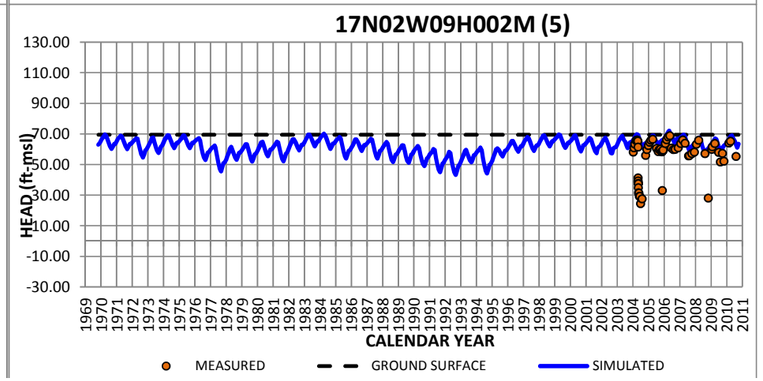

17N01E10A001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

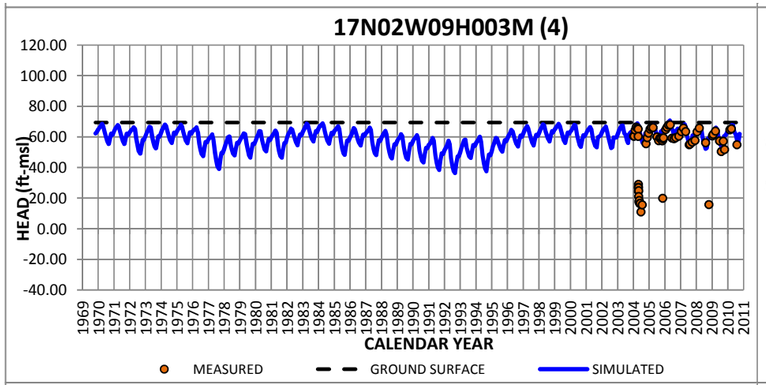

17N01E17F001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

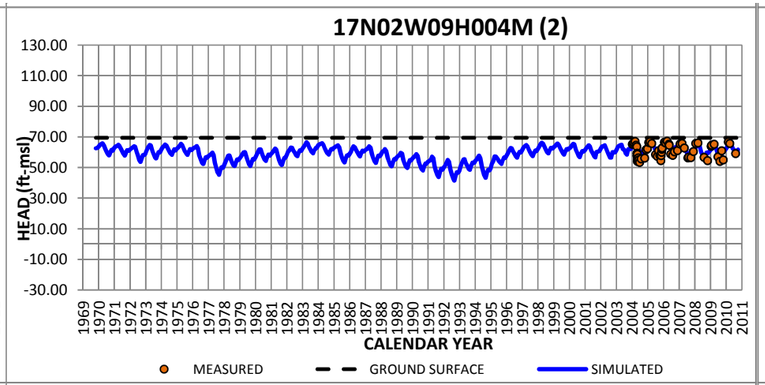

17N01E17F002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

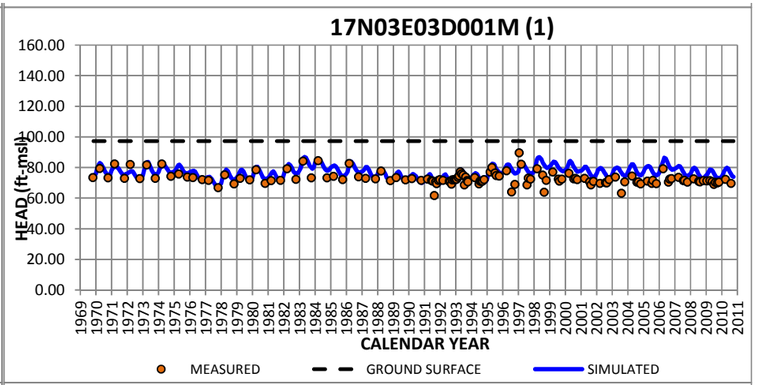

17N01E17F003M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

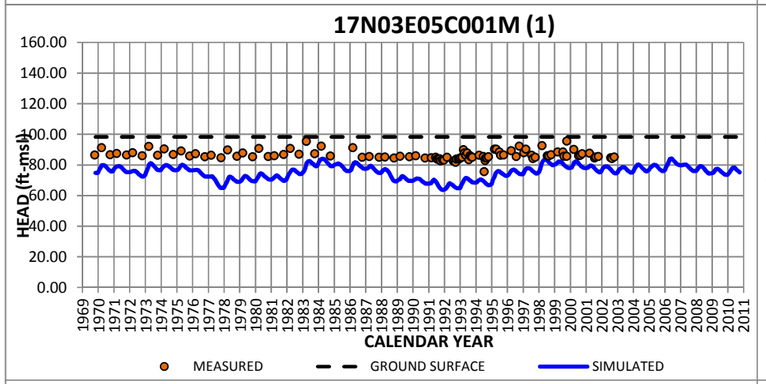

17N02E14A001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

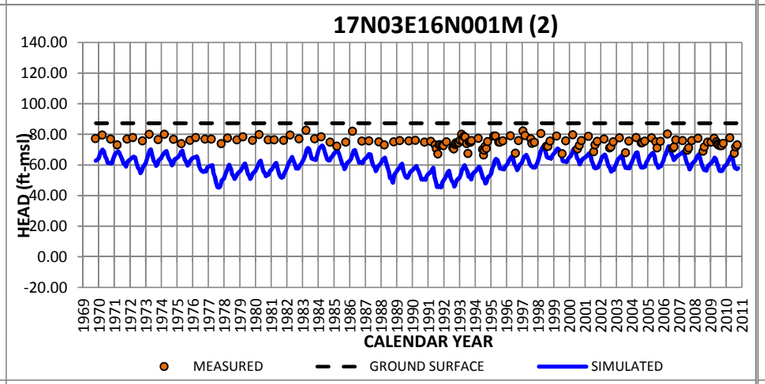

17N02W09H002M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

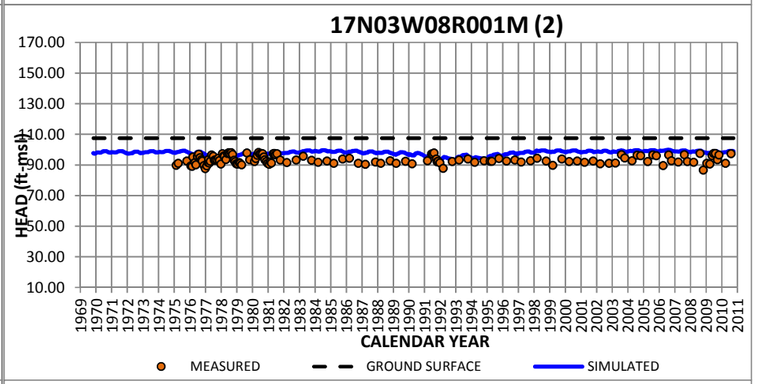

17N02W09H003M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

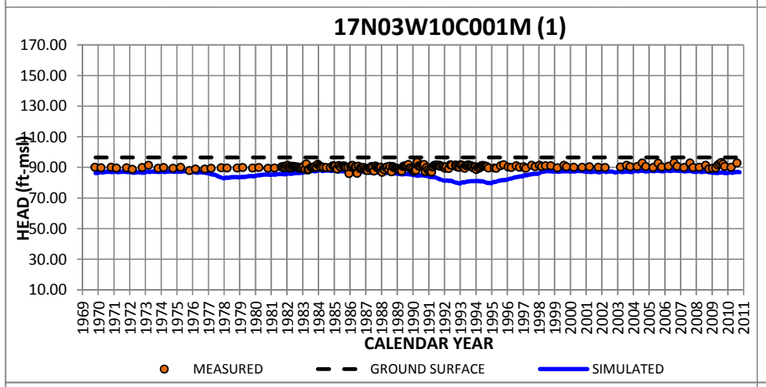

17N02W09H004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

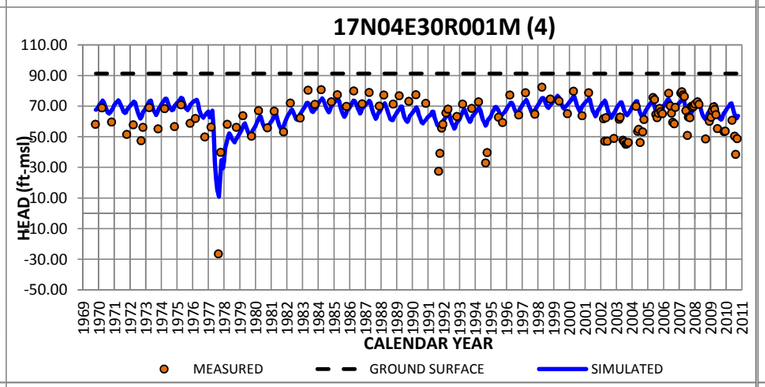

17N03E03D001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

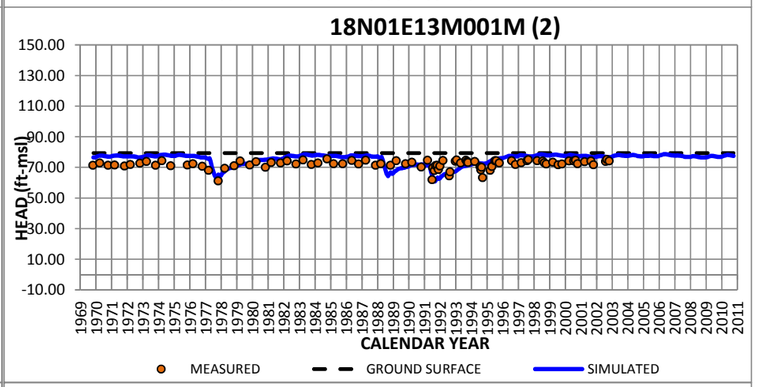

17N03E05C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

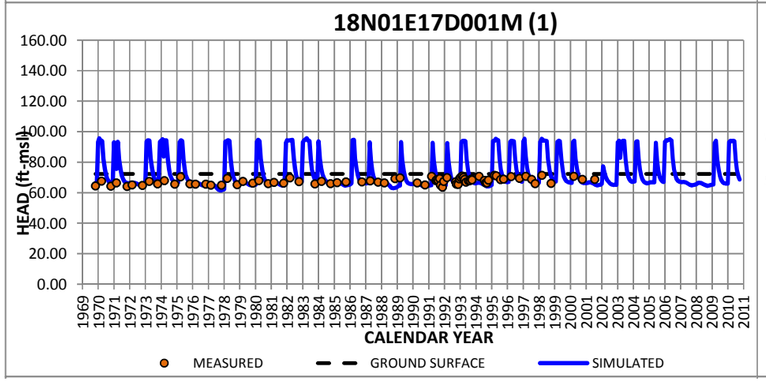

17N03E16N001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

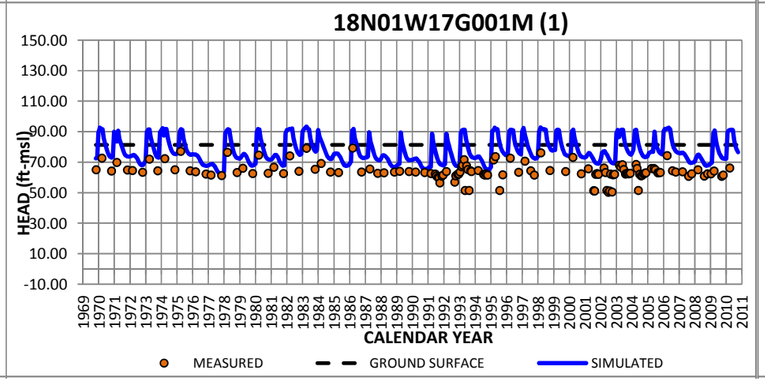

17N03W08R001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

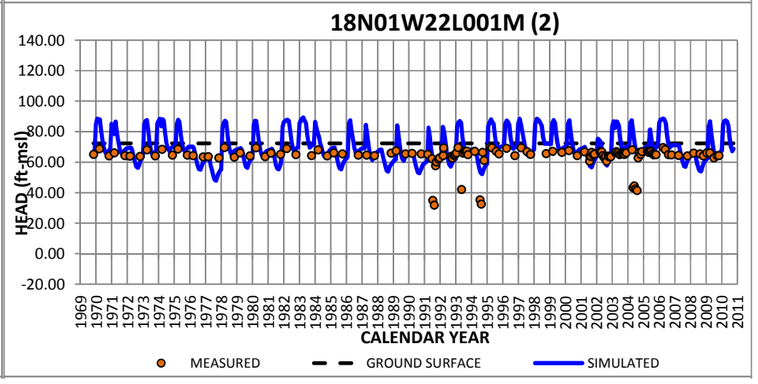

17N03W10C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

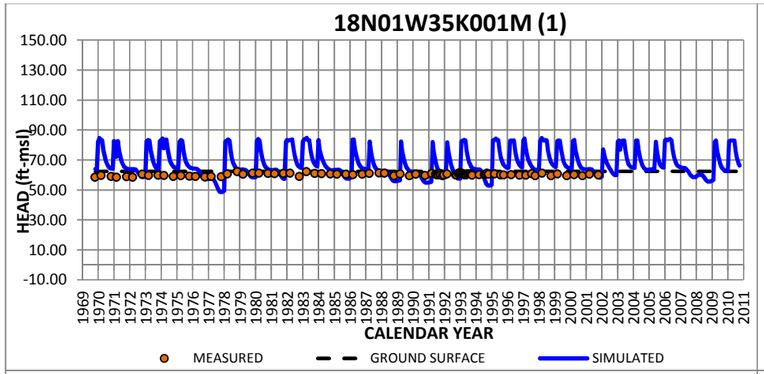

17N04E30R001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

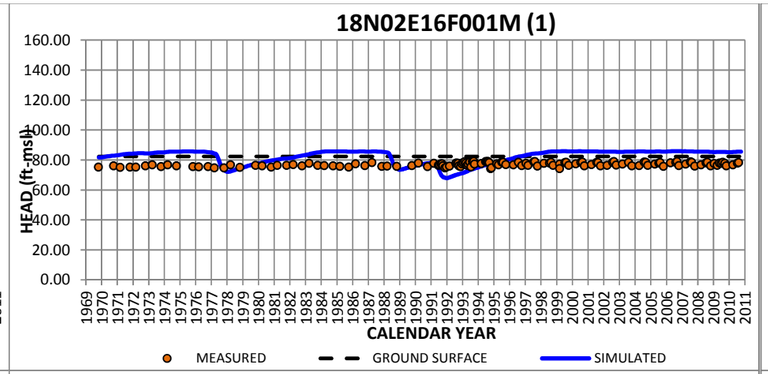

18N01E13M001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

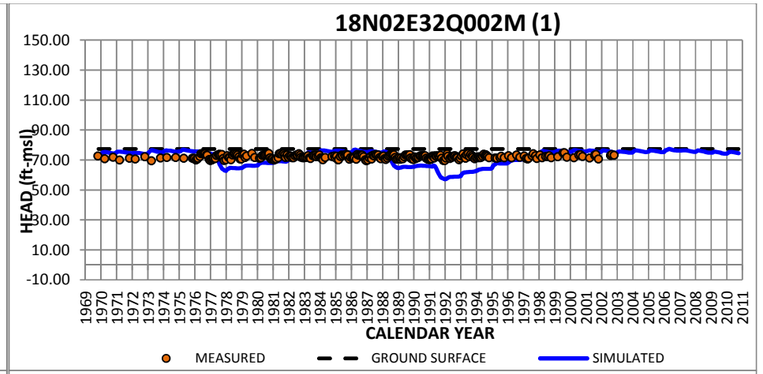

18N01E17D001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

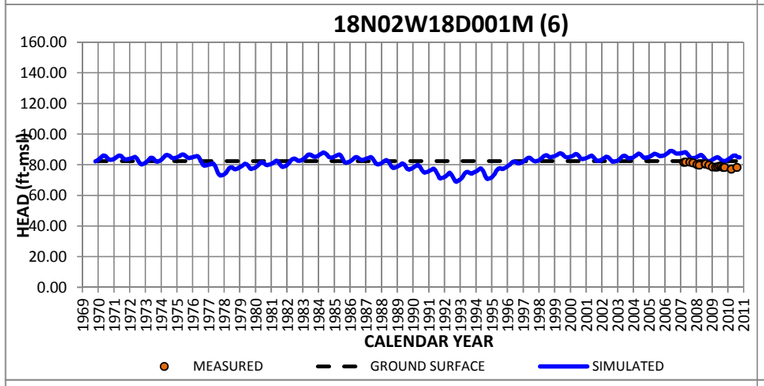

18N01W17G001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

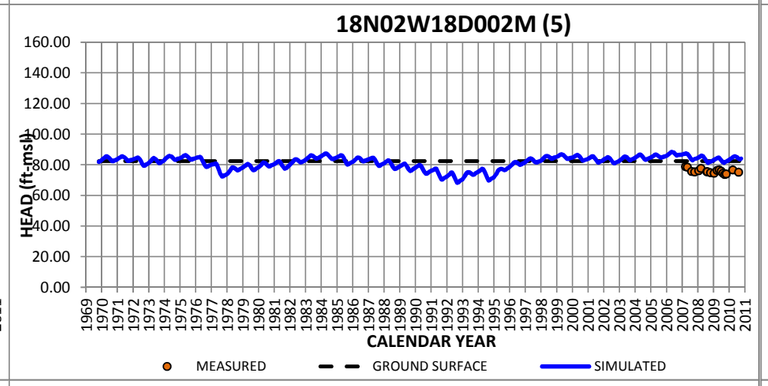

18N01W22L001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

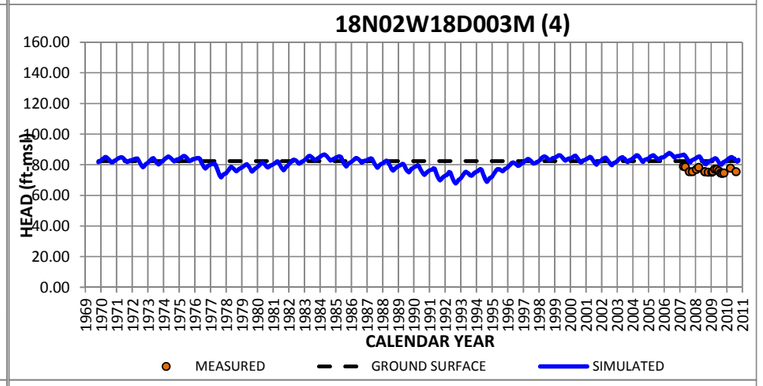

18N01W35K001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

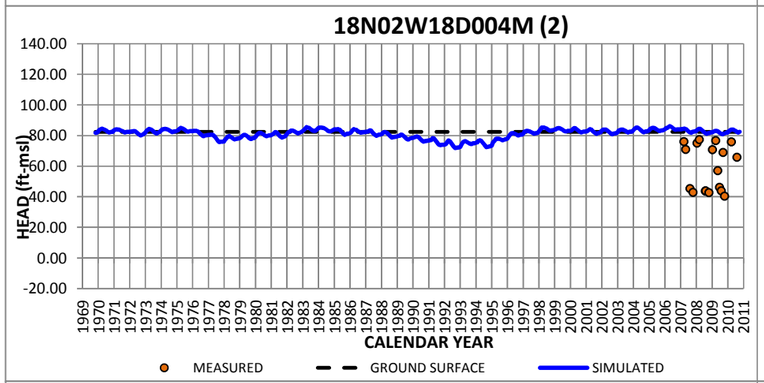

18N02E16F001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

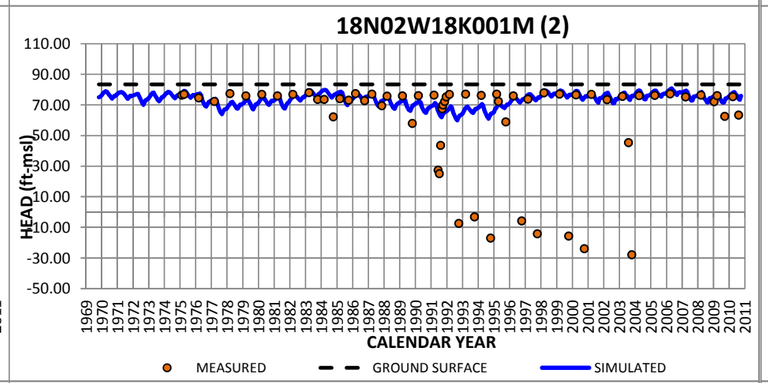

18N02E32Q002M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

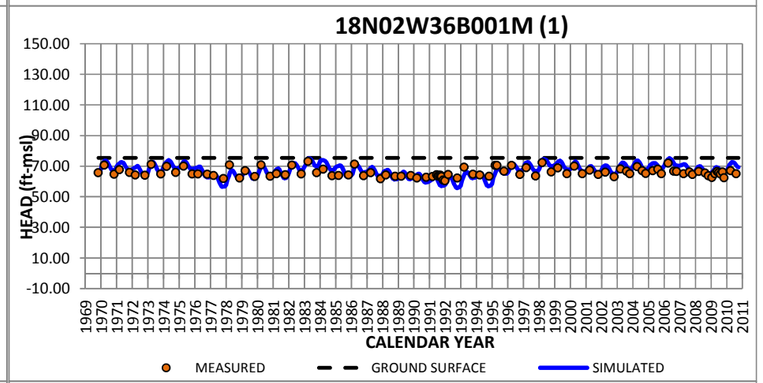

18N02W18D001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

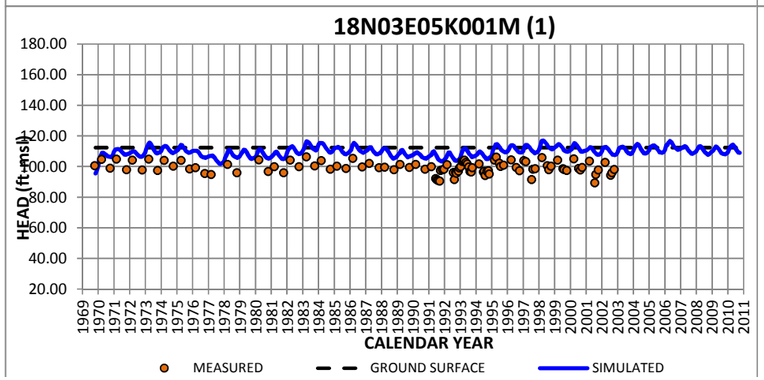

18N02W18D002M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

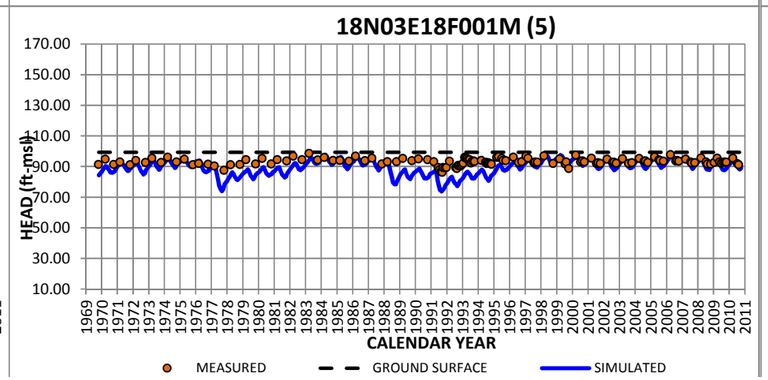

18N02W18D003M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

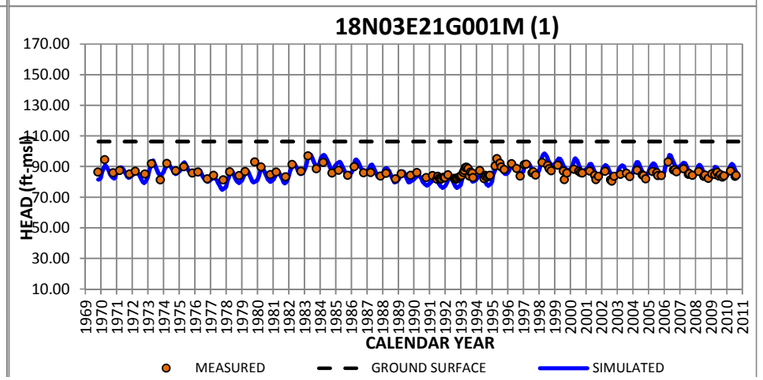

18N02W18D004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

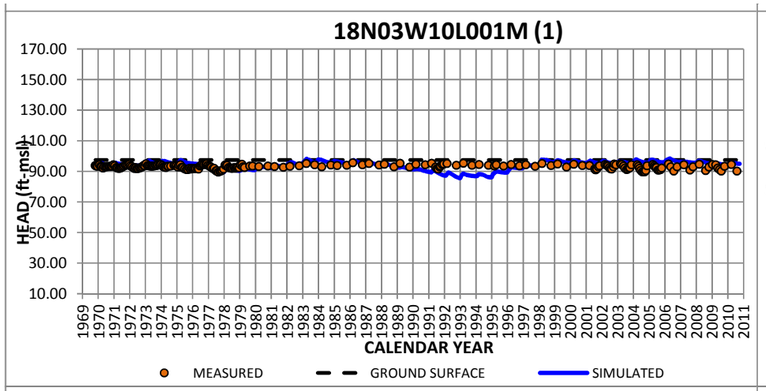

18N02W18K001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

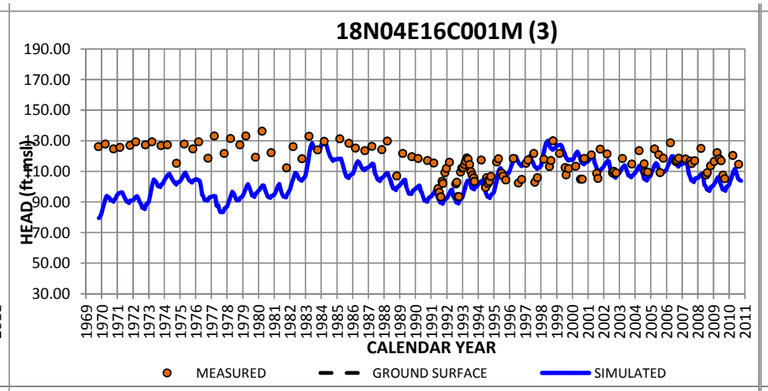

18N02W36B001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

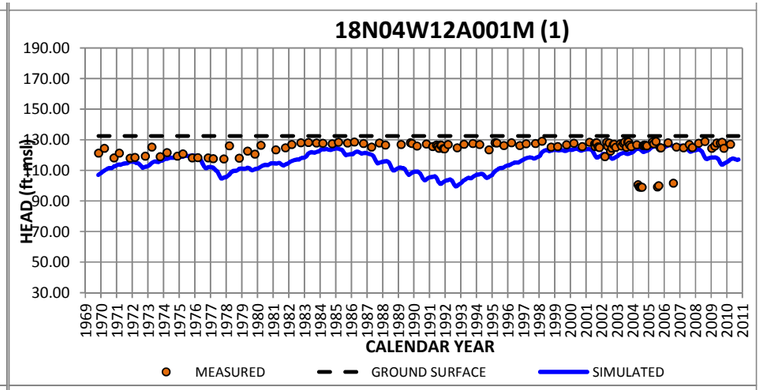

18N03E05K001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

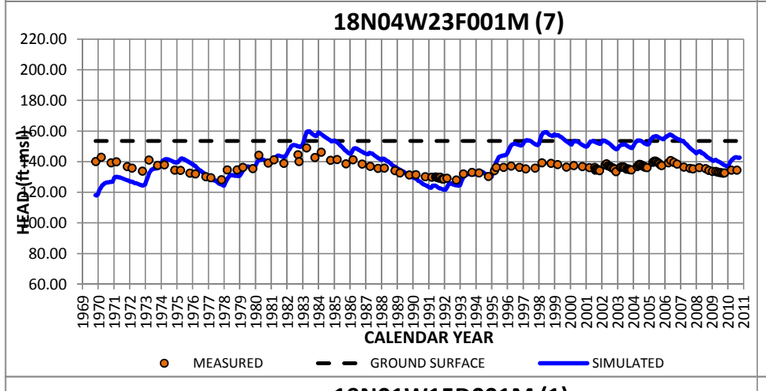

18N03E18F001M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

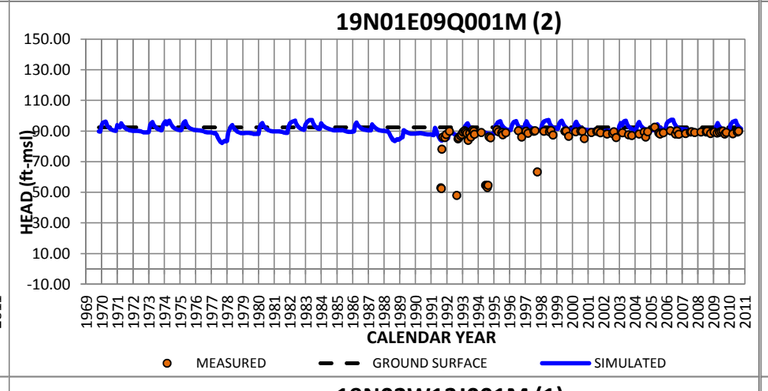

18N03E21G001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

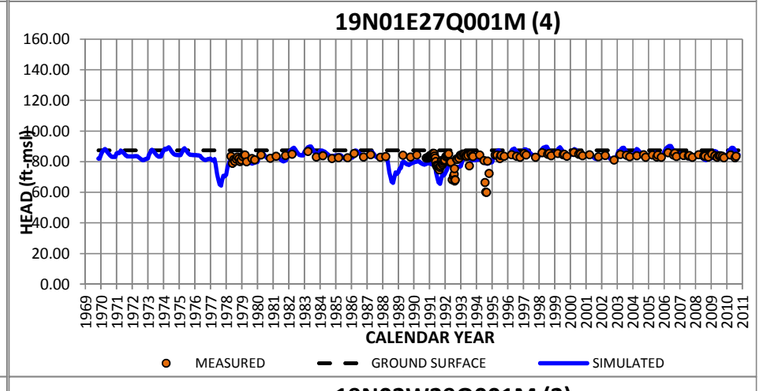

18N03W10L001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

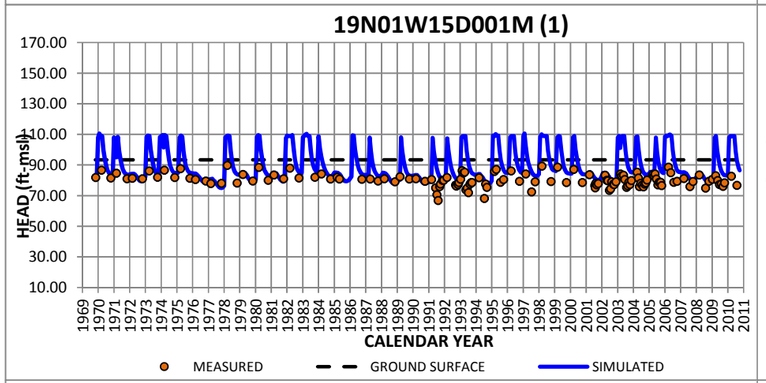

18N04E16C001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

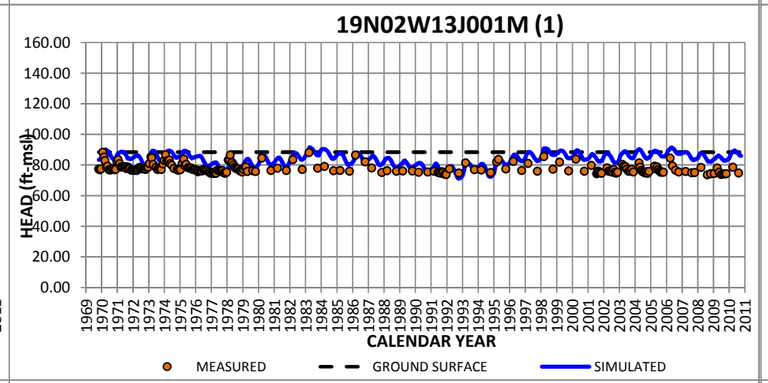

18N04W12A001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

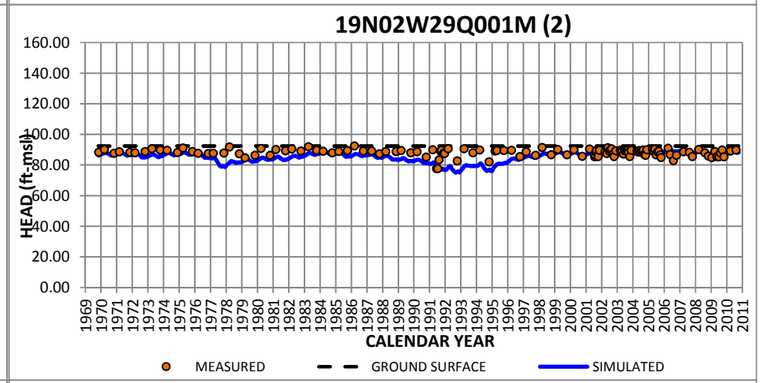

18N04W23F001M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

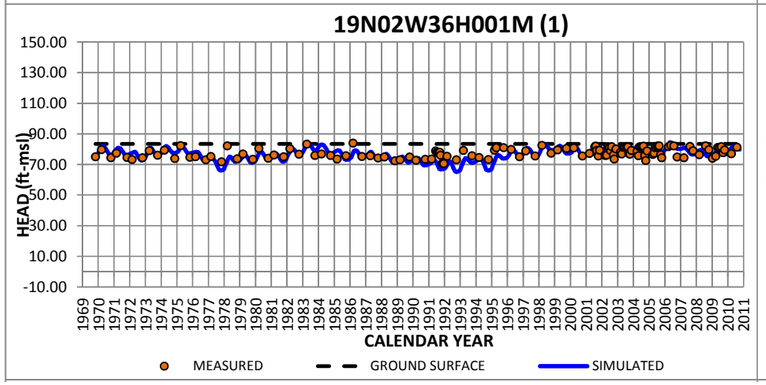

19N01E09Q001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

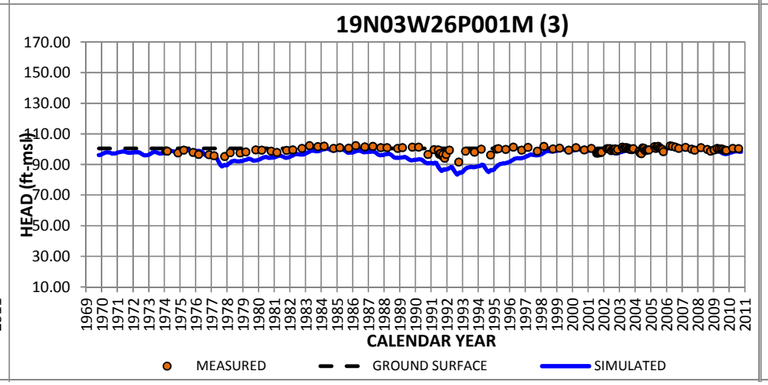

19N01E27Q001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

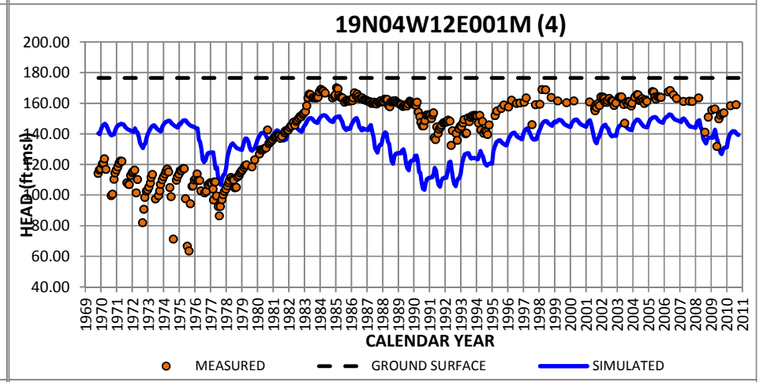

19N01W15D001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

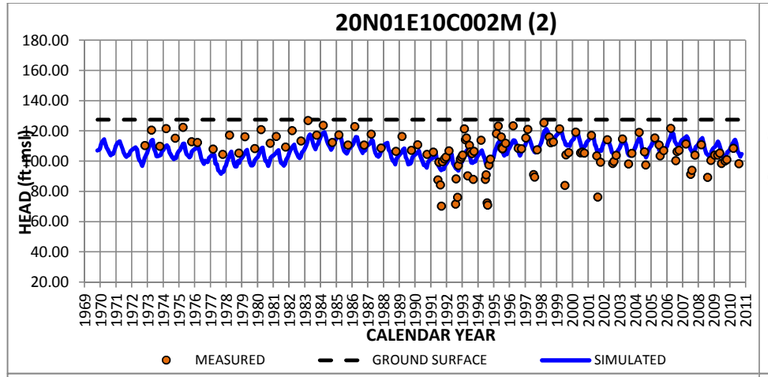

19N02W13J001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

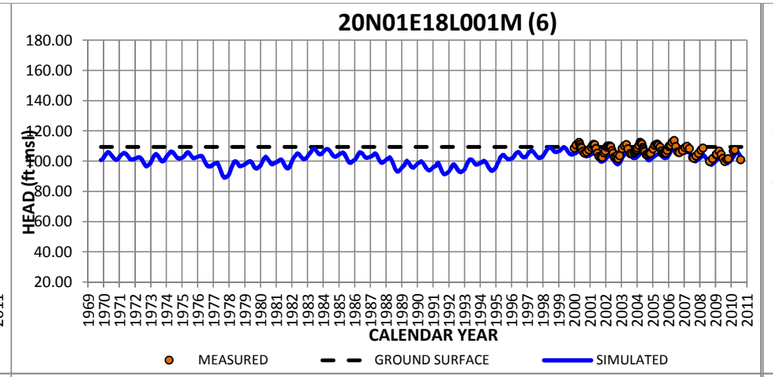

19N02W29Q001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

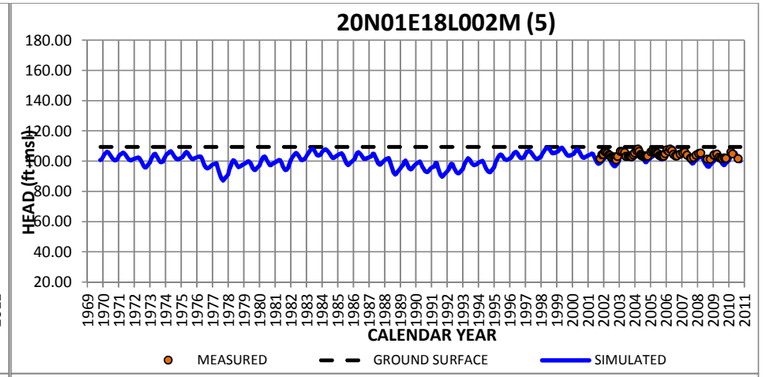

19N02W36H001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

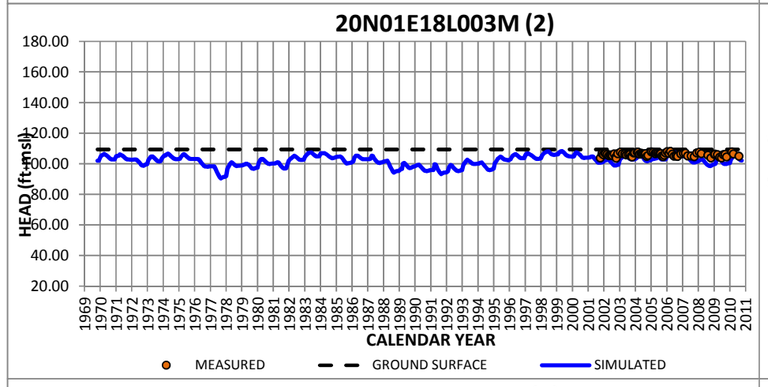

19N03W26P001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

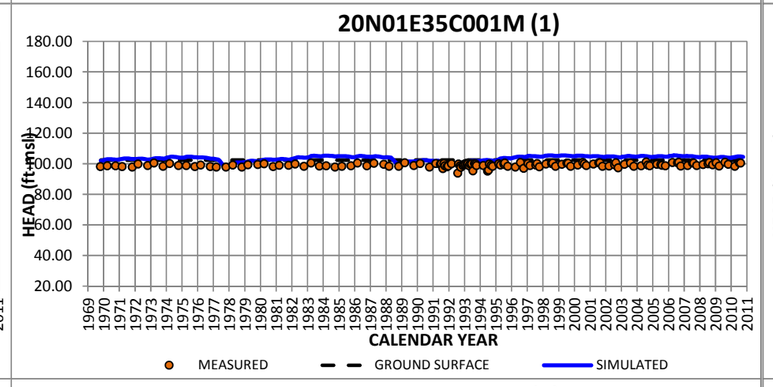

19N04W12E001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

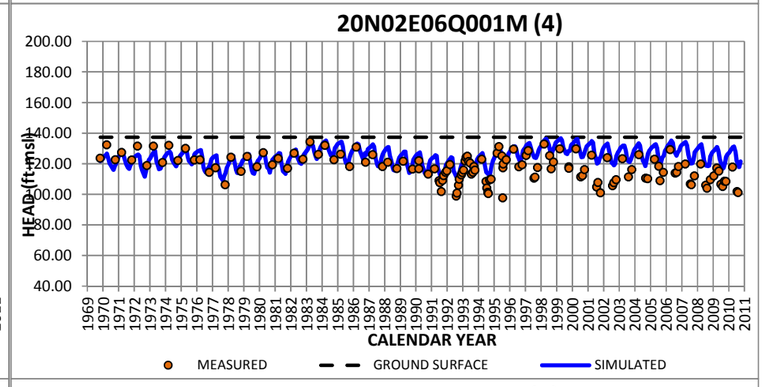

20N01E10C002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

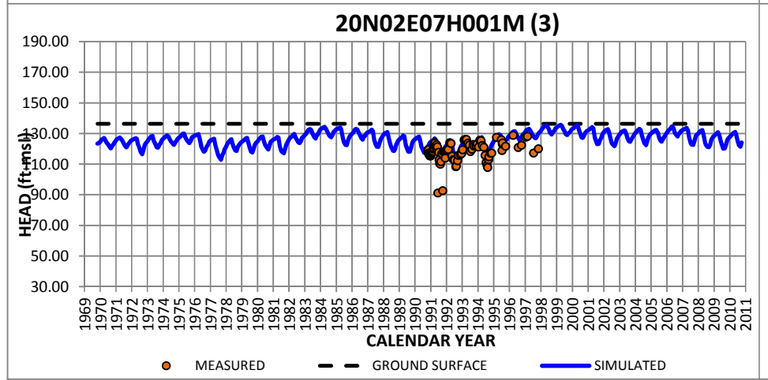

20N01E18L001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

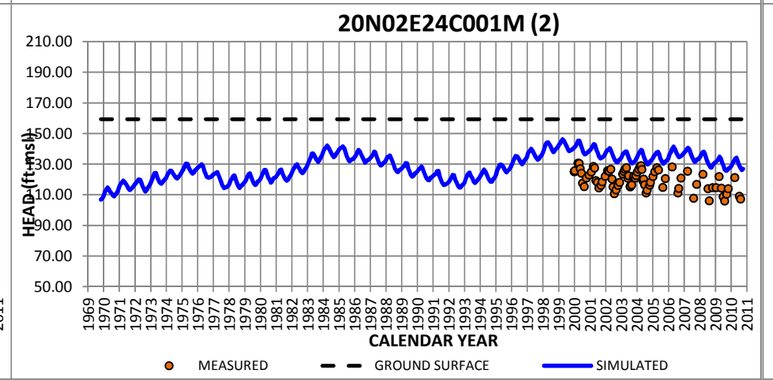

20N01E18L002M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

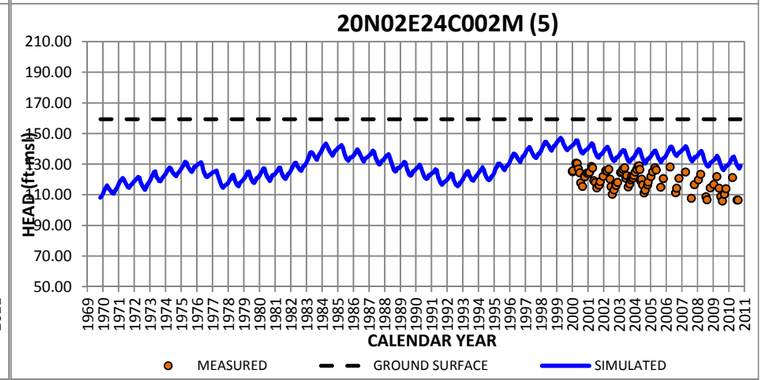

20N01E18L003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

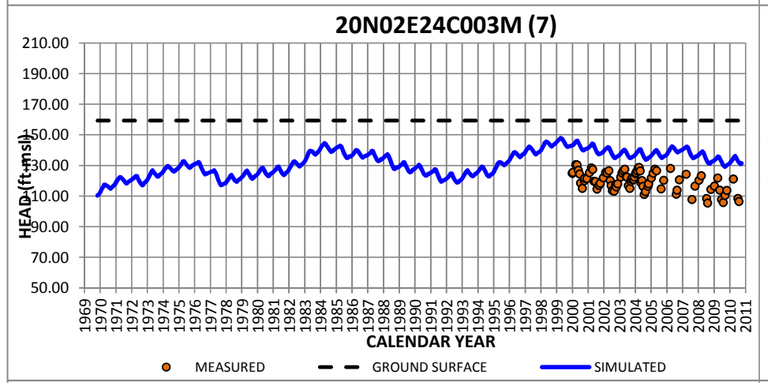

20N01E35C001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

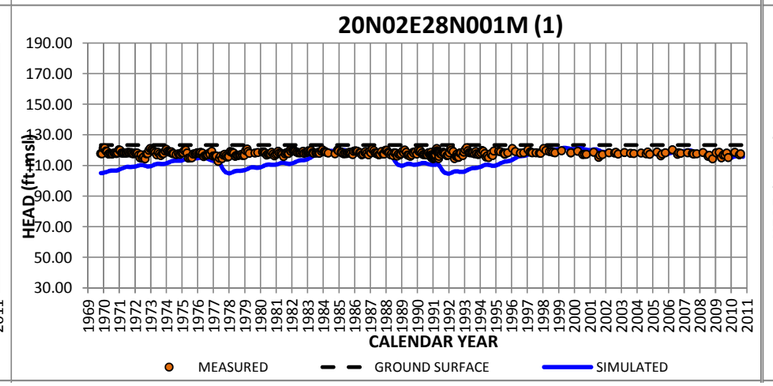

20N02E06Q001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

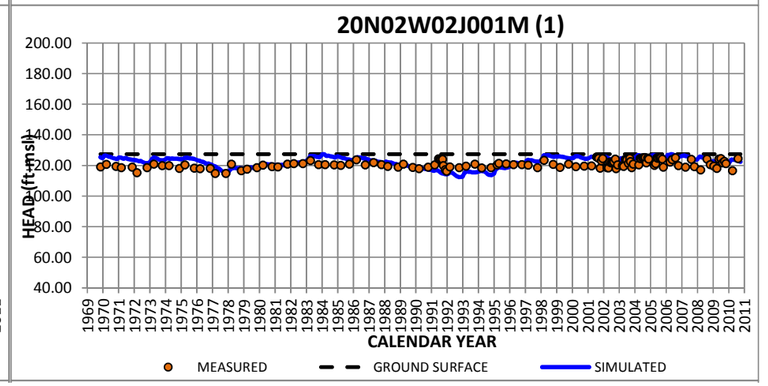

20N02E07H001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

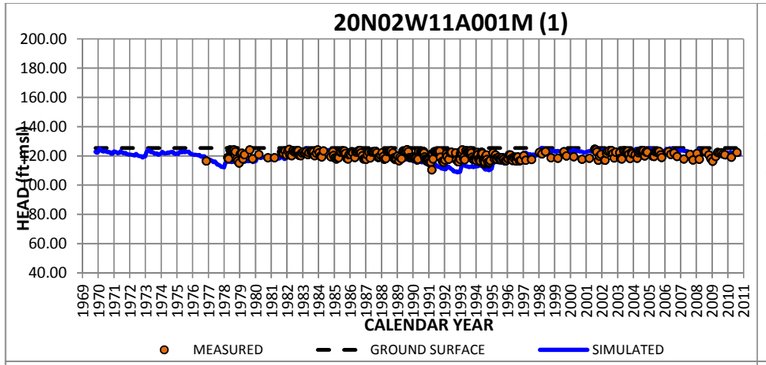

20N02E24C001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

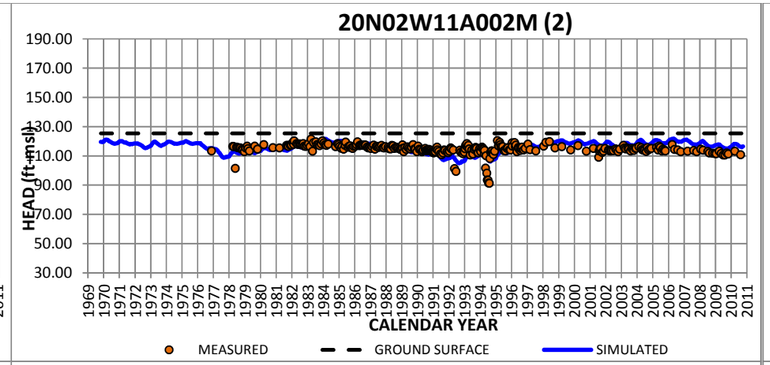

20N02E24C002M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

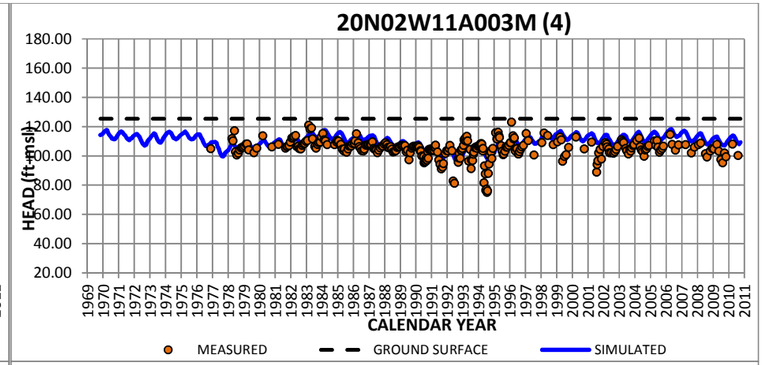

20N02E24C003M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

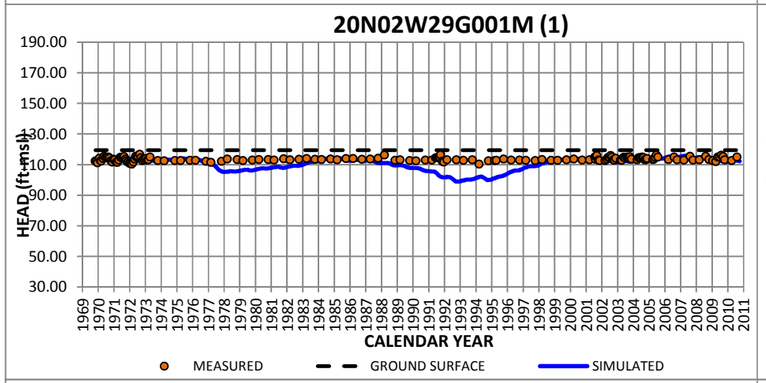

20N02E28N001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

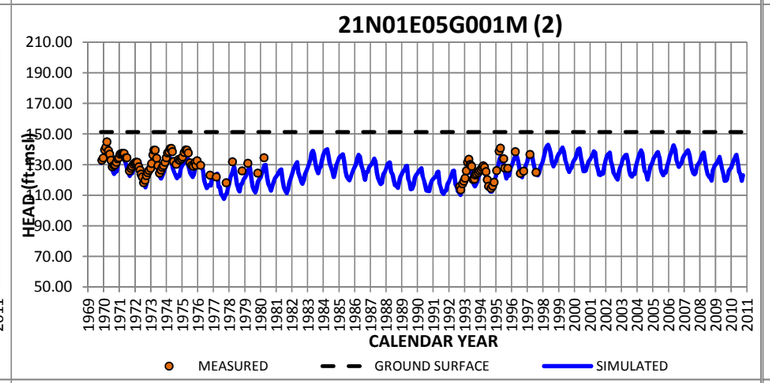

20N02W02J001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

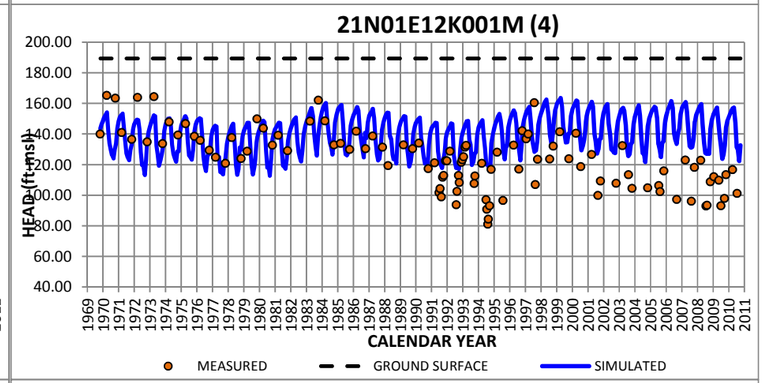

20N02W11A001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

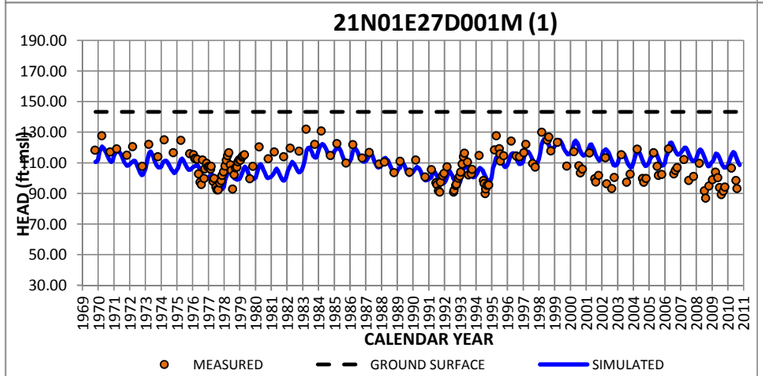

20N02W11A002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

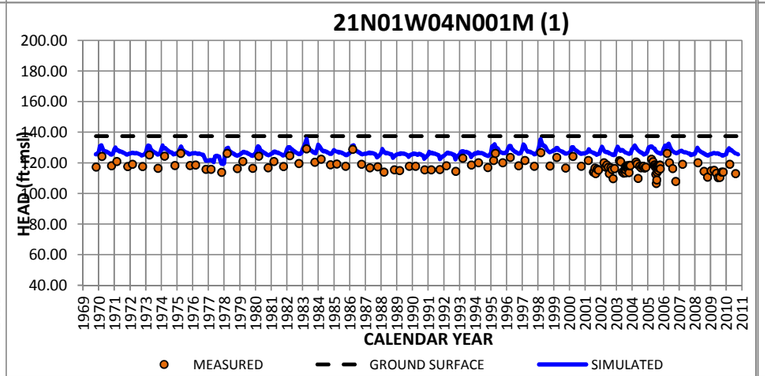

20N02W11A003M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

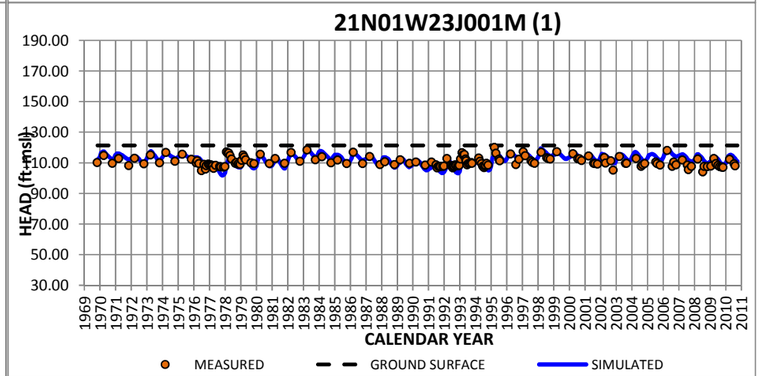

20N02W29G001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

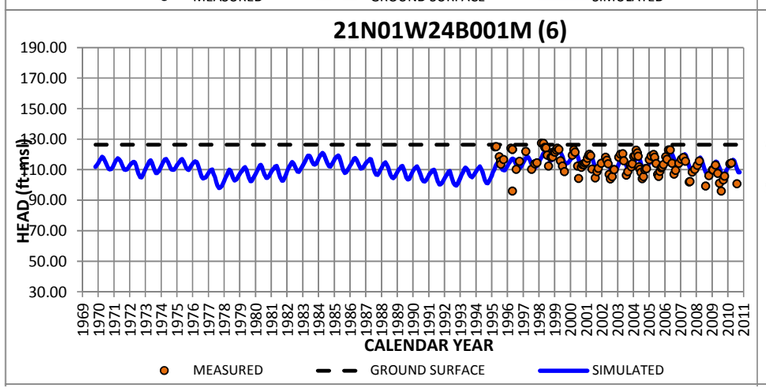

21N01E05G001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

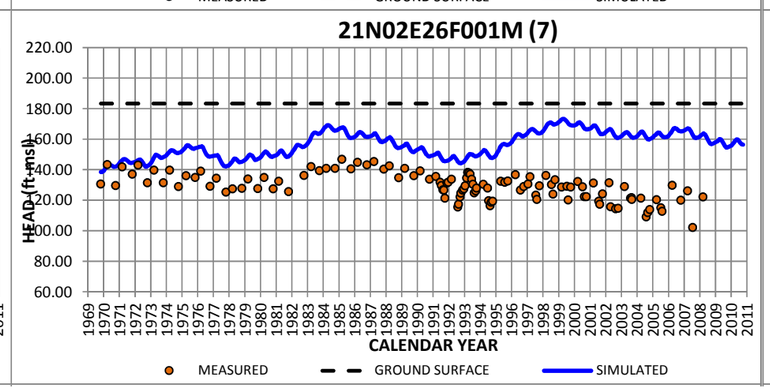

21N01E12K001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

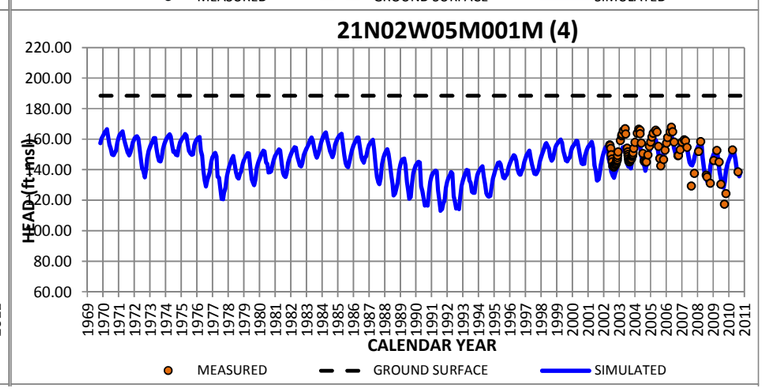

21N01E27D001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

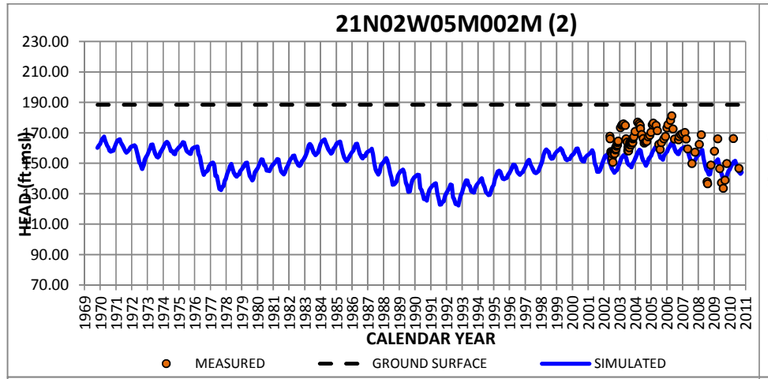

21N01W04N001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

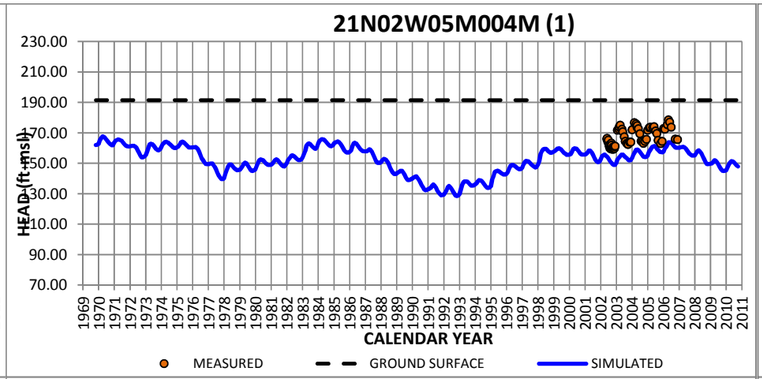

21N01W23J001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

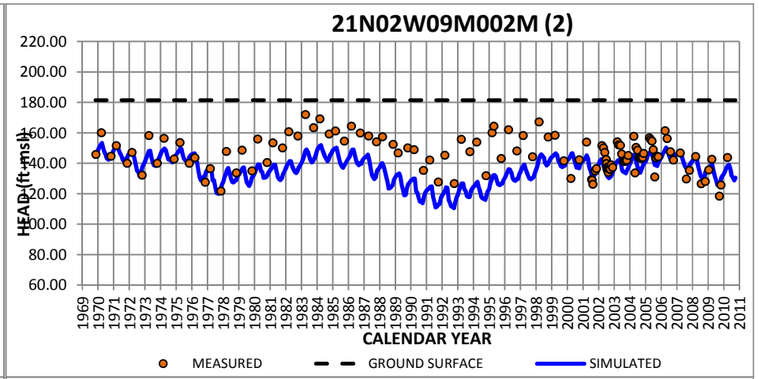

21N01W24B001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

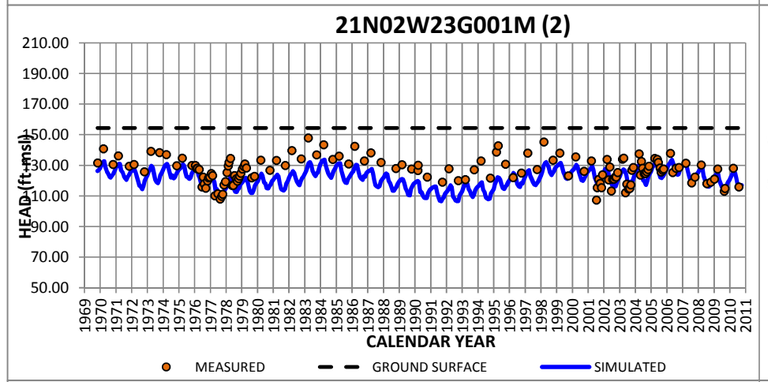

21N02E26F001M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

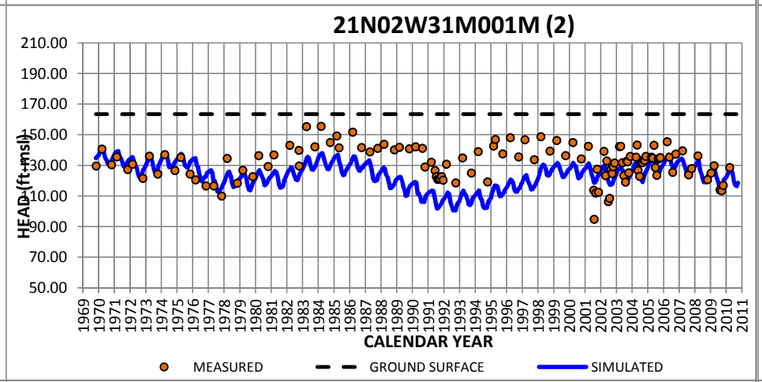

21N02W05M001M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

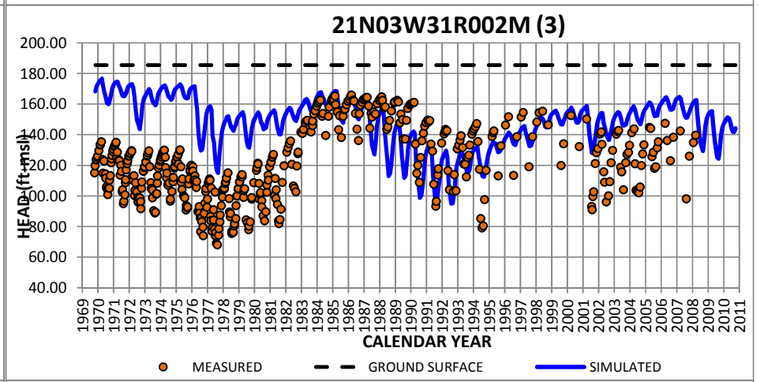

21N02W05M002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

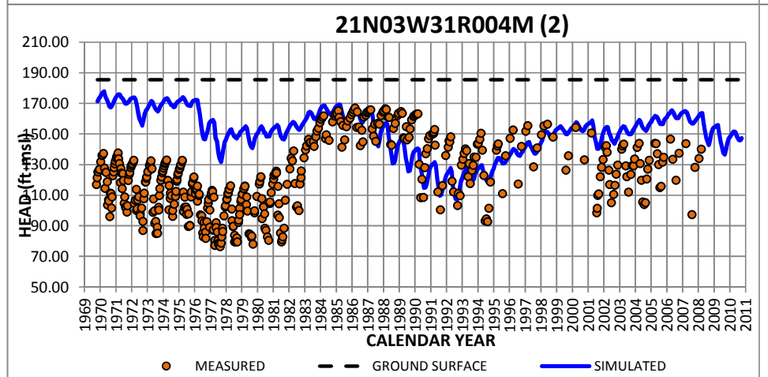

21N02W05M004M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

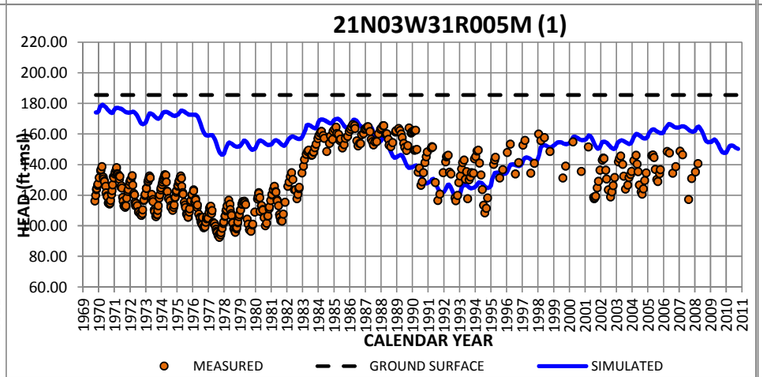

21N02W09M002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

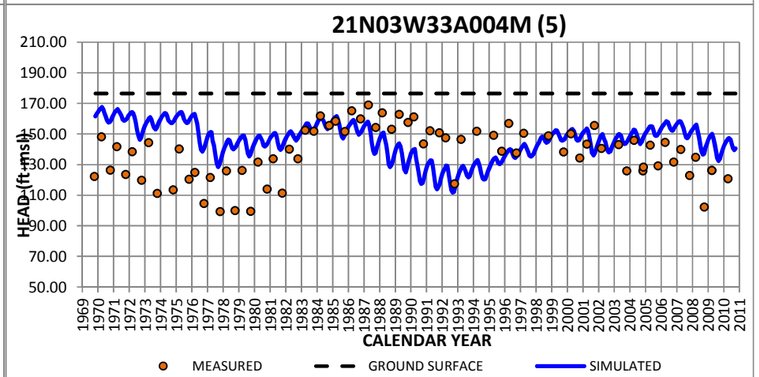

21N02W23G001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

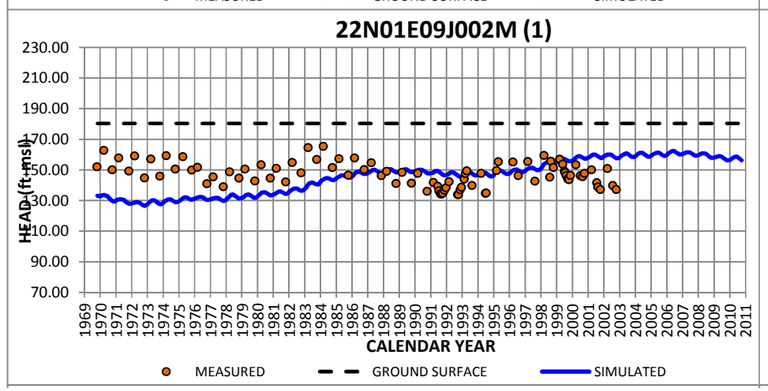

21N02W31M001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

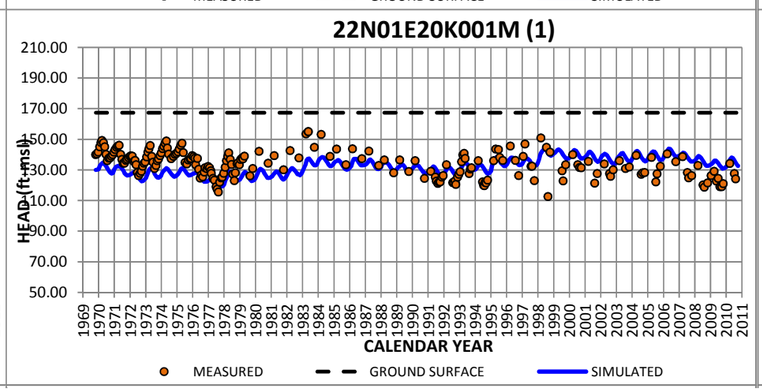

21N03W31R002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

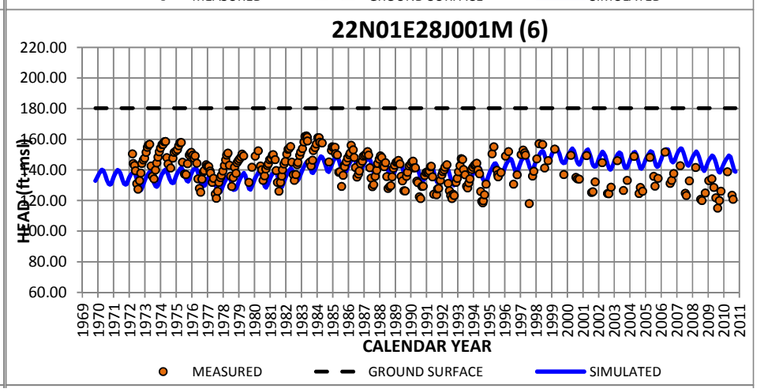

21N03W31R004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

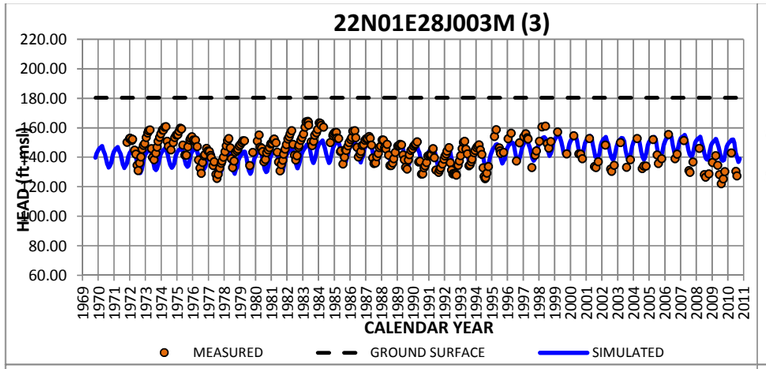

21N03W31R005M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

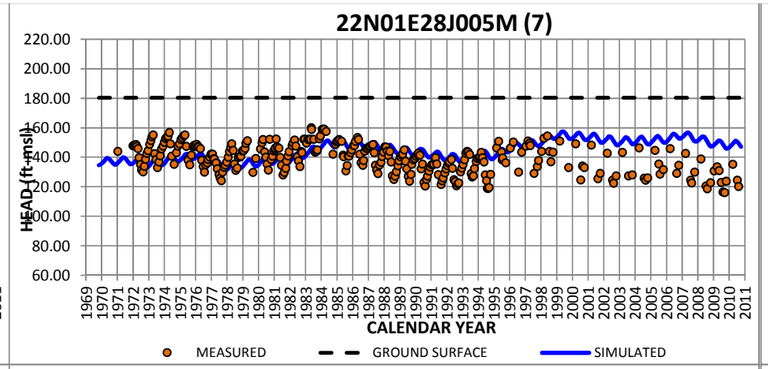

21N03W33A004M (5)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

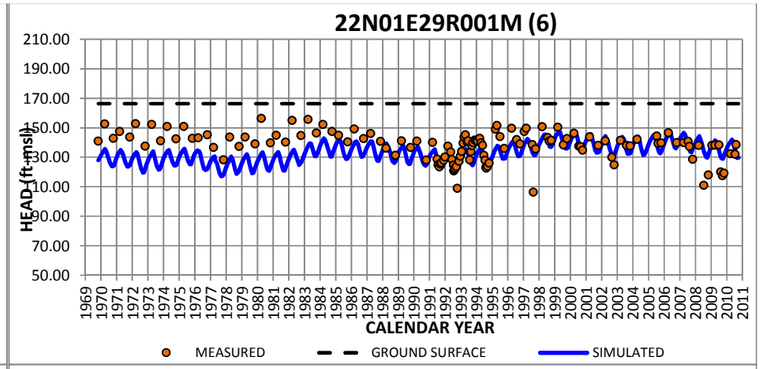

22N01E09J002M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

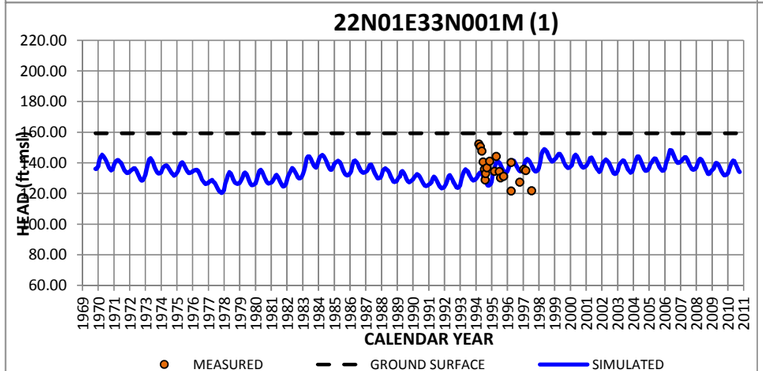

22N01E20K001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

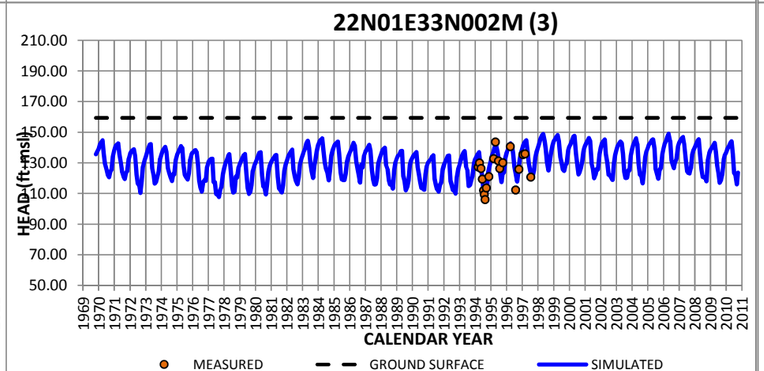

22N01E28J001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

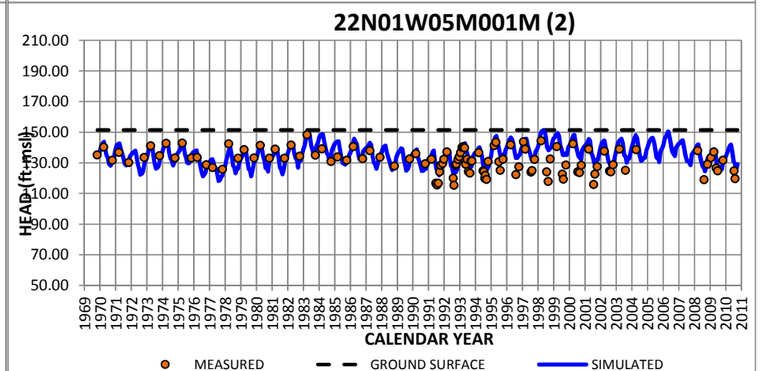

22N01E28J003M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

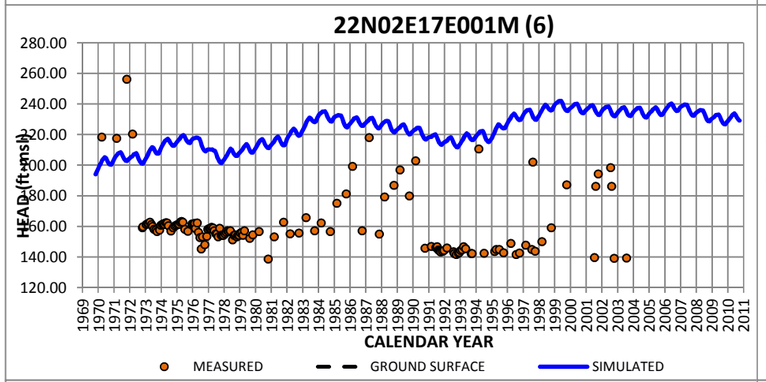

22N01E28J005M (7)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

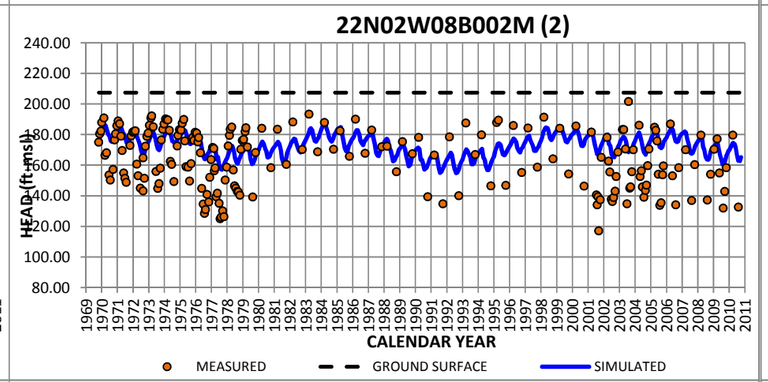

22N01E29R001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

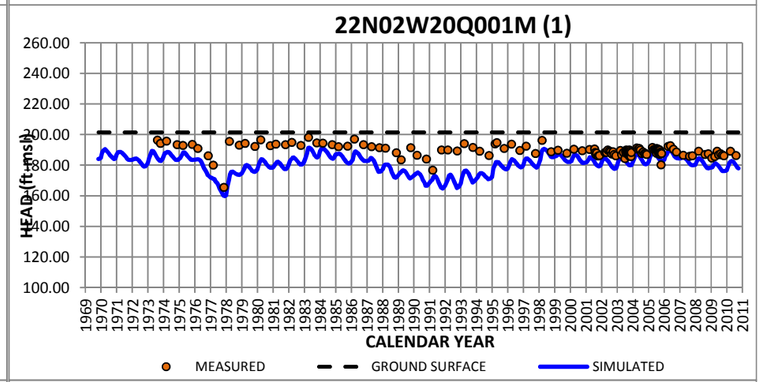

22N01E33N001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

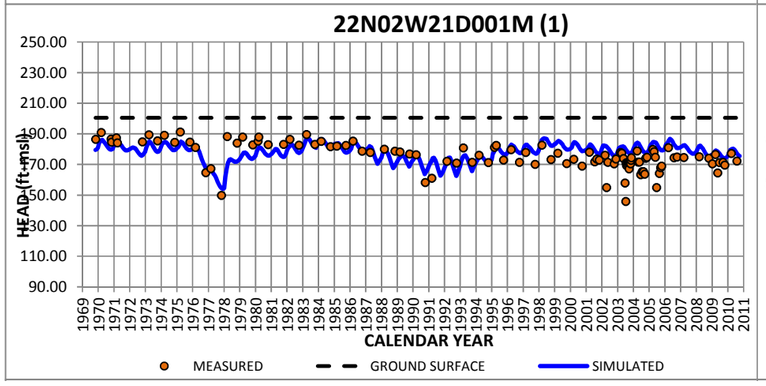

22N01E33N002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

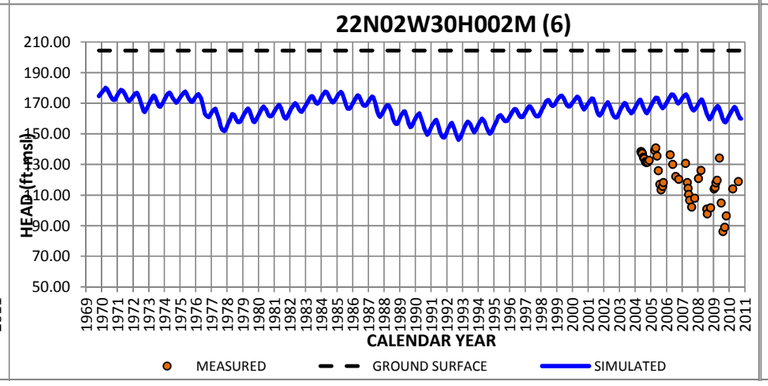

22N01W05M001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

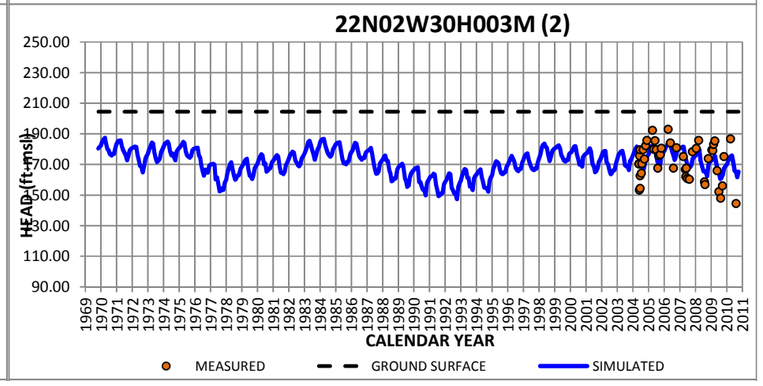

22N02E17E001M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

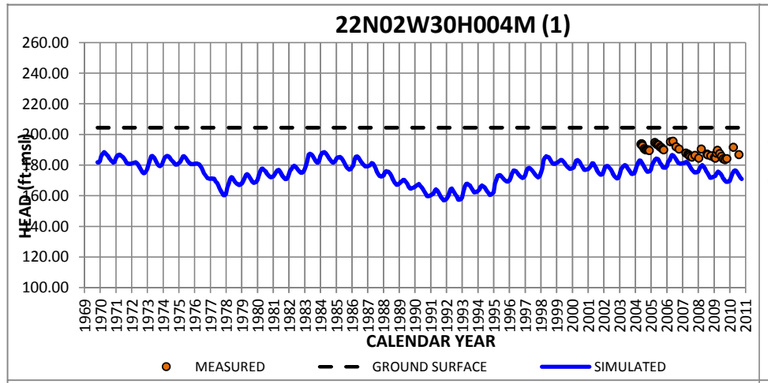

22N02W08B002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

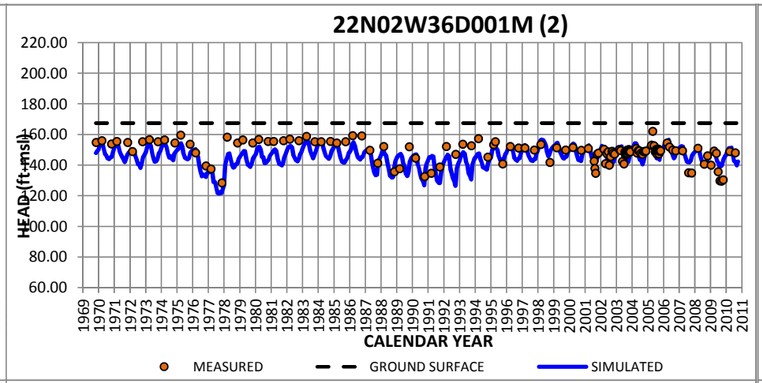

22N02W20Q001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

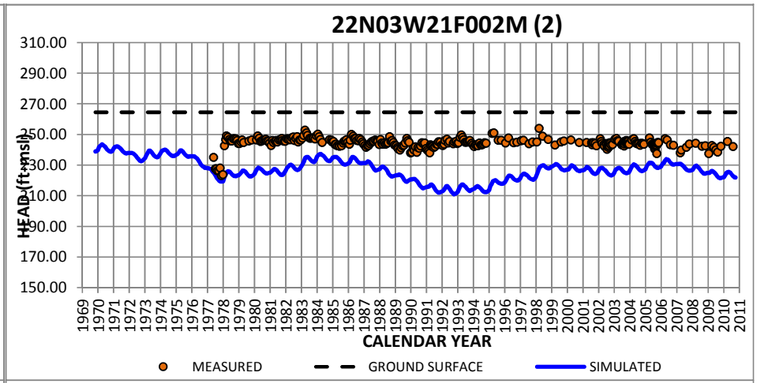

22N02W21D001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

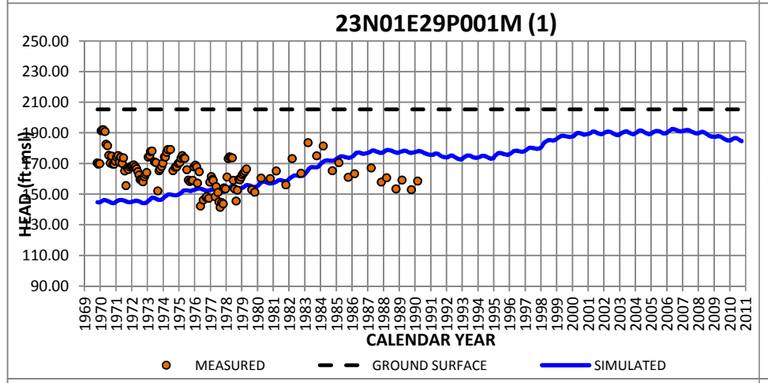

22N02W30H002M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

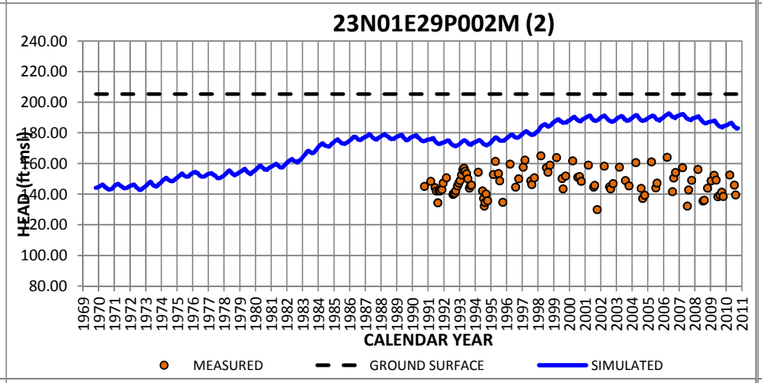

22N02W30H003M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

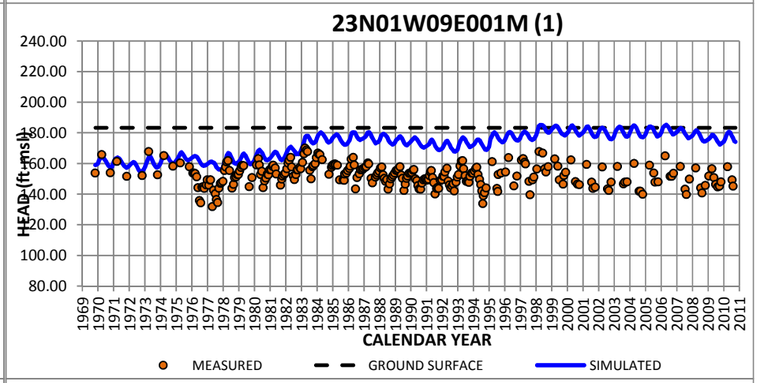

22N02W30H004M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

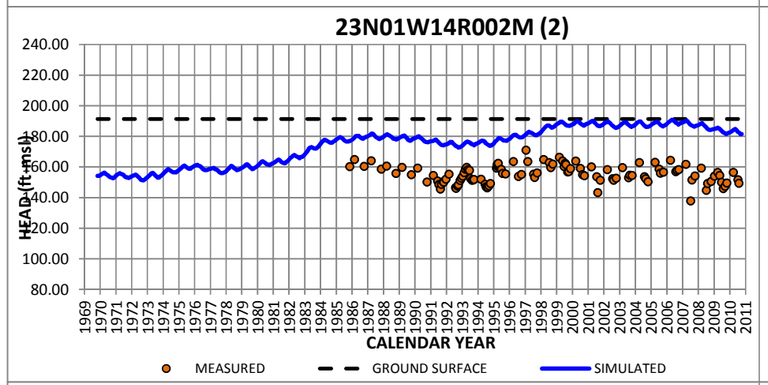

22N02W36D001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

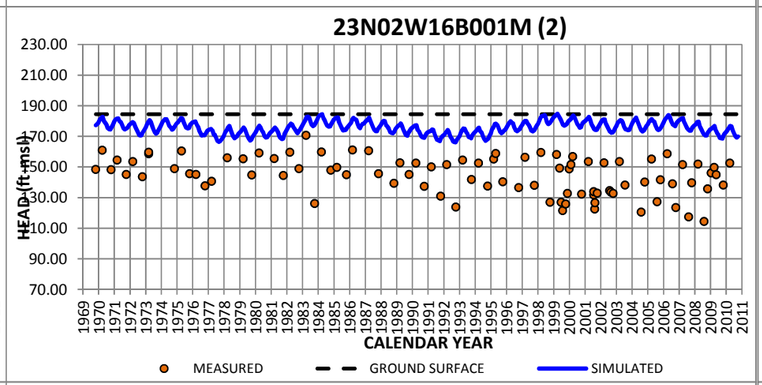

22N03W21F002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

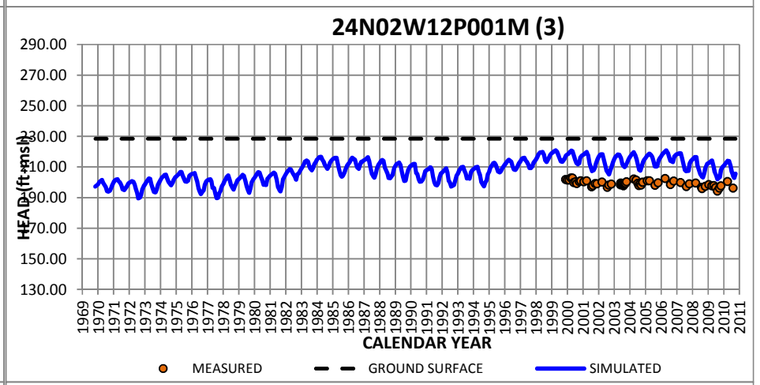

23N01E29P001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

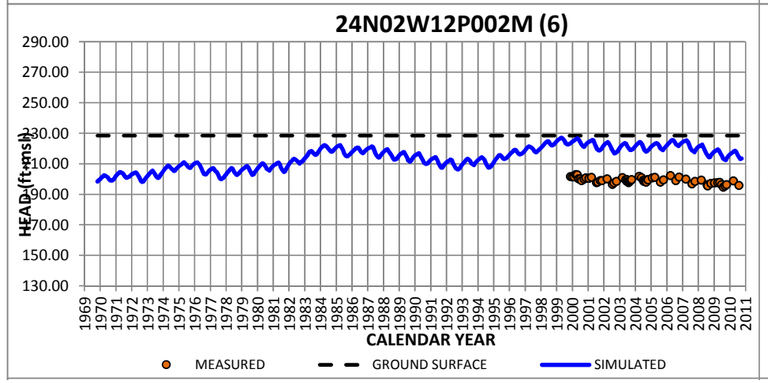

23N01E29P002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

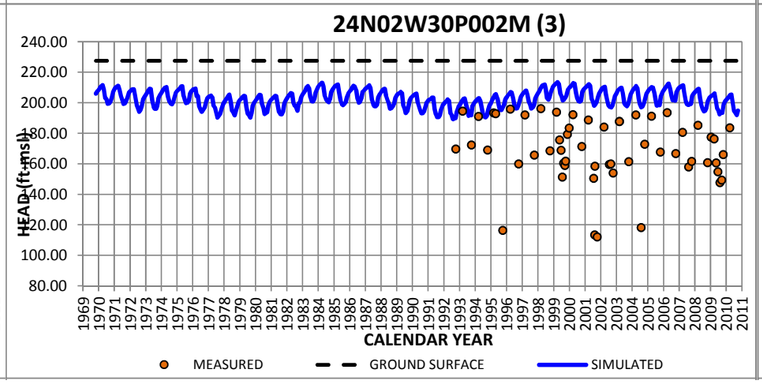

23N01W09E001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

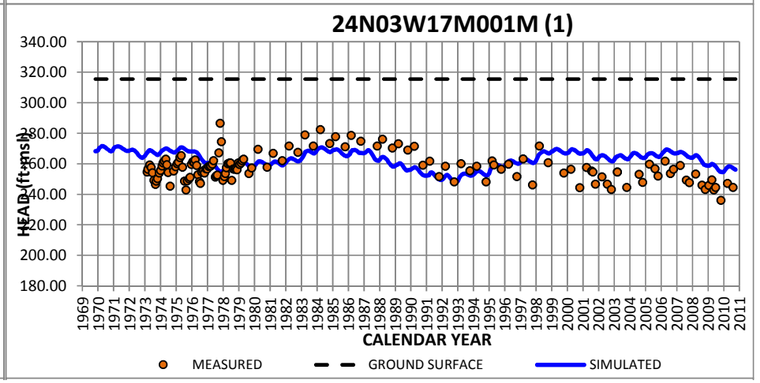

23N01W14R002M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

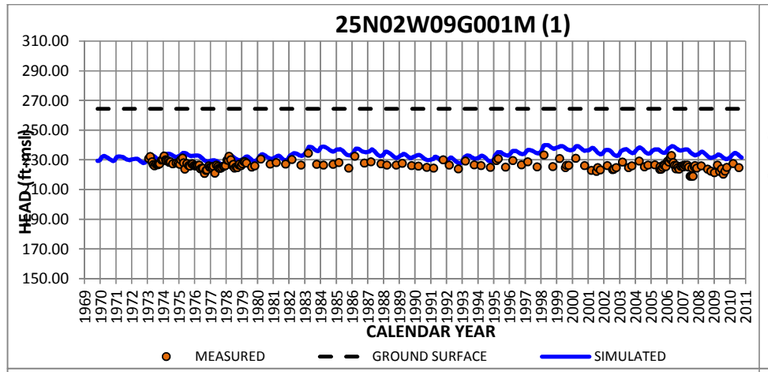

23N02W16B001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

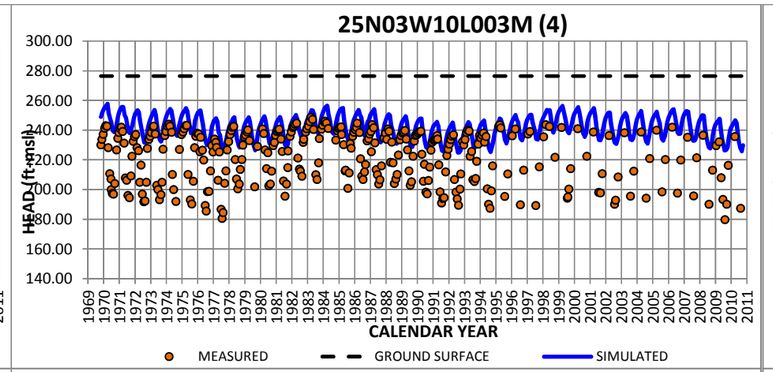

24N02W12P001M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

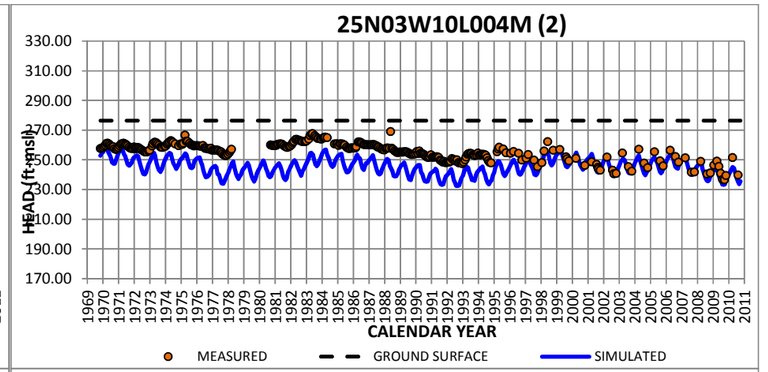

24N02W12P002M (6)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


24N02W30P002M (3)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


24N03W17M001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


25N02W09G001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


25N03W10L003M (4)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


25N03W10L004M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


27N03W10B001M (1)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


27N03W20K001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED


27N04W35E001M (2)
HEAD (ft-msl)
CALENDAR YEAR
MEASURED
GROUND SURFACE
SIMULATED

# Appendix D
# SACFEM2013.feb File

```
rem***********************************************************
rem        BEGIN SIMULATION
rem***********************************************************
LOAD
 h1=zero.par
 h2=zero.par
 h3=zero.par
 h4=zero.par
 h5=zero.par
 h6=zero.par
 h7=zero.par
 q1=zero.par
 q2=zero.par
 q3=zero.par
 q4=zero.par
 q5=zero.par
 q6=zero.par
 q7=zero.par
rem**********assign Transmissivity Values**********
LOAD
x3=SACFEM_v2_Kh_1_mpd_120313.par
x4=SACFEM_v2_Kh_2-5_mpd_120313.par
x5=SACFEM_v2_Kh_6-7_mpd_120313.par
EVAL
t1=mt1*x3
t2=mt2*x4
t3=mt3*x4
t4=mt4*x4
t5=mt5*x4
t6=mt6*x5
t7=mt7*x5
SAVE
t1=Trans.t1
t2=Trans.t2
t3=Trans.t3
```

```
t4=Trans.t4
t5=Trans.t5
t6=Trans.t6
t7=Trans.t7
rem**********assign vertical resistance values **********
LOAD
x6=SACFEM_v2_KhKv_Ratio_500.par
EVAL
c2=50*mt1^2/2/t1+x6*mt2^2/2/t2
c3=x6*mt2^2/2/t2+x6*mt3^2/2/t3
c4=x6*mt3^2/2/t3+x6*mt4^2/2/t4
c5=x6*mt4^2/2/t4+x6*mt5^2/2/t5
c6=x6*mt5^2/2/t5+x6*mt6^2/2/t6
c7=x6*mt6^2/2/t6+x6*mt7^2/2/t7
rem**********load extra register files **********
LOAD
x1=SACFEM_v2_GSE_Combined_mNAVD88_120313.par
x8=SACFEM_v2_WL1_042314.par
rem**********open ftq files**********
LOAD
lb=SACFEM_v2_all.lb
open-q all=all.ftq upper=1 lower=7
rem**********open ftq files for Water Budget Areas**********
LOAD
lb=SACFEM_v2_WBAs_121013.lb
open-q
WBA_2=WBA_2.ftq upper=1 lower=7
WBA_3=WBA_3.ftq upper=1 lower=7
WBA_4=WBA_4.ftq upper=1 lower=7
WBA_5=WBA_5.ftq upper=1 lower=7
WBA_6=WBA_6.ftq upper=1 lower=7
WBA_9=WBA_9.ftq upper=1 lower=7
WBA_10=WBA_10.ftq upper=1 lower=7
WBA_11=WBA_11.ftq upper=1 lower=7
WBA_12=WBA_12.ftq upper=1 lower=7
```

WBA_13=WBA_13.ftq upper=1 lower=7

WBA_14=WBA_14.ftq upper=1 lower=7

WBA_16=WBA_16.ftq upper=1 lower=7

WBA_18=WBA_18.ftq upper=1 lower=7

WBA_19=WBA_19.ftq upper=1 lower=7

WBA_20=WBA_20.ftq upper=1 lower=7

WBA_21=WBA_21.ftq upper=1 lower=7

WBA_22=WBA_22.ftq upper=1 lower=7

WBA_23=WBA_23.ftq upper=1 lower=7

WBA_24=WBA_24.ftq upper=1 lower=7

WBA_25=WBA_25.ftq upper=1 lower=7

WBA_27=WBA_27.ftq upper=1 lower=7

WBA_07N=WBA_07N.ftq upper=1 lower=7

WBA_07S=WBA_07S.ftq upper=1 lower=7

WBA_08N=WBA_08N.ftq upper=1 lower=7

WBA_08NS=WBA_08NS.ftq upper=1 lower=7

WBA_08S=WBA_08S.ftq upper=1 lower=7

WBA_15N=WBA_15N.ftq upper=1 lower=7

WBA_15S=WBA_15S.ftq upper=1 lower=7

WBA_17N=WBA_17N.ftq upper=1 lower=7

WBA_17S=WBA_17S.ftq upper=1 lower=7

WBA_26N=WBA_26N.ftq upper=1 lower=7

WBA_26S=WBA_26S.ftq upper=1 lower=7

no_WBA_North=no_WBA_North.ftq upper=1 lower=7

no_WBA_South=no_WBA_South.ftq upper=1 lower=7

rem**********open ftq files for streams**********

LOAD

lb=SACFEM_v2_Streams_FTQ_042314.lb

open-q

AMERICAN_RIV=AMERICAN_RIV.ftq upper=1 lower=1

ANTELOPE_CR=ANTELOPE_CR.ftq upper=1 lower=1

AUBURN_RAVINE=AUBURN_RAVINE.ftq upper=1 lower=1

BEAR_RIV=BEAR_RIV.ftq upper=1 lower=1

BIG_CHICO_CR=BIG_CHICO_CR.ftq upper=1 lower=1

BLACK_BUTTE_RESERVOIR=BLACK_BUTTE_RESERVOIR.ftq upper=1 lower=1

BUTTE_BYPASS=BUTTE_BYPASS.ftq upper=1 lower=1

BUTTE_CR=BUTTE_CR.ftq upper=1 lower=1

CACHE_CR=CACHE_CR.ftq upper=1 lower=1

COLUSA_BD=COLUSA_BD.ftq upper=1 lower=1

CONSUMNES_RIV=CONSUMNES_RIV.ftq upper=1 lower=1

COON_CR=COON_CR.ftq upper=1 lower=1

CORTINA_CR=CORTINA_CR.ftq upper=1 lower=1

DEER_CR_BUTTECO=DEER_CR_BUTTECO.ftq upper=1 lower=1

DEER_CR_CONSUMNES=DEER_CR_CONSUMNES.ftq upper=1 lower=1

DRY_CR_PUTAH=DRY_CR_PUTAH.ftq upper=1 lower=1

DRY_CR_YUBA=DRY_CR_YUBA.ftq upper=1 lower=1

EASTSIDE_CROSS_CANAL=EASTSIDE_CROSS_CANAL.ftq upper=1 lower=1

ELDER_CR=ELDER_CR.ftq upper=1 lower=1

FEATHER_RIV=FEATHER_RIV.ftq upper=1 lower=1

FRENCH_CR=FRENCH_CR.ftq upper=1 lower=1

FRESHWATER_CR=FRESHWATER_CR.ftq upper=1 lower=1

FUNKS_CR=FUNKS_CR.ftq upper=1 lower=1

GCID_CANAL=GCID_CANAL.ftq upper=1 lower=1

HONCUT_CR=HONCUT_CR.ftq upper=1 lower=1

LITTLE_CHICO_CR=LITTLE_CHICO_CR.ftq upper=1 lower=1

LURLINE_CR=LURLINE_CR.ftq upper=1 lower=1

MILL_CR_BUTTECO=MILL_CR_BUTTECO.ftq upper=1 lower=1

MILL_CR_THOMES=MILL_CR_THOMES.ftq upper=1 lower=1

MOKELUMNE_RIV=MOKELUMNE_RIV.ftq upper=1 lower=1

N_HONCUT_CR=N_HONCUT_CR.ftq upper=1 lower=1

NF_WALKER_CR=NF_WALKER_CR.ftq upper=1 lower=1

PAYNES_CR=PAYNES_CR.ftq upper=1 lower=1

PUTAH_CR=PUTAH_CR.ftq upper=1 lower=1

RD108_MAIN_DRAIN=RD108_MAIN_DRAIN.ftq upper=1 lower=1

S_HONCUT_CR=S_HONCUT_CR.ftq upper=1 lower=1

SACRAMENTO_RIV=SACRAMENTO_RIV.ftq upper=1 lower=1

SALT_RIV=SALT_RIV.ftq upper=1 lower=1

SAN_JOAQUIN_RIV=SAN_JOAQUIN_RIV.ftq upper=1 lower=1

SAND_CR=SAND_CR.ftq upper=1 lower=1

SEVENMILE_CR=SEVENMILE_CR.ftq upper=1 lower=1

SF_WILLOW_CR=SF_WILLOW_CR.ftq upper=1 lower=1

SPRING_VALLEY_CR=SPRING_VALLEY_CR.ftq upper=1 lower=1

STONE_CORRAL_CR=STONE_CORRAL_CR.ftq upper=1 lower=1

STONEY_CR=STONEY_CR.ftq upper=1 lower=1

SUTTER_BYPASS=SUTTER_BYPASS.ftq upper=1 lower=1

SYCAMORE_SLOUGH_LOWER=SYCAMORE_SLOUGH_LOWER.ftq upper=1 lower=1

SYCAMORE_SLOUGH_UPPER=SYCAMORE_SLOUGH_UPPER.ftq upper=1 lower=1

THERMALITO=THERMALITO.ftq upper=1 lower=1

THOMES_CR=THOMES_CR.ftq upper=1 lower=1

WALKER_CR=WALKER_CR.ftq upper=1 lower=1

WILKINS_SLOUGH_CANAL=WILKINS_SLOUGH_CANAL.ftq upper=1 lower=1

WILLOW_CR=WILLOW_CR.ftq upper=1 lower=1

WILSON_CR=WILSON_CR.ftq upper=1 lower=1

YOLO_BYPASS=YOLO_BYPASS.ftq upper=1 lower=1

YUBA_RIV=YUBA_RIV.ftq upper=1 lower=1

********open fth for WDL wells********

load

lb=SACFEM_v2_WDL_Wells.lb

open-h

^=WDL_Hydrographs.fth upper=1 lower=7

********assign initial heads********

load

h1=SACFEM_v2_09_86_Initial.h1

h2=SACFEM_v2_09_86_Initial.h2

h3=SACFEM_v2_09_86_Initial.h3

h4=SACFEM_v2_09_86_Initial.h4

h5=SACFEM_v2_09_86_Initial.h5

h6=SACFEM_v2_09_86_Initial.h6

h7=SACFEM_v2_09_86_Initial.h7

rem**********

rem BEGIN TRANSIENT SIMULATION

rem**********

```
rem**********assign mountain-front recharge**********
LOAD
lb =SACFEM_v2_VoidPolygons2013_v2.lb
q1=zero.par
q2=zero.par
q3=zero.par
q4=zero.par
q5=zero.par
q6=zero.par
q7=zero.par
EVAL
x22=8071480 label=1
x22=35050083 label=2
x22=80605692 label=3
x22=76028964 label=4
x22=229983341 label=5
x22=949454 label=6
x22=3220633 label=7
x22=111833985 label=8
x22=897801 label=9
x22=22812497 label=10
x22=9639695 label=11
x22=6424725 label=12
x22=15522224 label=13
x22=4100614 label=14
x22=3571035 label=15
x22=20167473 label=16
x22=42791390 label=17
x22=9736556 label=18
x22=44503920 label=19
x22=2034253 label=20
x22=56249042 label=21
x22=776695 label=22
x22=7543586 label=23
```

x22=5209652 label=24

x22=1555595 label=25

x22=501520 label=26

x22=17635217 label=27

x22=5532887 label=28

x22=2311739 label=29

x22=2613399 label=30

x22=12198098 label=31

x22=2633584 label=32

x22=43738528 label=33

x22=57825106 label=34

rem**********adjust mountain-front recharge**********

LOAD

x23=SACFEM_v2_MtnFront_L_Factor_2013_v2.par

EVAL

x22=p*0.030*0.50/31 label=1

x22=p*0.030*0.50/31 label=2

x22=p*0.030*0.50/31 label=3

x22=p*0.030*0.50/31 label=4

x22=p*0.030*0.50/31 label=5

x22=p*0.030*1.00/31 label=6

x22=p*0.030*1.00/31 label=7

x22=p*0.030*1.00/31 label=8

x22=p*0.030*1.00/31 label=9

x22=p*0.030*1.00/31 label=10

x22=p*0.030*1.00/31 label=11

x22=p*0.030*1.00/31 label=12

x22=p*0.030*1.00/31 label=13

x22=p*0.030*1.50/31 label=14

x22=p*0.030*1.50/31 label=15

x22=p*0.030*1.50/31 label=16

x22=p*0.030*0.50/31 label=17

x22=p*0.030*0.50/31 label=18

x22=p*0.030*1.50/31 label=19

x22=p*0.030*1.00/31 label=20

```
x22=p*0.030*1.00/31 label=21
x22=p*0.030*1.50/31 label=22
x22=p*0.030*1.50/31 label=23
x22=p*0.030*1.00/31 label=24
x22=p*0.030*1.00/31 label=25
x22=p*0.030*1.00/31 label=26
x22=p*0.030*1.00/31 label=27
x22=p*0.030*1.00/31 label=28
x22=p*0.030*1.00/31 label=29
x22=p*0.030*1.00/31 label=30
x22=p*0.030*1.00/31 label=31
x22=p*0.030*1.00/31 label=32
x22=p*0.030*1.00/31 label=33
x22=p*0.030*1.00/31 label=34
q1=x22*x23*-1
Save Q1=10_69.q1

rem**********Normal/Wet Water Year**********
LOAD
storativity=SACFEM_v2.sto
wl1=SACFEM_v2_WL1_042314.par
dh1=SACFEM_v2_GSE_Combined_mNAVD88_120313.par
PPN=10_69.ppn
WH1=10_69.wh1
WC1=10_69.wc1
DC1=10_69.dc1
Q1=10_69.q1
Q2=10_69.q2
Q3=10_69.q3
Q4=10_69.q4

TIME
 days=31
 steps=1
```

```
RUN
 itmin=50
 itmax=600
 relax=0
 error=0.005
 m3error=1

SAVE
 h1=10_69.h1
 h2=10_69.h2
 h3=10_69.h3
 h4=10_69.h4
 h5=10_69.h5
 h6=10_69.h6
 h7=10_69.h7

rem**********assign mountain-front recharge**********
LOAD
lb =SACFEM_v2_VoidPolygons2013_v2.lb
q1=zero.par
q2=zero.par
q3=zero.par
q4=zero.par
q5=zero.par
q6=zero.par
q7=zero.par
EVAL
x22=8071480 label=1
x22=35050083 label=2
x22=80605692 label=3
x22=76028964 label=4
x22=229983341 label=5
x22=949454 label=6
x22=3220633 label=7
x22=111833985 label=8
```

x22=897801 label=9

x22=22812497 label=10

x22=9639695 label=11

x22=6424725 label=12

x22=15522224 label=13

x22=4100614 label=14

x22=3571035 label=15

x22=20167473 label=16

x22=42791390 label=17

x22=9736556 label=18

x22=44503920 label=19

x22=2034253 label=20

x22=56249042 label=21

x22=776695 label=22

x22=7543586 label=23

x22=5209652 label=24

x22=1555595 label=25

x22=501520 label=26

x22=17635217 label=27

x22=5532887 label=28

x22=2311739 label=29

x22=2613399 label=30

x22=12198098 label=31

x22=2633584 label=32

x22=43738528 label=33

x22=57825106 label=34

rem**********adjust mountain-front recharge**********

LOAD

x23=SACFEM_v2_MtnFront_L_Factor_2013_v2.par

EVAL

x22=p*0.049*0.50/30 label=1

x22=p*0.049*0.50/30 label=2

x22=p*0.049*0.50/30 label=3

x22=p*0.049*0.50/30 label=4

x22=p*0.049*0.50/30 label=5

```
x22=p*0.049*1.00/30 label=6
x22=p*0.049*1.00/30 label=7
x22=p*0.049*1.00/30 label=8
x22=p*0.049*1.00/30 label=9
x22=p*0.049*1.00/30 label=10
x22=p*0.049*1.00/30 label=11
x22=p*0.049*1.00/30 label=12
x22=p*0.049*1.00/30 label=13
x22=p*0.049*1.50/30 label=14
x22=p*0.049*1.50/30 label=15
x22=p*0.049*1.50/30 label=16
x22=p*0.049*0.50/30 label=17
x22=p*0.049*0.50/30 label=18
x22=p*0.049*1.50/30 label=19
x22=p*0.049*1.00/30 label=20
x22=p*0.049*1.00/30 label=21
x22=p*0.049*1.50/30 label=22
x22=p*0.049*1.50/30 label=23
x22=p*0.049*1.00/30 label=24
x22=p*0.049*1.00/30 label=25
x22=p*0.049*1.00/30 label=26
x22=p*0.049*1.00/30 label=27
x22=p*0.049*1.00/30 label=28
x22=p*0.049*1.00/30 label=29
x22=p*0.049*1.00/30 label=30
x22=p*0.049*1.00/30 label=31
x22=p*0.049*1.00/30 label=32
x22=p*0.049*1.00/30 label=33
x22=p*0.049*1.00/30 label=34
q1=x22*x23*-1
Save Q1=11_69.q1

rem**********Normal/Wet Water Year**********
LOAD
PPN=11_69.ppn
```

```
WH1=11_69.wh1
WC1=11_69.wc1
DC1=11_69.dc1
Q1=11_69.q1
Q2=11_69.q2
Q3=11_69.q3
Q4=11_69.q4

TIME
 days=30
 steps=1

RUN
 itmin=50
 itmax=600
 relax=0
 error=0.005
 m3error=1

SAVE
 h1=11_69.h1
 h2=11_69.h2
 h3=11_69.h3
 h4=11_69.h4
 h5=11_69.h5
 h6=11_69.h6
 h7=11_69.h7

rem**********assign mountain-front recharge**********
LOAD
lb =SACFEM_v2_VoidPolygons2013_v2.lb
q1=zero.par
q2=zero.par
q3=zero.par
q4=zero.par
```

q5=zero.par

q6=zero.par

q7=zero.par

EVAL

x22=8071480 label=1

x22=35050083 label=2

x22=80605692 label=3

x22=76028964 label=4

x22=229983341 label=5

x22=949454 label=6

x22=3220633 label=7

x22=111833985 label=8

x22=897801 label=9

x22=22812497 label=10

x22=9639695 label=11

x22=6424725 label=12

x22=15522224 label=13

x22=4100614 label=14

x22=3571035 label=15

x22=20167473 label=16

x22=42791390 label=17

x22=9736556 label=18

x22=44503920 label=19

x22=2034253 label=20

x22=56249042 label=21

x22=776695 label=22

x22=7543586 label=23

x22=5209652 label=24

x22=1555595 label=25

x22=501520 label=26

x22=17635217 label=27

x22=5532887 label=28

x22=2311739 label=29

x22=2613399 label=30

x22=12198098 label=31

x22=2633584 label=32

x22=43738528 label=33

x22=57825106 label=34

rem**********adjust mountain-front recharge**********

LOAD

x23=SACFEM_v2_MtnFront_L_Factor_2013_v2.par

EVAL

x22=p*0.102*0.50/31 label=1

x22=p*0.102*0.50/31 label=2

x22=p*0.102*0.50/31 label=3

x22=p*0.102*0.50/31 label=4

x22=p*0.102*0.50/31 label=5

x22=p*0.102*1.00/31 label=6

x22=p*0.102*1.00/31 label=7

x22=p*0.102*1.00/31 label=8

x22=p*0.102*1.00/31 label=9

x22=p*0.102*1.00/31 label=10

x22=p*0.102*1.00/31 label=11

x22=p*0.102*1.00/31 label=12

x22=p*0.102*1.00/31 label=13

x22=p*0.102*1.50/31 label=14

x22=p*0.102*1.50/31 label=15

x22=p*0.102*1.50/31 label=16

x22=p*0.102*0.50/31 label=17

x22=p*0.102*0.50/31 label=18

x22=p*0.102*1.50/31 label=19

x22=p*0.102*1.00/31 label=20

x22=p*0.102*1.00/31 label=21

x22=p*0.102*1.50/31 label=22

x22=p*0.102*1.50/31 label=23

x22=p*0.102*1.00/31 label=24

x22=p*0.102*1.00/31 label=25

x22=p*0.102*1.00/31 label=26

x22=p*0.102*1.00/31 label=27

x22=p*0.102*1.00/31 label=28

```
x22=p*0.102*1.00/31 label=29
x22=p*0.102*1.00/31 label=30
x22=p*0.102*1.00/31 label=31
x22=p*0.102*1.00/31 label=32
x22=p*0.102*1.00/31 label=33
x22=p*0.102*1.00/31 label=34
q1=x22*x23*-1
Save Q1=12_69.q1

rem**********Normal/Wet Water Year**********
LOAD
PPN=12_69.ppn
WH1=12_69.wh1
WC1=12_69.wc1
DC1=12_69.dc1
Q1=12_69.q1
Q2=12_69.q2
Q3=12_69.q3
Q4=12_69.q4

TIME
 days=31
 steps=1

RUN
 itmin=50
 itmax=600
 relax=0
 error=0.005
 m3error=1

SAVE
 h1=12_69.h1
 h2=12_69.h2
 h3=12_69.h3
```

```
 h4=12_69.h4
 h5=12_69.h5
 h6=12_69.h6
 h7=12_69.h7

rem**********assign mountain-front recharge**********
LOAD
lb =SACFEM_v2_VoidPolygons2013_v2.lb
q1=zero.par
q2=zero.par
q3=zero.par
q4=zero.par
q5=zero.par
q6=zero.par
q7=zero.par
EVAL
x22=8540053 label=1
x22=37478822 label=2
x22=84904385 label=3
x22=77394633 label=4
x22=232419920 label=5
x22=887594 label=6
x22=3023540 label=7
x22=105745704 label=8
x22=867913 label=9
x22=21415694 label=10
x22=9077969 label=11
x22=5757600 label=12
x22=13543439 label=13
x22=3414958 label=14
x22=2899943 label=15
x22=17517225 label=16
x22=35852152 label=17
x22=8297912 label=18
x22=46602663 label=19
```

x22=2184550 label=20

x22=59413680 label=21

x22=798035 label=22

x22=7919410 label=23

x22=5539452 label=24

x22=1670086 label=25

x22=545398 label=26

x22=19199301 label=27

x22=6086705 label=28

x22=2445877 label=29

x22=2748554 label=30

x22=13039352 label=31

x22=2866293 label=32

x22=51790487 label=33

x22=55248914 label=34

rem**********adjust mountain-front recharge**********

LOAD

x23=SACFEM_v2_MtnFront_L_Factor_2013_v2.par

EVAL

x22=p*0.142*0.50/31 label=1

x22=p*0.142*0.50/31 label=2

x22=p*0.142*0.50/31 label=3

x22=p*0.142*0.50/31 label=4

x22=p*0.142*0.50/31 label=5

x22=p*0.142*1.00/31 label=6

x22=p*0.142*1.00/31 label=7

x22=p*0.142*1.00/31 label=8

x22=p*0.142*1.00/31 label=9

x22=p*0.142*1.00/31 label=10

x22=p*0.142*1.00/31 label=11

x22=p*0.142*1.00/31 label=12

x22=p*0.142*1.00/31 label=13

x22=p*0.142*1.50/31 label=14

x22=p*0.142*1.50/31 label=15

x22=p*0.142*1.50/31 label=16

```
x22=p*0.142*0.50/31 label=17
x22=p*0.142*0.50/31 label=18
x22=p*0.142*1.50/31 label=19
x22=p*0.142*1.00/31 label=20
x22=p*0.142*1.00/31 label=21
x22=p*0.142*1.50/31 label=22
x22=p*0.142*1.50/31 label=23
x22=p*0.142*1.00/31 label=24
x22=p*0.142*1.00/31 label=25
x22=p*0.142*1.00/31 label=26
x22=p*0.142*1.00/31 label=27
x22=p*0.142*1.00/31 label=28
x22=p*0.142*1.00/31 label=29
x22=p*0.142*1.00/31 label=30
x22=p*0.142*1.00/31 label=31
x22=p*0.142*1.00/31 label=32
x22=p*0.142*1.00/31 label=33
x22=p*0.142*1.00/31 label=34
q1=x22*x23*-1
Save Q1=01_70.q1

rem**********Normal/Wet Water Year**********
LOAD
PPN=01_70.ppn
WH1=01_70.wh1
WC1=01_70.wc1
DC1=01_70.dc1
Q1=01_70.q1
Q2=01_70.q2
Q3=01_70.q3
Q4=01_70.q4

TIME
 days=31
 steps=1
```

```
RUN
 itmin=50
 itmax=600
 relax=0
 error=0.005
 m3error=1

SAVE
 h1=01_70.h1
 h2=01_70.h2
 h3=01_70.h3
 h4=01_70.h4
 h5=01_70.h5
 h6=01_70.h6
 h7=01_70.h7

rem**********assign mountain-front recharge**********
LOAD
lb =SACFEM_v2_VoidPolygons2013_v2.lb
q1=zero.par
q2=zero.par
q3=zero.par
q4=zero.par
q5=zero.par
q6=zero.par
q7=zero.par
EVAL
x22=8540053 label=1
x22=37478822 label=2
x22=84904385 label=3
x22=77394633 label=4
x22=232419920 label=5
x22=887594 label=6
x22=3023540 label=7
```

x22=105745704 label=8

x22=867913 label=9

x22=21415694 label=10

x22=9077969 label=11

x22=5757600 label=12

x22=13543439 label=13

x22=3414958 label=14

x22=2899943 label=15

x22=17517225 label=16

x22=35852152 label=17

x22=8297912 label=18

x22=46602663 label=19

x22=2184550 label=20

x22=59413680 label=21

x22=798035 label=22

x22=7919410 label=23

x22=5539452 label=24

x22=1670086 label=25

x22=545398 label=26

x22=19199301 label=27

x22=6086705 label=28

x22=2445877 label=29

x22=2748554 label=30

x22=13039352 label=31

x22=2866293 label=32

x22=51790487 label=33

x22=55248914 label=34

rem**********adjust mountain-front recharge**********

LOAD

x23=SACFEM_v2_MtnFront_L_Factor_2013_v2.par

EVAL

x22=p*0.152*0.50/28 label=1

x22=p*0.152*0.50/28 label=2

x22=p*0.152*0.50/28 label=3

x22=p*0.152*0.50/28 label=4

```
x22=p*0.152*0.50/28 label=5
x22=p*0.152*1.00/28 label=6
x22=p*0.152*1.00/28 label=7
x22=p*0.152*1.00/28 label=8
x22=p*0.152*1.00/28 label=9
x22=p*0.152*1.00/28 label=10
x22=p*0.152*1.00/28 label=11
x22=p*0.152*1.00/28 label=12
x22=p*0.152*1.00/28 label=13
x22=p*0.152*1.50/28 label=14
x22=p*0.152*1.50/28 label=15
x22=p*0.152*1.50/28 label=16
x22=p*0.152*0.50/28 label=17
x22=p*0.152*0.50/28 label=18
x22=p*0.152*1.50/28 label=19
x22=p*0.152*1.00/28 label=20
x22=p*0.152*1.00/28 label=21
x22=p*0.152*1.50/28 label=22
x22=p*0.152*1.50/28 label=23
x22=p*0.152*1.00/28 label=24
x22=p*0.152*1.00/28 label=25
x22=p*0.152*1.00/28 label=26
x22=p*0.152*1.00/28 label=27
x22=p*0.152*1.00/28 label=28
x22=p*0.152*1.00/28 label=29
x22=p*0.152*1.00/28 label=30
x22=p*0.152*1.00/28 label=31
x22=p*0.152*1.00/28 label=32
x22=p*0.152*1.00/28 label=33
x22=p*0.152*1.00/28 label=34
q1=x22*x23*-1
Save Q1=02_70.q1

rem**********Normal/Wet Water Year**********
LOAD
```

PPN=02_70.ppn

WH1=02_70.wh1

WC1=02_70.wc1

DC1=02_70.dc1

Q1=02_70.q1

Q2=02_70.q2

Q3=02_70.q3

Q4=02_70.q4

TIME

days=28

steps=1

RUN

itmin=50

itmax=600

relax=0

error=0.005

m3error=1

SAVE

h1=02_70.h1

h2=02_70.h2

h3=02_70.h3

h4=02_70.h4

h5=02_70.h5

h6=02_70.h6

h7=02_70.h7

<<THE LOOPING PORTION OF SACFEM2013.FEB CONTINUES FOLLOWING SIMILAR SYNTAX AS THE PRECEDING STRESS PERIODS THROUGH SEPTEMBER 2010.>>

# Appendix I

# Air Quality Emission Calculations

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**Table I-1. General Conformity Applicability Evaluation (Unmitigated Emissions)**

| County/ Nonattainment Area | Emissions (tons per year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | VOC | NOx | CO | SOx | | PM10 | PM2.5 | |
| | Sacramento Metro[1,5] | Sacramento Metro[1,5] | Sacramento Area[2] | Sacramento[3,4] | Yuba City-Marysville[6] | Sacramento Co. | Sacramento[4] | Yuba City-Marysville[6] |
| Colusa | -- | -- | -- | -- | -- | -- | -- | -- |
| Glenn | -- | -- | -- | -- | -- | -- | -- | -- |
| Sacramento | 2.1 | 71.9 | 5.6 | 0.010 | -- | 0.2 | 0.2 | -- |
| Shasta | -- | -- | -- | -- | -- | -- | -- | -- |
| Solano | 0.0 | 0.0 | -- | -- | -- | -- | -- | -- |
| Sutter | 2.3 | 19.5 | -- | -- | 3.1 | -- | -- | 0.8 |
| Tehama | -- | -- | -- | -- | -- | -- | -- | -- |
| Yolo | 0.7 | 7.9 | -- | -- | -- | -- | -- | -- |
| Yuba | -- | -- | -- | -- | 0.0 | -- | -- | 0.0 |
| Total | 5.1 | 99.3 | 5.6 | 0.010 | 3.1 | 0.2 | 0.2 | 0.8 |
| Classification | Severe | Severe | Maintenance | PM2.5 Precursor | PM2.5 Precursor | Maintenance | Nonattainment | Nonattainment |
| De Minimis Threshold (tpy) | 25 | 25 | 100 | 100 | 100 | 100 | 100 | 100 |
| Exceed? | No | Yes | No | No | No | No | No | No |

Note:
[1]The Sacramento Metro 8-hour O3 nonattainment area consists of Sacramento and Yolo Counties and parts of El Dorado, Placer, Solano, and Sutter Counties. Emissions occurring within the attainment area of these counties are excluded from the total emissions.
[2]The Sacramento Area CO maintenance area is based on the Census Bureau Urbanized Area and consists of parts of Placer, Sacramento, and Yolo Counties. The general conformity applicability evaluation is based on emissions that would occur within the entire county to be conservative.
[3]All counties are designated as attainment areas for SO2; however, since SO2 is a precursor to PM2.5, its emissions must be evaluated under general conformity.
[4]The 24-hour PM2.5 nonattainment area for Sacramento includes Sacramento County and parts of El Dorado, Placer, Solano, and Yolo Counties. The general conformity applicability analysis assumes that all emissions that could occur within each county would occur within the Sacramento nonattainment area to be conservative.
[5]VOC and NOx emissions are excluded from Sutter County for Cranmore Farms, Garden Highway Mutual Water Company, Gilsizer Slough Ranch, Pelger Mutual Water Company, Reclamation District 1004, and Tule Basin Farms because they are located in areas designated as attainment for the federal 8-hour O3 NAAQS.

**Table I-2. Emissions Outside of 8-Hour Ozone Nonattainment Area (tons per year)**

| Water Agency | County | VOC | NOx |
|---|---|---|---|
| Cranmore Farms | Sutter | Electric | Electric |
| Garden Highway Mutual Water Company | Sutter | Electric | Electric |
| Gilsizer Slough Ranch | Sutter | 0.7 | 8.8 |
| Pelger Mutual Water Company | Sutter | 0.1 | 1.2 |
| Reclamation District 1004 | Sutter | n/a | n/a |
| Tule Basin Farms | Sutter | 0.3 | 9.4 |
| Total | | 1.0 | 19.3 |

## Summary of Daily Groundwater Substitution Emissions by County (Unmitigated)

**Table I-3. Daily VOC Emissions**

| Water Agency | Daily VOC Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 13.32 | | 13.32 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.55 | | | | | | | | | 1.55 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.92 | | | | 0.92 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 33.08 | | Electric | | 33.08 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 27.07 | 3.98 | | | | n/a | | | | 31.05 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 22.78 | | | | | | | 22.78 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 9.62 | | | | 9.62 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 3.70 | | | | 3.70 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **28.61** | **3.98** | **22.78** | **0.00** | **0.00** | **47.32** | **0.00** | **13.32** | **0.00** | **116.02** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Unmitigated)

**Table I-4. Daily NOx Emissions**

| Water Agency | Daily NOx Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 147.70 | | 147.70 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 29.38 | | | | | | | | | 29.38 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 17.49 | | | | 17.49 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 285.31 | | Electric | | 285.31 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 354.91 | 49.10 | | | | n/a | | | | 404.01 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 787.78 | | | | | | | 787.78 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 118.61 | | | | 118.61 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 128.06 | | | | 128.06 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **384.29** | **49.10** | **787.78** | **0.00** | **0.00** | **549.47** | **0.00** | **147.70** | **0.00** | **1,918.33** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Unmitigated)

**Table I-5. Daily CO Emissions**

| Water Agency | Daily CO Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 125.01 | | 125.01 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 27.06 | | | | | | | | | 27.06 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 23.01 | | | | 23.01 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 125.64 | | Electric | | 125.64 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 118.57 | 10.58 | | | | n/a | | | | 129.15 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 61.21 | | | | | | | 61.21 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 25.56 | | | | 25.56 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 9.95 | | | | 9.95 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **145.63** | **10.58** | **61.21** | **0.00** | **0.00** | **184.16** | **0.00** | **125.01** | **0.00** | **526.59** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Unmitigated)

**Table I-6. Daily SOx Emissions**

| Water Agency | Daily SOx Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 25.40 | | 25.40 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 9.63 | | | | | | | | | 9.63 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 5.73 | | | | 5.73 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 31.29 | | Electric | | 31.29 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 36.05 | 3.25 | | | | n/a | | | | 39.29 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.11 | | | | | | | 0.11 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 7.84 | | | | 7.84 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.02 | | | | 0.02 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **45.68** | **3.25** | **0.11** | **0.00** | **0.00** | **44.89** | **0.00** | **25.40** | **0.00** | **119.32** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Unmitigated)

**Table I-7. Daily PM10 Emissions**

| Water Agency | Daily PM10 Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 6.39 | | 6.39 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.55 | | | | | | | | | 1.55 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.38 | | | | 1.38 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 8.13 | | Electric | | 8.13 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 6.37 | 0.52 | | | | n/a | | | | 6.90 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 1.93 | | | | | | | 1.93 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.86 | | | | 1.86 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.31 | | | | 0.31 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **7.92** | **0.52** | **1.93** | **0.00** | **0.00** | **11.68** | **0.00** | **6.39** | **0.00** | **28.43** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Unmitigated)

**Table I-8. Daily PM2.5 Emissions**

| Water Agency | Daily PM2.5 Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 6.39 | | 6.39 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.55 | | | | | | | | | 1.55 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.38 | | | | 1.38 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 8.00 | | Electric | | 8.00 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 6.30 | 0.51 | | | | n/a | | | | 6.81 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 1.93 | | | | | | | 1.93 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.81 | | | | 1.81 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.31 | | | | 0.31 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **7.84** | **0.51** | **1.93** | **0.00** | **0.00** | **11.50** | **0.00** | **6.39** | **0.00** | **28.17** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Unmitigated)

**Table I-9. Annual VOC Emissions**

| Water Agency | Annual VOC Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 0.71 | | 0.71 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.11 | | | | | | | | | 0.11 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.06 | | | | 0.06 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 2.26 | | Electric | | 2.26 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 1.03 | 0.15 | | | | n/a | | | | 1.18 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 2.08 | | | | | | | 2.08 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.71 | | | | 0.71 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.27 | | | | 0.27 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **1.14** | **0.15** | **2.08** | **0.00** | **0.00** | **3.31** | **0.00** | **0.71** | **0.00** | **7.39** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Unmitigated)

**Table I-10. Annual NOx Emissions**

| Water Agency | Annual NOx Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 7.89 | | 7.89 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 2.14 | | | | | | | | | 2.14 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.16 | | | | 1.16 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 19.53 | | Electric | | 19.53 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 13.49 | 1.87 | | | | n/a | | | | 15.36 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 71.89 | | | | | | | 71.89 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 8.79 | | | | 8.79 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 9.38 | | | | 9.38 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **15.64** | **1.87** | **71.89** | **0.00** | **0.00** | **38.86** | **0.00** | **7.89** | **0.00** | **136.14** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Unmitigated)

**Table I-11. Annual CO Emissions**

| Water Agency | Annual CO Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 6.68 | | 6.68 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.97 | | | | | | | | | 1.97 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.53 | | | | 1.53 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 8.60 | | Electric | | 8.60 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 4.51 | 0.40 | | | | n/a | | | | 4.91 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 5.59 | | | | | | | 5.59 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.89 | | | | 1.89 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.73 | | | | 0.73 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **6.48** | **0.40** | **5.59** | **0.00** | **0.00** | **12.75** | **0.00** | **6.68** | **0.00** | **31.89** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Unmitigated)

**Table I-12. Annual SOx Emissions**

| Water Agency | Annual SOx Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 1.36 | | 1.36 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.70 | | | | | | | | | 0.70 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.38 | | | | 0.38 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 2.14 | | Electric | | 2.14 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 1.37 | 0.12 | | | | n/a | | | | 1.49 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.01 | | | | | | | 0.01 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.58 | | | | 0.58 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.00 | | | | 0.00 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **2.07** | **0.12** | **0.01** | **0.00** | **0.00** | **3.10** | **0.00** | **1.36** | **0.00** | **6.67** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Unmitigated)

**Table I-13. Annual PM10 Emissions**

| Water Agency | Annual PM10 Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 0.34 | | 0.34 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.11 | | | | | | | | | 0.11 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.09 | | | | 0.09 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 0.56 | | Electric | | 0.56 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 0.24 | 0.02 | | | | n/a | | | | 0.26 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.18 | | | | | | | 0.18 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.14 | | | | 0.14 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.02 | | | | 0.02 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **0.36** | **0.02** | **0.18** | **0.00** | **0.00** | **0.81** | **0.00** | **0.34** | **0.00** | **1.70** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Unmitigated)

**Table I-14. Annual PM2.5 Emissions**

| Water Agency | Annual PM2.5 Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 0.34 | | 0.34 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.11 | | | | | | | | | 0.11 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.09 | | | | 0.09 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 0.55 | | Electric | | 0.55 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 0.24 | 0.02 | | | | n/a | | | | 0.26 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.18 | | | | | | | 0.18 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.13 | | | | 0.13 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.02 | | | | 0.02 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **0.35** | **0.02** | **0.18** | **0.00** | **0.00** | **0.80** | **0.00** | **0.34** | **0.00** | **1.68** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | |
|---|---|---|
| Agency | Anderson-Cottonwood Irrigation District | |
| Transfer Volume | 5,226 | acre feet/year |
| Location | Shasta | County |
| | Tehama | County |

Federal Attainment Status

| | *Shasta* | *Tehama* | |
|---|---|---|---|
| PM10 | A | A | *Engines not subject to ATCM if remotely-located.* |
| PM2.5 | A | A | |
| O3 | A | A | |

**Table I-15. Anderson-Cottonwood Irrigation District Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Barney Street | Barney Street | Shasta | Electric | 2012 | 200 | n/a | 5,500 | 85% | 737 | 4,422 | 24 | 4,366 |
| Crowley Gulch | Crowley Gulch | Shasta | Electric | 2012 | 50 | n/a | 1,000 | 15% | 134 | 804 | 24 | 4,366 |
| | | | | | | **Total** | **6,500** | **100%** | **871** | **5,226** | **48** | **8,733** |
| | | | | | | **Total (Shasta County)** | **6,500** | **100%** | **871** | **5,226** | **48** | **8,733** |
| | | | | | | **Total (Tehama County)** | **0** | **0** | **0** | **0** | **0** | **0** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | |
|---|---|---|---|---|---|
| Agency | Conaway Preservation Group | Federal Attainment Status | | | Peak Month |
| Transfer Volume | 35,000 acre feet/year | PM10 | A | *Engines subject to ATCM.* | 9,964 AF/month |
| Location | Yolo County | PM2.5 | N | | 72,735 gallons/minute |
| | | O3 | N | | 74% peak pump rate |

**Table I-16. Conaway Preservation Group Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ConawayPG12W-1 | 12W-1 | Yolo | Electric | | 250 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG12W-2 | 12W-2 | Yolo | Electric | TBD | 250 | n/a | 2,500 | 3% | 255 | 895 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG12W-5 | 12W-5 | Yolo | Electric | TBD | 250 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG13W-3 | 13W-3 | Yolo | Electric | | 200 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG16W-2 | 16W-2 | Yolo | Diesel | 2005 | 227 | T2 | 1,600 | 2% | 163 | 573 | 18 | 1,944 | 24,751 | 0.2 | 4.7 | 2.6 | 0.93 | 0.15 | 0.15 | 2.24 | 42.60 | 23.78 | 8.47 | 1.36 | 1.36 | 0.12 | 2.28 | 1.27 | 0.45 | 0.07 | 0.07 |
| ConawayPG17W-3 | 17W-3 | Yolo | Diesel | 2005 | 227 | T2 | 1,700 | 2% | 173 | 608 | 18 | 1,944 | 24,751 | 0.2 | 4.7 | 2.6 | 0.93 | 0.15 | 0.15 | 2.24 | 42.60 | 23.78 | 8.47 | 1.36 | 1.36 | 0.12 | 2.28 | 1.27 | 0.45 | 0.07 | 0.07 |
| ConawayPG1W-3 | 1W-3 | Yolo | Electric | | 250 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG20W-1 | 20W-1 | Yolo | Electric | | 100 | n/a | 2,500 | 3% | 255 | 895 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG21W-1 | 21W-1 | Yolo | Electric | TBD | 250 | n/a | 2,500 | 3% | 255 | 895 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG21W-3 | 21W-3 | Yolo | Electric | | 100 | n/a | 2,500 | 3% | 255 | 895 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG24W-1 | 24W-1 | Yolo | Electric | TBD | 250 | n/a | 2,500 | 3% | 255 | 895 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG31W-1 | 31W-1 | Yolo | Electric | | 100 | n/a | 2,300 | 2% | 234 | 823 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG32NW-1 | 32NW-1 | Yolo | Electric | | 100 | n/a | 3,300 | 3% | 336 | 1,181 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG32NW-2 | 32NW-2 | Yolo | Electric | | 250 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG32W-3 | 32W-3 | Yolo | Electric | | 250 | n/a | 2,500 | 3% | 255 | 895 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-1 | 33NW-1 | Yolo | Electric | | 100 | n/a | 2,300 | 2% | 234 | 823 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-2 | 33NW-2 | Yolo | Electric | | 100 | n/a | 2,200 | 2% | 224 | 787 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-3 | 33NW-3 | Yolo | Electric | | 100 | n/a | 2,100 | 2% | 214 | 752 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-4 | 33NW-4 | Yolo | Electric | | 100 | n/a | 3,400 | 3% | 346 | 1,217 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-5 | 33NW-5 | Yolo | Electric | | 100 | n/a | 1,800 | 2% | 183 | 644 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-6 | 33NW-6 | Yolo | Electric | | 100 | n/a | 2,100 | 2% | 214 | 752 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-7 | 33NW-7 | Yolo | Electric | | 100 | n/a | 1,400 | 1% | 143 | 501 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG33NW-8 | 33NW-8 | Yolo | Electric | | 100 | n/a | 2,200 | 2% | 224 | 787 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG5W-2 | 5W-2 | Yolo | Electric | | 250 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG5W-3 | 5W-3 | Yolo | Electric | | 250 | n/a | 2,700 | 3% | 275 | 966 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG6W-2 | 6W-2 | Yolo | Electric | | 100 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG7W-1 | 7W-1 | Yolo | Electric | | 75 | n/a | 1,800 | 2% | 183 | 644 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG7W-2 | 7W-2 | Yolo | Electric | | 250 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG7W-4 | 7W-4 | Yolo | Electric | | 200 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG7W-4S | 7W-4S | Yolo | Electric | | 200 | n/a | 3,500 | 4% | 357 | 1,253 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPG8W-2 | 8W-2 | Yolo | Diesel | 2002 | 227 | T1 | 2,300 | 2% | 234 | 823 | 18 | 1,944 | 24,751 | 1.0 | 6.9 | 8.5 | 0.93 | 0.40 | 0.40 | 8.83 | 62.50 | 77.45 | 8.47 | 3.67 | 3.67 | 0.47 | 3.34 | 4.14 | 0.45 | 0.20 | 0.20 |
| ConawayPG8W-2N | 8W-2N | Yolo | Electric | | 200 | n/a | 1,500 | 2% | 153 | 537 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPGOW-1 | OW-1 | Yolo | Electric | | 100 | n/a | 2,600 | 3% | 265 | 930 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPGOW-2 | OW-2 | Yolo | Electric | | 100 | n/a | 3,400 | 3% | 346 | 1,217 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPGOW-3 | OW-3 | Yolo | Electric | | 125 | n/a | 3,400 | 3% | 346 | 1,217 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPGOW-4 | OW-4 | Yolo | Electric | | 100 | n/a | 1,700 | 2% | 173 | 608 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| ConawayPGOW-5 | OW-5 | Yolo | Electric | | 125 | n/a | 2,000 | 2% | 204 | 716 | 18 | 1,944 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **97,800** | **100%** | **9,964** | **35,000** | **673** | **71,912** | **74,253** | | | | | | | **13.32** | **147.70** | **125.01** | **25.40** | **6.39** | **6.39** | **0.71** | **7.89** | **6.68** | **1.36** | **0.34** | **0.34** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend

| | |
|---|---|
| | Assumed to be electric (similar to 32W-2) |
| | Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type |
| | Emission factor based on NMHC+NOx emission standard |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | | |
|---|---|---|
| 0.4 | lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 | g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 | lb/gal | |

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## Groundwater Substitution Air Quality Emissions (Unmitigated)

Agency: Cordua Irrigation District
Transfer Volume: 12,000 acre feet/year
Location: Yuba County

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | A | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | A | |

**Table I-17. Cordua Irrigation District Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COR1 | COR1 | Yuba | Electric | | 60 | n/a | 1,000 | 3% | 129 | 323 | 23 | 1,757 |
| COR2 | COR2 | Yuba | Electric | | 50 | n/a | 900 | 2% | 116 | 291 | 23 | 1,757 |
| COR3 | COR3 | Yuba | Electric | | 60 | n/a | 1,000 | 3% | 129 | 323 | 23 | 1,757 |
| COR4 | COR4 | Yuba | Electric | | 75 | n/a | 1,400 | 4% | 181 | 453 | 23 | 1,757 |
| COR5 | COR5 | Yuba | Electric | | 75 | n/a | 1,300 | 4% | 168 | 420 | 23 | 1,757 |
| COR8 | COR8 | Yuba | Electric | | 75 | n/a | 2,000 | 5% | 259 | 647 | 23 | 1,757 |
| COR9 | COR9 | Yuba | Electric | | 60 | n/a | 1,000 | 3% | 129 | 323 | 23 | 1,757 |
| COR10 | COR10 | Yuba | Electric | | 75 | n/a | 1,300 | 4% | 168 | 420 | 23 | 1,757 |
| COR11 | COR11 | Yuba | Electric | | 60 | n/a | 1,800 | 5% | 233 | 582 | 23 | 1,757 |
| COR12 | COR12 | Yuba | Electric | | 100 | n/a | 1,400 | 4% | 181 | 453 | 23 | 1,757 |
| COR13 | COR13 | Yuba | Electric | | 100 | n/a | 2,100 | 6% | 272 | 679 | 23 | 1,757 |
| COR14 | COR14 | Yuba | Electric | | 75 | n/a | 1,800 | 5% | 233 | 582 | 23 | 1,757 |
| COR18 | COR18 | Yuba | Electric | 2013 | 100 | n/a | 2,000 | 5% | 259 | 647 | 23 | 1,757 |
| COR20 | COR20 | Yuba | Electric | 2013 | 125 | n/a | 2,150 | 6% | 278 | 695 | 23 | 1,757 |
| COR21 | COR21 | Yuba | Electric | | 75 | n/a | 1,250 | 3% | 162 | 404 | 23 | 1,757 |
| COR22 | COR22 | Yuba | Electric | | 60 | n/a | 1,750 | 5% | 226 | 566 | 23 | 1,757 |
| COR23 | COR23 | Yuba | Electric | | 75 | n/a | 1,150 | 3% | 149 | 372 | 23 | 1,757 |
| COR25 | COR25 | Yuba | Electric | 2013 | 75 | n/a | 1,600 | 4% | 207 | 518 | 23 | 1,757 |
| COR26 | COR26 | Yuba | Electric | 2013 | 100 | n/a | 1,800 | 5% | 233 | 582 | 23 | 1,757 |
| COR27 | COR27 | Yuba | Electric | | 100 | n/a | 1,700 | 5% | 220 | 550 | 23 | 1,757 |
| COR16 | COR16 | Yuba | Electric | | 100 | n/a | 2,300 | 6% | 298 | 744 | 23 | 1,757 |
| COR17 | COR17 | Yuba | Electric | | 100 | n/a | 2,400 | 6% | 311 | 776 | 23 | 1,757 |
| COR24 | COR24 | Yuba | Electric | | 100 | n/a | 2,000 | 5% | 259 | 647 | 23 | 1,757 |
| | | | | | | **Total** | **37,100** | **100%** | **4,800** | **12,000** | **531** | **40,402** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

1 hour = 60 minutes
1 acre-foot = 325,851 gallons

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## Groundwater Substitution Air Quality Emissions (Unmitigated)

Agency Cranmore Farms
Transfer Volume 8,000 acre feet/year
Location Sutter County

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | A | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | N | |

**Table I-18. Cranmore Farms Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cranmore Farms1 | 1 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 17% | 343 | 1,333 | 20 | 2,414 |
| Cranmore Farms2 | 2 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 17% | 343 | 1,333 | 20 | 2,414 |
| Cranmore Farms3 | 3 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 17% | 343 | 1,333 | 20 | 2,414 |
| Cranmore Farms4 | 4 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 17% | 343 | 1,333 | 20 | 2,414 |
| Cranmore Farms5 | 5 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 17% | 343 | 1,333 | 20 | 2,414 |
| Cranmore Farms6 | 6 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 17% | 343 | 1,333 | 20 | 2,414 |
| | | | | | | **Total** | **18,000** | **100%** | **2,056** | **8,000** | **122** | **14,482** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

1 hour = 60 minutes
1 acre-foot = 325,851 gallons
http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Agency | Eastside Mutual Water Company | Federal Attainment Status | | | Peak Month | |
| Transfer Volume | 2,230 acre feet/year | PM10 | A | *Engines not subject to ATCM if remotely-located.* | 465 | AF/month |
| Location | Colusa County | PM2.5 | A | | 3,396 | gallons/minute |
| | | O3 | A | | 89% | peak pump rate |

**Table I-19. Eastside Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7631T | 7631T | Colusa | Diesel | 2006 | 215 | T3 | 3,800 | 100% | 465 | 2,230 | 22 | 3,187 | 38,441 | 0.1 | 2.8 | 2.6 | 0.93 | 0.15 | 0.15 | 1.55 | 29.38 | 27.06 | 9.63 | 1.55 | 1.55 | 0.11 | 2.14 | 1.97 | 0.70 | 0.11 | 0.11 |
| | | | | | | n/a | **3,800** | **100%** | **465** | **2,230** | **22** | **3,187** | **38,441** | | | | | | | **1.55** | **29.38** | **27.06** | **9.63** | **1.55** | **1.55** | **0.11** | **2.14** | **1.97** | **0.70** | **0.11** | **0.11** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend
Emission factor based on NMHC+NOx emission standard

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | | |
|---|---|---|
| 0.4 | lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 | g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 | lb/gal | |

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## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | |
|---|---|
| Agency | Glenn-Colusa Irrigation District |
| Transfer Volume | 25,000 acre feet/year |
| Location | Glenn County |
| | Colusa County |

Federal Attainment Status

| | *Glenn* | *Colusa* |
|---|---|---|
| PM10 | A | A |
| PM2.5 | A | A |
| O3 | A | A |

*Engines not subject to ATCM if remotely-located.*

**Table I-20. Glenn-Colusa Irrigation District Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GCID 1 | GCID 1 | Glenn | Electric | | 110 | n/a | 3,305 | 10% | 437 | 2,622 | 24 | 4,309 |
| GCID 2 | GCID 2 | Glenn | Electric | | 110 | n/a | 3,305 | 10% | 437 | 2,622 | 24 | 4,309 |
| GCID 3 | GCID 3 | Glenn | Electric | | 110 | n/a | 3,305 | 10% | 437 | 2,622 | 24 | 4,309 |
| GCID 4 | GCID 4 | Glenn | Electric | | 110 | n/a | 3,305 | 10% | 437 | 2,622 | 24 | 4,309 |
| GCID 5 | GCID 5 | Glenn | Electric | | 110 | n/a | 2,605 | 8% | 345 | 2,067 | 24 | 4,309 |
| GCID X1 | GCID X1 | Glenn | Electric | | 110 | n/a | 2,389 | 8% | 316 | 1,896 | 24 | 4,309 |
| GCID X2 | GCID X2 | Glenn | Electric | | 110 | n/a | 3,305 | 10% | 437 | 2,622 | 24 | 4,309 |
| GCID X3 | GCID X3 | Glenn | Electric | | 110 | n/a | 2,605 | 8% | 345 | 2,067 | 24 | 4,309 |
| GCID X4 | GCID X4 | Glenn | Electric | | 110 | n/a | 2,389 | 8% | 316 | 1,896 | 24 | 4,309 |
| GCID X5 | GCID X5 | Glenn | Electric | | 110 | n/a | 2,605 | 8% | 345 | 2,067 | 24 | 4,309 |
| Test Hole 7 | Test Hole 7 | Glenn | Electric | | 110 | n/a | 2,389 | 8% | 316 | 1,896 | 24 | 4,309 |
| | | | | | | **Total** | **31,507** | **100%** | **4,167** | **25,000** | **260** | **47,402** |
| | | | | | | **Total (Glenn County)** | **31,507** | **100%** | **4,167** | **25,000** | **260** | **47,402** |
| | | | | | | **Total (Colusa County)** | **0** | **0%** | **0** | **0** | **0** | **0** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

Assumed to be electric (similar to other wells operated by water agency)

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

Agency: Natomas Central Mutual Water Company
Transfer Volume: 30,000 acre feet/year
Location: Sacramento County, Sutter County

Federal Attainment Status

| | *Sacramento* | *Sutter* | |
|---|---|---|---|
| PM10 | M | A | *Engines subject to ATCM.* |
| PM2.5 | N | N | |
| O3 | N | N | |

**Table I-21. Natomas Central Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Natomas Central MWCWilley, Ed | Willey, Ed | Sacramento | Electric | | 250 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCOse, Mary-site 8, well 1 | Ose, Mary-site 8, well 1 | Sacramento | Electric | | 200 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCOse, Mary-site 9, well 2 | Ose, Mary-site 9, well 2 | Sacramento | Electric | | 150 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert-site 1 well 2 | Leal, Robert-site 1 well 2 | Sutter | Electric | | 100 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-1 | DeWitt, Jack-1 | Sacramento | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-2 | DeWitt, Jack-2 | Sacramento | Electric | | 80 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-3 | DeWitt, Jack-3 | Sacramento | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-4 | DeWitt, Jack-4 | Sacramento | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-5 | DeWitt, Jack-5 | Sacramento | Electric | | 20 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-6 | DeWitt, Jack-6 | Sacramento | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-7 | DeWitt, Jack-7 | Sutter | Electric | | 25 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack-7 | DeWitt, Jack-7 | Sutter | Electric | | 25 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCDeWitt, Jack--8 | DeWitt, Jack--8 | Sacramento | Electric | | 250 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCMorrison, Phil #2-site 5 well 14 | Morrison, Phil #2-site 5 well 14 | Sutter | Electric | | 40 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCBianchi, John- site 2, well 10 | Bianchi, John- site 2, well 10 | Sutter | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCBianchi, John-site 2 well 11 | Bianchi, John-site 2 well 11 | Sutter | Electric | | 80 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLauppe and Sons | Lauppe and Sons | Sutter | Electric | | 40 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCWiley, Wane-site 7 , well 18 | Wiley, Wane-site 7 , well 18 | Sacramento | Electric | | 40 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-1 (rice box) | Leal, Robert L-1 (rice box) | Sutter | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-3 | Leal, Robert L-3 | Sutter | Electric | | 50 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-4 | Leal, Robert L-4 | Sutter | Electric | | 110 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-5 | Leal, Robert L-5 | Sutter | Electric | | 110 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-6 | Leal, Robert L-6 | Sutter | Electric | | 110 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-7 | Leal, Robert L-7 | Sutter | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-8 | Leal, Robert L-8 | Sutter | Electric | | 200 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-9 | Leal, Robert L-9 | Sutter | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert L-2 | Leal, Robert L-2 | Sutter | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert #1 | Leal, Robert #1 | Sutter | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCLeal, Robert #2 | Leal, Robert #2 | Sutter | Electric | | 40 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCSpangler, Dan-site 4 well 13 | Spangler, Dan-site 4 well 13 | Sutter | Electric | | 80 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCVestal, Sid | Vestal, Sid | Sutter | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCVestal, Sid-1 | Vestal, Sid-1 | Sutter | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Dewitt, Jack-9 Housley N | Dewitt, Jack-9 Housley N | Sutter | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Dewitt, Jack-10 Housley | Dewitt, Jack-10 Housley | Sutter | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Dewitt, Jack-11 Housley | Dewitt, Jack-11 Housley | Sutter | Electric | | 20 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCMorrison, Phil-#3 site 5 well 15 | Morrison, Phil-#3 site 5 well 15 | Sutter | Electric | | 40 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCMorrison, Phil-#4 site 5 well 16 | Morrison, Phil-#4 site 5 well 16 | Sutter | Electric | | 40 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Frazer | NBC-Frazer | Sutter | Electric | | 50 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Lucich North | NBC-Lucich North | Sutter | Electric | | 75 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC- Natomas Farm#1 | NBC- Natomas Farm#1 | Sacramento | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Cummings | NBC-Cummings | Sacramento | Electric | | 20 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCMorrison, Phillip-#5 | Morrison, Phillip-#5 | Sutter | Electric | | 60 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCPerry, Joe | Perry, Joe | Sacramento | Electric | | 125 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Kismat-2 | NBC-Kismat-2 | Sacramento | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Kismat-3 | NBC-Kismat-3 | Sutter | Electric | | 30 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Kismat-4 | NBC-Kismat-4 | Sacramento | Electric | | 110 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| Natomas Central MWCNBC-Sliva | NBC-Sliva | Sacramento | Electric | | 50 | n/a | 5,500 | 2% | 128 | 638 | 4 | 630 |
| | | | | | | **Total** | **258,500** | 100% | **6,000** | **30,000** | **195** | **29,623** |
| | | | | | | **Total (Sacramento County)** | **93,500** | **36%** | **2,170** | **10,851** | **70** | **10,715** |
| | | | | | | **Total (Sutter County)** | **165,000** | **64%** | **3,830** | **19,149** | **124** | **18,908** |

Legend

| | |
|---|---|
| | Assumed to be electric |
| | Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type |

Conversion Factors

| | |
|---|---|
| 1 hour = | 60 minutes |
| 1 acre-foot = | 325,851 gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | |
|---|---|---|---|---|---|
| Agency | Pelger Mutual Water Company | Federal Attainment Status | | | Peak Month |
| Transfer Volume | 3,750 acre feet/year | PM10 | A | *Engines subject to ATCM.* | 860 AF/month |
| Location | Sutter County | PM2.5 | N | | 6,281 gallons/minute |
| | | O3 | N | | 66% peak pump rate |

**Table I-22. Pelger Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pelger MWCWell 1 Tucker | Well 1 Tucker | Sutter | Electric | 0 | 110 | n/a | 3,100 | 33% | 281 | 1,224 | 16 | 2,144 | n/a | | | | | | | | | | | | | | | | | | |
| Pelger MWCWell 2 Flopet | Well 2 Flopet | Sutter | Diesel | 2008 | 173 | T3 | 2,100 | 22% | 190 | 829 | 16 | 2,144 | 20,806 | 0.1 | 2.8 | 3.7 | 0.93 | 0.22 | 0.22 | 0.92 | 17.49 | 23.01 | 5.73 | 1.38 | 1.38 | 0.06 | 1.16 | 1.53 | 0.38 | 0.09 | 0.09 |
| Pelger MWCWell 3 Klein | Well 3 Klein | Sutter | Electric | 0 | 110 | n/a | 4,300 | 45% | 389 | 1,697 | 16 | 2,144 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **9,500** | **100%** | **860** | **3,750** | **49** | **6,431** | **20,806** | | | | | | | **0.92** | **17.49** | **23.01** | **5.73** | **1.38** | **1.38** | **0.06** | **1.16** | **1.53** | **0.38** | **0.09** | **0.09** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend

| | |
|---|---|
| | Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type |
| | Emission factor based on NMHC+NOx emission standard |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | | |
|---|---|---|
| 0.4 | lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 | g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 | lb/gal | |

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Agency | Pleasant Grove-Verona Mutual Water Company | | Federal Attainment Status | | | | Peak Month |
| Transfer Volume | 18,000 acre feet/year | | | *Sutter* | *Yolo* | | 4,000 AF/month |
| Location | Sutter County | | PM10 | A | A | *Engines subject to ATCM.* | 29,198 gallons/minute |
| | Yolo County | | PM2.5 | N | N | | 37% peak pump rate |
| | | | O3 | N | N | | |

**Table I-23. Pleasant Grove-Verona Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PGVMWCWill-Lee 4A | Will-Lee 4A | Sutter | Diesel | 2000 | 160 | T1 | 1,500 | 2% | 77 | 345 | 9 | 1,248 | 11,206 | 1.1 | 6.9 | 3.0 | 0.93 | 0.22 | 0.21 | 3.67 | 22.09 | 9.75 | 2.99 | 0.71 | 0.69 | 0.25 | 1.51 | 0.67 | 0.20 | 0.05 | 0.05 |
| PGVMWCRiver Ranch #19 | River Ranch #19 | Sutter | Diesel | 1995 | 200 | T0 | 2,500 | 3% | 128 | 575 | 9 | 1,248 | 14,008 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 4.59 | 56.55 | 12.19 | 3.74 | 0.60 | 0.59 | 0.31 | 3.87 | 0.83 | 0.26 | 0.04 | 0.04 |
| PGVMWCMLF #1 | MLF #1 | Sutter | Electric | | 30 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #2 | MLF #2 | Sutter | Electric | | 250 | n/a | 5,000 | 6% | 255 | 1,149 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF Monster Well | MLF Monster Well | Sutter | Electric | | 60 | n/a | 3,100 | 4% | 158 | 713 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #17/12 | MLF #17/12 | Sutter | Electric | | 50 | n/a | 1,500 | 2% | 77 | 345 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #11 | MLF #11 | Sutter | Diesel | 2004 | 250 | T2 | 4,200 | 5% | 215 | 966 | 9 | 1,248 | 17,510 | 0.2 | 4.7 | 2.6 | 0.93 | 0.15 | 0.15 | 1.24 | 23.52 | 13.13 | 4.67 | 0.75 | 0.75 | 0.08 | 1.61 | 0.90 | 0.32 | 0.05 | 0.05 |
| PGVMWCMLF #13/15 | MLF #13/15 | Sutter | Electric | | 240 | n/a | 4,800 | 6% | 245 | 1,103 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #16 | MLF #16 | Sutter | Electric | | 240 | n/a | 1,700 | 2% | 87 | 391 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWilley #1 | Willey #1 | Sutter | Diesel | 2000 | 168 | T1 | 3,000 | 4% | 153 | 690 | 9 | 1,248 | 11,767 | 1.1 | 6.9 | 3.0 | 0.93 | 0.22 | 0.21 | 3.85 | 23.19 | 10.24 | 3.14 | 0.74 | 0.73 | 0.26 | 1.59 | 0.70 | 0.21 | 0.05 | 0.05 |
| PGVMWCWilley #2 | Willey #2 | Sutter | Electric | | 250 | n/a | 3,000 | 4% | 153 | 690 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWilley #3 | Willey #3 | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWilley #4 | Willey #4 | Sutter | Diesel | 1974 | 150 | T0 | 3,000 | 4% | 153 | 690 | 9 | 1,248 | 10,506 | 1.1 | 14.1 | 3.0 | 0.93 | 0.22 | 0.21 | 3.44 | 42.41 | 9.14 | 2.80 | 0.66 | 0.65 | 0.24 | 2.90 | 0.63 | 0.19 | 0.05 | 0.04 |
| PGVMWCScheidel&Osterli #18A | Scheidel&Osterli #18A | Sutter | Electric | TBD | 250 | n/a | 2,500 | 3% | 128 | 575 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWill-Lee 30 | Will-Lee 30 | Sutter | Diesel | 2000 | 100 | T1 | 1,500 | 2% | 77 | 345 | 9 | 1,248 | 7,004 | 1.1 | 6.9 | 3.0 | 0.93 | 0.22 | 0.21 | 2.29 | 13.81 | 6.09 | 1.87 | 0.44 | 0.43 | 0.16 | 0.94 | 0.42 | 0.13 | 0.03 | 0.03 |
| PGVMWCWill-Lee 31 | Will-Lee 31 | Sutter | Electric | | 250 | n/a | 2,500 | 3% | 128 | 575 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWill-Lee 32 | Will-Lee 32 | Sutter | Electric | | 250 | n/a | 2,500 | 3% | 128 | 575 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWill-Lee 33 | Will-Lee 33 | Sutter | Electric | | 250 | n/a | 2,500 | 3% | 128 | 575 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas Sand Field Well | Nicholas Sand Field Well | Sutter | Diesel | 2002 | 62.1 | T1 | 2,000 | 3% | 102 | 460 | 9 | 1,248 | 4,350 | 1.1 | 6.9 | 3.0 | 0.93 | 0.30 | 0.29 | 1.42 | 8.57 | 3.78 | 1.16 | 0.37 | 0.37 | 0.10 | 0.59 | 0.26 | 0.08 | 0.03 | 0.03 |
| PGVMWCNicholas Filipino Camp #2 | Nicholas Filipino Camp #2 | Sutter | Electric | | 40 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas Filipino Camp South | Nicholas Filipino Camp South | Sutter | Diesel | 2002 | 62.1 | T1 | 2,000 | 3% | 102 | 460 | 9 | 1,248 | 4,350 | 1.1 | 6.9 | 3.0 | 0.93 | 0.30 | 0.29 | 1.42 | 8.57 | 3.78 | 1.16 | 0.37 | 0.37 | 0.10 | 0.59 | 0.26 | 0.08 | 0.03 | 0.03 |
| PGVMWCNicholas Johnston Field Well #2 | Nicholas Johnston Field Well #2 | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas Johnston Well | Nicholas Johnston Well | Yolo | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas 72-acre Field South | Nicholas 72-acre Field South | Sutter | Diesel | 2002 | 62.1 | T1 | 2,000 | 3% | 102 | 460 | 9 | 1,248 | 4,350 | 1.1 | 6.9 | 3.0 | 0.93 | 0.30 | 0.29 | 1.42 | 8.57 | 3.78 | 1.16 | 0.37 | 0.37 | 0.10 | 0.59 | 0.26 | 0.08 | 0.03 | 0.03 |
| PGVMWCNicholas 72-Acre Field North | Nicholas 72-Acre Field North | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas BBC Well | Nicholas BBC Well | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCKelly 190 Field Well #2 | Kelly 190 Field Well #2 | Sutter | Electric | | 30 | n/a | 2,000 | 3% | 102 | 460 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCKelly Windmill Field Well #2 | Kelly Windmill Field Well #2 | Sutter | Diesel | 2002 | 62.1 | T1 | 2,000 | 3% | 102 | 460 | 9 | 1,248 | 4,350 | 1.1 | 6.9 | 3.0 | 0.93 | 0.30 | 0.29 | 1.42 | 8.57 | 3.78 | 1.16 | 0.37 | 0.37 | 0.10 | 0.59 | 0.26 | 0.08 | 0.03 | 0.03 |
| PGVMWCKelly Windmill North Field Well | Kelly Windmill North Field Well | Sutter | Diesel | 2002 | 62.1 | T1 | 2,000 | 3% | 102 | 460 | 9 | 1,248 | 4,350 | 1.1 | 6.9 | 3.0 | 0.93 | 0.30 | 0.29 | 1.42 | 8.57 | 3.78 | 1.16 | 0.37 | 0.37 | 0.10 | 0.59 | 0.26 | 0.08 | 0.03 | 0.03 |
| PGVMWCKelly 306 Well | Kelly 306 Well | Sutter | Electric | | 250 | n/a | 2,600 | 3% | 133 | 598 | 9 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCScheidel&Osterli #16 | Scheidel&Osterli #16 | Sutter | Diesel | 1997 | 234 | T1 | 3,400 | 4% | 174 | 782 | 9 | 1,248 | 16,389 | 1.0 | 6.9 | 8.5 | 0.93 | 0.40 | 0.40 | 4.56 | 32.31 | 40.03 | 4.38 | 1.90 | 1.90 | 0.31 | 2.21 | 2.74 | 0.30 | 0.13 | 0.13 |
| PGVMWCScheidel&Osterli #17 | Scheidel&Osterli #17 | Sutter | Diesel | 1999 | 101 | T0 | 1,500 | 2% | 77 | 345 | 9 | 1,248 | 7,074 | 1.1 | 14.1 | 3.0 | 0.93 | 0.22 | 0.21 | 2.32 | 28.56 | 6.15 | 1.89 | 0.45 | 0.44 | 0.16 | 1.95 | 0.42 | 0.13 | 0.03 | 0.03 |
| | | | | | | **Total** | **78,300** | **100%** | **4,000** | **18,000** | **292** | **39,951** | **117,213** | | | | | | | **33.08** | **285.31** | **125.64** | **31.29** | **8.13** | **8.00** | **2.26** | **19.53** | **8.60** | **2.14** | **0.56** | **0.55** |
| | | | | | | **Total (Sutter County)** | **76,300** | **97%** | **3,898** | **17,540** | **283** | **38,703** | **117,213** | | | | | | | **33.08** | **285.31** | **125.64** | **31.29** | **8.13** | **8.00** | **2.26** | **19.53** | **8.60** | **2.14** | **0.56** | **0.55** |
| | | | | | | **Total (Yolo County)** | **2,000** | **3%** | **102** | **460** | **9** | **1,248** | **0** | | | | | | | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend

| | |
|---|---|
| | Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type |
| | Emission factor based on NMHC+NOx emission standard |
| | Emission factor based on AP-42 (engine not subject to emission standard for pollutant in ATCM) |

Conversion Factors

| | | | |
|---|---|---|---|
| 1 lb = | 453.6 | g | |
| 1 ton = | 2,000 | lbs | |
| 1 month = | 30.4 | days | |
| 1 hour = | 60 | minutes | |
| 1 acre-foot = | 325,851 | gallons | |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | | |
|---|---|---|
| 0.4 | lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 | g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 | lb/gal | |

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | |
|---|---|---|
| Agency | Reclamation District 108 | |
| Transfer Volume | 15,000 | acre feet/year |
| Location | Colusa County | |
| | Yolo County | |

Federal Attainment Status

| | *Colusa* | *Yolo* | |
|---|---|---|---|
| PM10 | A | A | *Engines subject to ATCM.* |
| PM2.5 | A | N | |
| O3 | A | N | |

**Table I-24. Reclamation District 108 Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RD 108Well#1 Heidrick | Well#1 Heidrick | Colusa | Electric | | 100 | n/a | 3,500 | 18% | 458 | 2,749 | 23 | 4,265 |
| RD 108Well #5 RiggsRanch | Well #5 RiggsRanch | Colusa | Electric | | 150 | n/a | 1,700 | 9% | 223 | 1,335 | 23 | 4,265 |
| RD 108Well #6 CountyLine | Well #6 CountyLine | Colusa | Electric | | 250 | n/a | 5,900 | 31% | 772 | 4,634 | 23 | 4,265 |
| RD 108Well#7 Tract 6 | Well#7 Tract 6 | Yolo | Electric | | 250 | n/a | 4,000 | 21% | 524 | 3,141 | 23 | 4,265 |
| RD 108Well #4 Huff | Well #4 Huff | Colusa | Electric | | 250 | n/a | 4,000 | 21% | 524 | 3,141 | 23 | 4,265 |
| | | | | | | **Total** | **19,100** | **100%** | **2,500** | **15,000** | **117** | **21,325** |
| | | | | | | **Total (Colusa County)** | **15,100** | **79%** | **1,976** | **11,859** | **93** | **17,060** |
| | | | | | | **Total (Yolo County)** | **4,000** | **21%** | **524** | **3,141** | **23** | **4,265** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

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**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Agency | Reclamation District 1004 | Federal Attainment Status | | | | Peak Month | |
| Transfer Volume | 7,175 acre feet/year | | *Colusa* | *Glenn* | *Sutter* | | 2,870 AF/month |
| Location | Colusa County | PM10 | A | A | A | *Engines subject to ATCM.* | 20,950 gallons/minute |
| | Glenn County | PM2.5 | A | A | N | | 29% peak pump rate |
| | Sutter County | O3 | A | A | N | | |

**Table I-25. Reclamation District 1004 Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gardener No. 374672 | Gardener No. 374672 | Colusa | Diesel | 2008 | 215 | T3 | 3,500 | 5% | 138 | 345 | 7 | 535 | 6,456 | 0.1 | 2.8 | 2.6 | 0.93 | 0.15 | 0.15 | 0.50 | 9.46 | 8.71 | 3.10 | 0.50 | 0.50 | 0.02 | 0.36 | 0.33 | 0.12 | 0.02 | 0.02 |
| Gardener No. 498178 | Gardener No. 498178 | Colusa | Diesel | 2009 | 215 | T3 | 3,500 | 5% | 138 | 345 | 7 | 535 | 6,456 | 0.1 | 2.8 | 2.6 | 0.93 | 0.15 | 0.15 | 0.50 | 9.46 | 8.71 | 3.10 | 0.50 | 0.50 | 0.02 | 0.36 | 0.33 | 0.12 | 0.02 | 0.02 |
| Stonewell #6 No. 11334 | Stone Well #6 No.11334 | Colusa | Electric | 2006 | 40 | n/a | 1,800 | 2% | 71 | 177 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Drumheller Well #7 | Drumheller Well No.7 | Colusa | Diesel | TBD | 225 | T0 | 4,000 | 5% | 158 | 394 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| Myers Well #1 No. 3457 | Myers Well #1 No.3457 | Colusa | Electric | 2006 | 40 | n/a | 2,200 | 3% | 87 | 217 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Myers Well #2 No. 340884 | Myers Well #2 No. 340884 | Colusa | Electric | 1982 | 100 | n/a | 4,100 | 6% | 162 | 404 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Sikes & Parachini #1 No. 93124 | Sikes & Parachini Well #1 WS No.93124 | Colusa | Diesel | 2006 | 173 | T2 | 4,000 | 5% | 158 | 394 | 7 | 535 | 5,195 | 0.2 | 4.7 | 3.7 | 0.93 | 0.22 | 0.22 | 0.66 | 12.56 | 10.02 | 2.50 | 0.60 | 0.60 | 0.03 | 0.48 | 0.38 | 0.09 | 0.02 | 0.02 |
| Sikes & Parachini #2 No. 374682 | Sikes & Parachini Well #2 WS No. 374682 | Colusa | Diesel | 2008 | 150 | T3 | 4,000 | 5% | 158 | 394 | 7 | 535 | 4,504 | 0.1 | 2.8 | 3.7 | 0.93 | 0.22 | 0.22 | 0.35 | 6.60 | 8.69 | 2.16 | 0.52 | 0.52 | 0.01 | 0.25 | 0.33 | 0.08 | 0.02 | 0.02 |
| Rancho Caleta No. 726883 | Rancho Caleta No. 726883 | Colusa | Diesel | 2004 | 170 | T2 | 4,500 | 6% | 177 | 444 | 7 | 535 | 5,105 | 0.2 | 4.7 | 3.7 | 0.93 | 0.22 | 0.22 | 0.65 | 12.34 | 9.84 | 2.45 | 0.59 | 0.59 | 0.02 | 0.47 | 0.37 | 0.09 | 0.02 | 0.02 |
| Behring Ranch Club House No. 496461 | Behring Ranch Club House Well No.496461 | Colusa | Electric | | 125 | n/a | 3,400 | 5% | 134 | 335 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Behring Ranch West Well No. 97863 | Behring Ranch West Well No.97863 | Colusa | Electric | | 125 | n/a | 2,300 | 3% | 91 | 227 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Behring Ranch 10 Field Well No. 496441 | Behring Ranch 10 Field Well No. 496441 | Colusa | Diesel | 2008 | 225 | T3 | 5,800 | 8% | 229 | 572 | 7 | 535 | 6,756 | 0.1 | 2.8 | 2.6 | 0.93 | 0.15 | 0.15 | 0.52 | 9.90 | 9.12 | 3.25 | 0.52 | 0.52 | 0.02 | 0.38 | 0.35 | 0.12 | 0.02 | 0.02 |
| Behring Ranch Pearl 20094 | Behring Ranch Pearl Well No. 20094 | Colusa | Diesel | TBD | 225 | T0 | 2,500 | 3% | 99 | 246 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| Behring Ranch Nursery Well No. 17N1W10H1 | Behring Ranch Nursery Well No. 17N1W10H1 | Colusa | Diesel | TBD | 225 | T0 | 1,000 | 1% | 39 | 99 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| Hall Well No. X | Hall Well No. X | Colusa | Electric | TBD | 125 | n/a | 4,500 | 6% | 177 | 444 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Hall Well No. 369428 | Hall Well No.369428 | Colusa | Electric | 2011 | 125 | n/a | 4,500 | 6% | 177 | 444 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| East Morgan Well | East Morgan Well #1 No. 374667 17N01W14N001M | Colusa | Diesel | TBD | 225 | T0 | 2,600 | 4% | 103 | 256 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| ast Morgan Well | East Morgan Well#2 No. 498195 17N01W15Q001M | Colusa | Diesel | TBD | 225 | T0 | 1,300 | 2% | 51 | 128 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| Mohammad No. | Mohammad No.e0084085 17N01W02D001M | Colusa | Electric | TBD | 125 | n/a | 4,500 | 6% | 177 | 444 | 7 | 535 | n/a | | | | | | | | | | | | | | | | | | |
| Southam Sartain | Southam Sartain Well 18N01W26D001M | Glenn | Diesel | TBD | 225 | T0 | 4,800 | 7% | 189 | 473 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| Barale Well | Barale Well | Colusa | Diesel | TBD | 225 | T0 | 4,000 | 5% | 158 | 394 | 7 | 535 | 6,756 | 1.1 | 14.1 | 3.0 | 0.93 | 0.15 | 0.15 | 3.98 | 49.10 | 10.58 | 3.25 | 0.52 | 0.51 | 0.15 | 1.87 | 0.40 | 0.12 | 0.02 | 0.02 |
| | | | | | | **Total** | **72,800** | **100%** | **2,870** | **7,175** | **148** | **11,240** | **81,767** | | | | | | | **31.05** | **404.01** | **129.15** | **39.29** | **6.90** | **6.81** | **1.18** | **15.36** | **4.91** | **1.49** | **0.26** | **0.26** |
| | | | | | | **Total (Colusa County)** | **68,000** | **93%** | **2,681** | **6,702** | **141** | **10,705** | **75,010** | | | | | | | **27.07** | **354.91** | **118.57** | **36.05** | **6.37** | **6.30** | **1.03** | **13.49** | **4.51** | **1.37** | **0.24** | **0.24** |
| | | | | | | **Total (Glenn County)** | **4,800** | **7%** | **189** | **473** | **7** | **535** | **6,756** | | | | | | | **3.98** | **49.10** | **10.58** | **3.25** | **0.52** | **0.51** | **0.15** | **1.87** | **0.40** | **0.12** | **0.02** | **0.02** |
| | | | | | | **Total (Sutter County)** | **0** | **0%** | **0** | **0** | **0** | **0** | **0** | | | | | | | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |

Notes:

If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).

AP-42 emission factors used for SOx in all cases.

If an emission standard is not available for a given pollutant, then AP-42 emission factors used.

PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend

| | |
|---|---|
| | Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type |
| | Emission factor based on NMHC+NOx emission standard |

Conversion Factors

| | |
|---|---|
| 1 lb = | 453.6 g |
| 1 ton = | 2,000 lbs |
| 1 month = | 30.4 days |
| 1 hour = | 60 minutes |
| 1 acre-foot = | 325,851 gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | |
|---|---|
| 0.4 lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 lb/gal | |

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## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | | | |
|---|---|---|---|---|
| Agency | River Garden Farms | Federal Attainment Status | | |
| Transfer Volume | 9,000 acre feet/year | PM10 | A | *Engines subject to ATCM.* |
| Location | Yolo County | PM2.5 | N | |
| | | O3 | N | |

**Table I-26. River Garden Farms Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River Garden FarmsField 65 PW | Field 65 PW | Yolo | Electric | 2008 | 110 | n/a | 2,500 | 14% | 287 | 1,293 | 21 | 2,810 |
| River Garden FarmsField 71 PW | Field 71 PW | Yolo | Electric | 2001 | 110 | n/a | 1,700 | 10% | 195 | 880 | 21 | 2,810 |
| River Garden FarmsField 98 PW | Field 98 PW | Yolo | Electric | 1963 | 110 | n/a | 2,900 | 17% | 333 | 1,500 | 21 | 2,810 |
| River Garden FarmsField 104 PW | Field 104 PW | Yolo | Electric | 2008 | 110 | n/a | 2,500 | 14% | 287 | 1,293 | 21 | 2,810 |
| River Garden FarmsField 104-09 PW | Field 104-09 PW | Yolo | Electric | 2009 | 110 | n/a | 2,990 | 17% | 344 | 1,547 | 21 | 2,810 |
| River Garden FarmsField 91-09 PW | Field 91-09 PW | Yolo | Electric | 2009 | 110 | n/a | 2,840 | 16% | 327 | 1,469 | 21 | 2,810 |
| River Garden FarmsField 117 PW | Field 117 PW | Yolo | Electric | 2009 | 110 | n/a | 1,965 | 11% | 226 | 1,017 | 21 | 2,810 |
| | | | | | | **Total** | **17,395** | **100%** | **2,000** | **9,000** | **144** | **19,669** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | | |
|---|---|---|---|
| Agency | Sycamore Mutual Water Company | Federal Attainment Status | |
| Transfer Volume | 15,000 acre feet/year | PM10 | A |
| Location | Colusa County | PM2.5 | A |
| | | O3 | A |

*Engines not subject to ATCM if remotely-located.*

**Table I-27. Sycamore Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sycamore Family Trust1 | 1 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust2 | 2 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust3 | 3 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust4 | 4 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust5 | 5 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust6 | 6 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust7 | 7 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust8 | 8 | Colusa | Electric | TBD | 125 | n/a | 3,000 | 9% | 257 | 1,286 | 15 | 2,328 |
| Sycamore Family Trust11 | 11 | Colusa | Electric | | 100 | n/a | 2,500 | 7% | 214 | 1,071 | 15 | 2,328 |
| Sycamore Family Trust14 | 14 | Colusa | Electric | | 100 | n/a | 2,500 | 7% | 214 | 1,071 | 15 | 2,328 |
| Sycamore Family Trust15 | 15 | Colusa | Electric | | 75 | n/a | 2,500 | 7% | 214 | 1,071 | 15 | 2,328 |
| Sycamore Family Trust17 | 17 | Colusa | Electric | | 125 | n/a | 3,500 | 10% | 300 | 1,500 | 15 | 2,328 |
| | | | | | | **Total** | **35,000** | **100%** | **3,000** | **15,000** | **184** | **27,930** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

1 hour = 60 minutes

1 acre-foot = 325,851 gallons

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | |
|---|---|---|
| Agency | Te Velde Revocable Family Trust | |
| Transfer Volume | 7,094 acre feet/year | |
| Location | Yolo County | |

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | A | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | N | |

**Table I-28. Te Velde Revocable Family Trust Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Te VeldeGW1 | GW1 | Yolo | Electric | N/A | 127 | n/a | 4,656 | 29% | 518 | 2,090 | 20 | 2,438 |
| Te VeldeGW10 | GW10 | Yolo | Electric | N/A | 143 | n/a | 2,833 | 18% | 315 | 1,272 | 20 | 2,438 |
| Te VeldeGW9 | GW9 | Yolo | Electric | N/A | 104 | n/a | 2,200 | 14% | 245 | 988 | 20 | 2,438 |
| Te VeldeGW4 | GW4 | Yolo | Electric | N/A | 125 | n/a | 3,715 | 24% | 413 | 1,668 | 20 | 2,438 |
| Te VeldeGW3 | GW3 | Yolo | Electric | N/A | 52 | n/a | 2,400 | 15% | 267 | 1,077 | 20 | 2,438 |
| | | | | | | **Total** | **15,804** | **100%** | **1,758** | **7,094** | **99** | **12,189** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | | |
|---|---|---|---|
| Agency | City of Sacramento | | |
| Transfer Volume | 5,000 | acre feet/year | |
| Location | Sacramento | County | |

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | M | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | N | |

**Table I-29. City of Sacramento Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| City of Sacramento WSA83 | WELL83 | Sacramento | electric | | 30 | n/a | 373 | 2% | 29 | 88 | 14 | 1,278 |
| City of Sacramento WSA92 | WELL92 | Sacramento | electric | | 50 | n/a | 785 | 4% | 62 | 185 | 14 | 1,278 |
| City of Sacramento WSA93 | WELL93 | Sacramento | electric | | 50 | n/a | 411 | 2% | 32 | 97 | 14 | 1,278 |
| City of Sacramento WSA94 | WELL94 | Sacramento | electric | | 50 | n/a | 879 | 4% | 69 | 207 | 14 | 1,278 |
| City of Sacramento WSA107 | WELL107 | Sacramento | electric | | 50 | n/a | 727 | 3% | 57 | 171 | 14 | 1,278 |
| City of Sacramento WSA116 | WELL116 | Sacramento | electric | | 75 | n/a | 673 | 3% | 53 | 158 | 14 | 1,278 |
| City of Sacramento WSA120 | WELL120 | Sacramento | electric | | 50 | n/a | 572 | 3% | 45 | 135 | 14 | 1,278 |
| City of Sacramento WSA122 | WELL122 | Sacramento | electric | | 50 | n/a | 470 | 2% | 37 | 111 | 14 | 1,278 |
| City of Sacramento WSA124 | WELL124 | Sacramento | electric | | 50 | n/a | 541 | 3% | 42 | 127 | 14 | 1,278 |
| City of Sacramento WSA126 | WELL126 | Sacramento | electric | | 50 | n/a | 433 | 2% | 34 | 102 | 14 | 1,278 |
| City of Sacramento WSA127 | WELL127 | Sacramento | electric | | 50 | n/a | 592 | 3% | 46 | 139 | 14 | 1,278 |
| City of Sacramento WSA129 | WELL129 | Sacramento | electric | | 50 | n/a | 466 | 2% | 37 | 110 | 14 | 1,278 |
| City of Sacramento WSA131 | WELL131 | Sacramento | electric | | 50 | n/a | 431 | 2% | 34 | 101 | 14 | 1,278 |
| City of Sacramento WSA133 | WELL133 | Sacramento | electric | | 150 | n/a | 757 | 4% | 59 | 178 | 14 | 1,278 |
| City of Sacramento WSA134 | WELL134 | Sacramento | electric | | 60 | n/a | 676 | 3% | 53 | 159 | 14 | 1,278 |
| City of Sacramento WSA137 | WELL137 | Sacramento | electric | | 75 | n/a | 541 | 3% | 42 | 127 | 14 | 1,278 |
| City of Sacramento WSA138 | WELL138 | Sacramento | electric | | 75 | n/a | 505 | 2% | 40 | 119 | 14 | 1,278 |
| City of Sacramento WSA139 | WELL139 | Sacramento | electric | | 50 | n/a | 818 | 4% | 64 | 193 | 14 | 1,278 |
| City of Sacramento WSA142 | WELL142 | Sacramento | electric | | 75 | n/a | 940 | 4% | 74 | 221 | 14 | 1,278 |
| City of Sacramento WSA143 | WELL143 | Sacramento | electric | | 50 | n/a | 379 | 2% | 30 | 89 | 14 | 1,278 |
| City of Sacramento WSA144 | WELL144 | Sacramento | electric | | 50 | n/a | 549 | 3% | 43 | 129 | 14 | 1,278 |
| City of Sacramento WSA153 | WELL153 | Sacramento | electric | | 100 | n/a | 1027 | 5% | 81 | 242 | 14 | 1,278 |
| City of Sacramento WSA154 | WELL154 | Sacramento | electric | | 50 | n/a | 502 | 2% | 39 | 118 | 14 | 1,278 |
| City of Sacramento WSA155 | WELL155 | Sacramento | electric | | 50 | n/a | 675 | 3% | 53 | 159 | 14 | 1,278 |
| City of Sacramento WSA156 | WELL156 | Sacramento | electric | | 75 | n/a | 525 | 2% | 41 | 124 | 14 | 1,278 |
| City of Sacramento WSA157 | WELL157 | Sacramento | electric | | 50 | n/a | 781 | 4% | 61 | 184 | 14 | 1,278 |
| City of Sacramento WSA158 | WELL158 | Sacramento | electric | | 50 | n/a | 781 | 4% | 61 | 184 | 14 | 1,278 |
| City of Sacramento WSA159 | WELL159 | Sacramento | electric | | 75 | n/a | 535 | 3% | 42 | 126 | 14 | 1,278 |
| City of Sacramento WSA164 | WELL164 | Sacramento | electric | | 150 | n/a | 1101 | 5% | 86 | 259 | 14 | 1,278 |
| City of Sacramento WSAX1 | WELLX1 | Sacramento | electric | | 150 | n/a | 1400 | 7% | 110 | 329 | 14 | 1,278 |
| City of Sacramento WSAX2 | WELLX2 | Sacramento | electric | | 150 | n/a | 1400 | 7% | 110 | 329 | 14 | 1,278 |
| | | | | | | **Total** | **21,245** | **100%** | **1,667** | **5,000** | **434** | **39,623** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

| | |
|---|---|
| | Assumed to be electric (similar to other wells operated by water agency) |
| | Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type |

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | |
|---|---|---|---|---|
| Agency | Sacramento County Water Agency | Federal Attainment Status | | |
| Transfer Volume | 15,000 acre feet/year | PM10 | M | *Engines subject to ATCM.* |
| Location | Sacramento County | PM2.5 | N | |
| | | O3 | N | |

**Table I-30. Sacramento County Water Agency Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sacramento County WAW 040 | W 040 | Sacramento | Electric | | 115 | n/a | 1,160 | 2% | 104 | 312 | 16 | 1,463 |
| Sacramento County WAW 041 | W 041 | Sacramento | Electric | | 65 | n/a | 676 | 1% | 61 | 182 | 16 | 1,463 |
| Sacramento County WAW 042 | W 042 | Sacramento | Electric | | 77 | n/a | 727 | 1% | 65 | 196 | 16 | 1,463 |
| Sacramento County WAW 043 | W 043 | Sacramento | Electric | | 94 | n/a | 918 | 2% | 82 | 247 | 16 | 1,463 |
| Sacramento County WAW 044 | W 044 | Sacramento | Electric | | 73 | n/a | 515 | 1% | 46 | 139 | 16 | 1,463 |
| Sacramento County WAW 047 | W 047 | Sacramento | Electric | | 88 | n/a | 1,030 | 2% | 92 | 277 | 16 | 1,463 |
| Sacramento County WAW 049 | W 049 | Sacramento | Electric | | 92 | n/a | 853 | 2% | 77 | 230 | 16 | 1,463 |
| Sacramento County WAW 052 | W 052 | Sacramento | Electric | | 120 | n/a | 1,192 | 2% | 107 | 321 | 16 | 1,463 |
| Sacramento County WAW 056 | W 056 | Sacramento | Electric | | 200 | n/a | 3,000 | 5% | 269 | 808 | 16 | 1,463 |
| Sacramento County WAW 061 | W 061 | Sacramento | Electric | | 145 | n/a | 1,570 | 3% | 141 | 423 | 16 | 1,463 |
| Sacramento County WAW 062 | W 062 | Sacramento | Electric | | 100 | n/a | 455 | 1% | 41 | 123 | 16 | 1,463 |
| Sacramento County WAW 063 | W 063 | Sacramento | Electric | | 100 | n/a | 1,119 | 2% | 100 | 301 | 16 | 1,463 |
| Sacramento County WAW 064 | W 064 | Sacramento | Electric | | 141 | n/a | 1,205 | 2% | 108 | 325 | 16 | 1,463 |
| Sacramento County WAW 065 | W 065 | Sacramento | Electric | | 57 | n/a | 589 | 1% | 53 | 159 | 16 | 1,463 |
| Sacramento County WAW 066 | W 066 | Sacramento | Electric | | 125 | n/a | 1,700 | 3% | 153 | 458 | 16 | 1,463 |
| Sacramento County WAW 067 | W 067 | Sacramento | Electric | | 135 | n/a | 1,425 | 3% | 128 | 384 | 16 | 1,463 |
| Sacramento County WAW 068 | W 068 | Sacramento | Electric | | 141 | n/a | 1,624 | 3% | 146 | 437 | 16 | 1,463 |
| Sacramento County WAW 069 | W 069 | Sacramento | Electric | | 154 | n/a | 1,663 | 3% | 149 | 448 | 16 | 1,463 |
| Sacramento County WAW 070 | W 070 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 073 | W 073 | Sacramento | Electric | | 175 | n/a | 2,000 | 4% | 180 | 539 | 16 | 1,463 |
| Sacramento County WAW 074 | W 074 | Sacramento | Electric | | 50 | n/a | 500 | 1% | 45 | 135 | 16 | 1,463 |
| Sacramento County WAW 076 | W 076 | Sacramento | Electric | | 150 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 077 | W 077 | Sacramento | Electric | | 125 | n/a | 2,000 | 4% | 180 | 539 | 16 | 1,463 |
| Sacramento County WAW 078 | W 078 | Sacramento | Electric | | 125 | n/a | 2,400 | 4% | 216 | 647 | 16 | 1,463 |
| Sacramento County WAW 087 | W 087 | Sacramento | Electric | | 150 | n/a | 1,900 | 3% | 171 | 512 | 16 | 1,463 |
| Sacramento County WAW 092 | W 092 | Sacramento | Electric | | 75 | n/a | 1,160 | 2% | 104 | 312 | 16 | 1,463 |
| Sacramento County WAW 095 | W 095 | Sacramento | Electric | | 200 | n/a | 2,200 | 4% | 198 | 593 | 16 | 1,463 |
| Sacramento County WAW 096 | W 096 | Sacramento | Electric | | 150 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 105 | W 105 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 106 | W 106 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 109 | W 109 | Sacramento | Electric | | 200 | n/a | 2,600 | 5% | 233 | 700 | 16 | 1,463 |
| Sacramento County WAW 110 | W 110 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 112 | W 112 | Sacramento | Electric | | 100 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 114 | W 114 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 129 | W 129 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 130 | W 130 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 122 | W 122 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 123 | W 123 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| Sacramento County WAW 124 | W 124 | Sacramento | Electric | | 200 | n/a | 1,500 | 3% | 135 | 404 | 16 | 1,463 |
| | | | | | | **Total** | **55,681** | **100%** | **5,000** | **15,000** | **625** | **57,058** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

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**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | |
|---|---|---|---|---|---|
| Agency | Sacramento Suburban Water District | Federal Attainment Status | | | Peak Month |
| Transfer Volume | 30,000 acre feet/year | PM10 | M | *Engines subject to ATCM.* | 5,000 AF/month |
| Location | Sacramento County | PM2.5 | N | | 36,498 gallons/minute |
| | | O3 | N | | 74% peak pump rate |

**Table I-31. Sacramento Suburban Water District Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (MMBtu/yr) | Emission Factors (lb/MMBtu) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sacramento Suburban WD5 | 5 | Sacramento | Electric | | 110 | n/a | 330 | 1% | 34 | 201 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD7 | 7 | Sacramento | Electric | | 110 | n/a | 180 | 0% | 18 | 110 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD9 | 9 | Sacramento | Electric | | 110 | n/a | 625 | 1% | 64 | 381 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD12 | 12 | Sacramento | Electric | | 110 | n/a | 540 | 1% | 55 | 329 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD13 | 13 | Sacramento | Electric | | 110 | n/a | 820 | 2% | 83 | 500 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD14 | 14 | Sacramento | Electric | | 110 | n/a | 570 | 1% | 58 | 348 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD18 | 18 | Sacramento | Electric | | 110 | n/a | 840 | 2% | 85 | 512 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD19 | 19 | Sacramento | Electric | | 110 | n/a | 950 | 2% | 97 | 579 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD22 | 22 | Sacramento | Electric | | 110 | n/a | 650 | 1% | 66 | 396 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD23 | 23 | Sacramento | Electric | | 110 | n/a | 550 | 1% | 56 | 335 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD24 | 24 | Sacramento | Electric | | 110 | n/a | 590 | 1% | 60 | 360 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD25 | 25 | Sacramento | Electric | | 110 | n/a | 750 | 2% | 76 | 457 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD26 | 26 | Sacramento | Electric | | 110 | n/a | 650 | 1% | 66 | 396 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD28 | 28 | Sacramento | Electric | | 110 | n/a | 585 | 1% | 59 | 357 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD30 | 30 | Sacramento | Electric | | 110 | n/a | 650 | 1% | 66 | 396 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD35 | 35 | Sacramento | Electric | | 110 | n/a | 1000 | 2% | 102 | 610 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD37 | 37 | Sacramento | Natural Gas | | 190 | n/a | 700 | 1% | 71 | 427 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD38 | 38 | Sacramento | Natural Gas | | 190 | n/a | 500 | 1% | 51 | 305 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD40 | 40 | Sacramento | Natural Gas | | 190 | n/a | 675 | 1% | 69 | 412 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD41 | 41 | Sacramento | Electric/Natural Gas | | 190 | n/a | 600 | 1% | 61 | 366 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD43 | 43 | Sacramento | Electric/Natural Gas | | 190 | n/a | 850 | 2% | 86 | 518 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD45 | 45 | Sacramento | Natural Gas | | 190 | n/a | 750 | 2% | 76 | 457 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD47 | 47 | Sacramento | Electric/Natural Gas | | 190 | n/a | 885 | 2% | 90 | 540 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD50 | 50 | Sacramento | Electric | | 110 | n/a | 500 | 1% | 51 | 305 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD51 | 51 | Sacramento | Electric | | 110 | n/a | 285 | 1% | 29 | 174 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD60 | 60 | Sacramento | Electric | | 110 | n/a | 600 | 1% | 61 | 366 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD65 | 65 | Sacramento | Electric | | 110 | n/a | 1250 | 3% | 127 | 762 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD66 | 66 | Sacramento | Electric | | 110 | n/a | 1350 | 3% | 137 | 823 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD69 | 69 | Sacramento | Electric | | 110 | n/a | 450 | 1% | 46 | 274 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD70 | 70 | Sacramento | Electric | | 110 | n/a | 350 | 1% | 36 | 213 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD71 | 71 | Sacramento | Electric | | 110 | n/a | 2675 | 5% | 272 | 1,631 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD72 | 72 | Sacramento | Electric | | 110 | n/a | 1850 | 4% | 188 | 1,128 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD73 | 73 | Sacramento | Electric | | 110 | n/a | 3500 | 7% | 356 | 2,134 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD74 | 74 | Sacramento | Electric | | 110 | n/a | 2700 | 5% | 274 | 1,647 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD75 | 75 | Sacramento | Electric | | 110 | n/a | 1150 | 2% | 117 | 701 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD76 | 76 | Sacramento | Electric | | 110 | n/a | 250 | 1% | 25 | 152 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD77 | 77 | Sacramento | Electric | | 110 | n/a | 400 | 1% | 41 | 244 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD20A | 20A | Sacramento | Electric | | 110 | n/a | 1100 | 2% | 112 | 671 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD2A | 2A | Sacramento | Electric | | 110 | n/a | 995 | 2% | 101 | 607 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD32A | 32A | Sacramento | Electric | | 110 | n/a | 1905 | 4% | 194 | 1,162 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD33A | 33A | Sacramento | Electric | | 110 | n/a | 2675 | 5% | 272 | 1,631 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD3A | 3A | Sacramento | Electric | | 110 | n/a | 370 | 1% | 38 | 226 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD40A | 40A | Sacramento | Electric | | 110 | n/a | 2525 | 5% | 257 | 1,540 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD46R | 46R | Sacramento | Electric/Natural Gas | | 190 | n/a | 800 | 2% | 81 | 488 | 18 | 3,312 | 4,405 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 2.85 | 98.47 | 7.65 | 0.01 | 0.24 | 0.24 | 0.26 | 8.99 | 0.70 | 0.00 | 0.02 | 0.02 |
| Sacramento Suburban WD4B | 4B | Sacramento | Electric | | 110 | n/a | 2675 | 5% | 272 | 1,631 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD55A | 55A | Sacramento | Electric | | 110 | n/a | 2000 | 4% | 203 | 1,220 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD68R | 68R | Sacramento | Electric | | 110 | n/a | 1600 | 3% | 163 | 976 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **49,195** | **100%** | **5,000** | **30,000** | **853** | **155,656** | **35,238** | | | | | | | **22.78** | **787.78** | **61.21** | **0.11** | **1.93** | **1.93** | **2.08** | **71.89** | **5.59** | **0.01** | **0.18** | **0.18** |

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 MMBtu = | 1,000,000 | Btu |
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Natural Gas Engine Fuel Consumption

| | | | |
|---|---|---|---|
| Estimated BSFC = | 7,000 | Btu/bhp-hr | (Estimated from Waukesha engine specifications) |
| Higher Heating Value | 1,020 | Btu/scf | (AP-42, Chapter 3.2: Natural Gas-fired Reciprocating Engines) |

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## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | |
|---|---|---|
| Agency | Butte Water District | |
| Transfer Volume | 5,500 acre feet/year | |
| Location | Butte County | |
| | Sutter County | |

Federal Attainment Status

| | *Butte* | *Sutter* | |
|---|---|---|---|
| PM10 | A | A | *Engines subject to ATCM.* |
| PM2.5 | N | N | |
| O3 | N | N | |

**Table I-32. Butte Water District Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Butte Water District#1 | #1 | Sutter | Electric | 2008 Floway 16 MKM | 300 | n/a | 4,000 | 49% | 447 | 2,683 | 20 | 3,643 |
| Butte Water District#2 | #2 | Sutter | Electric | 2008 Floway 16 DKH | 350 | n/a | 4,200 | 51% | 470 | 2,817 | 20 | 3,643 |
| | | | | | | **Total** | **8,200** | **100%** | **917** | **5,500** | **40** | **7,285** |
| | | | | | | **Total (Butte County)** | **0** | **0%** | **0** | **0** | **0** | **0** |
| | | | | | | **Total (Sutter County)** | **8,200** | **100%** | **917** | **5,500** | **40** | **7,285** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | |
|---|---|---|
| Agency | Garden Highway Mutual Water Company | |
| Transfer Volume | 14,000 acre feet/year | |
| Location | Sutter County | |

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | A | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | N | |

**Table I-33. Garden Highway Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Garden Highway MWC4 | #4 | Sutter | Electric | | 110 | n/a | 2,300 | 12% | 295 | 1,651 | 23 | 3,899 |
| Garden Highway MWC17 | #17 | Sutter | Electric | | 110 | n/a | 3,100 | 16% | 397 | 2,226 | 23 | 3,899 |
| Garden Highway MWC19 | #19 | Sutter | Electric | | 110 | n/a | 2,800 | 14% | 359 | 2,010 | 23 | 3,899 |
| Garden Highway MWC22 | #22 | Sutter | Electric | | 110 | n/a | 2,700 | 14% | 346 | 1,938 | 23 | 3,899 |
| Garden Highway MWC23 | #23 | Sutter | Electric | | 110 | n/a | 2,200 | 11% | 282 | 1,579 | 23 | 3,899 |
| Garden Highway MWC24 | #24 | Sutter | Electric | TBD | 110 | n/a | 3,200 | 16% | 410 | 2,297 | 23 | 3,899 |
| Garden Highway MWC25 | #25 | Sutter | Electric | TBD | 110 | n/a | 3,200 | 16% | 410 | 2,297 | 23 | 3,899 |
| | | | | | | **Total** | **19,500** | **100%** | **2,500** | **14,000** | **160** | **27,294** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | |
|---|---|---|---|---|---|
| Agency | Gilsizer Slough Ranch | Federal Attainment Status | | | Peak Month |
| Transfer Volume | 3,900 acre feet/year | PM10 | A | *Engines subject to ATCM.* | 800 AF/month |
| Location | Sutter County | PM2.5 | N | | 5,840 gallons/minute |
| | | O3 | N | | 97% peak pump rate |

**Table I-34. Gilsizer Slough Ranch Criteria Pollutant Emissions**

| | | | | | | | | | | | | | Emission Factors (g/bhp-hr) | | | | | | Daily Emissions (lbs/day) | | | | | | Annual Emissions (tons per year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | (% of Total) | Transfer Volume (AF/month) | (AF/year) | Operation (hours/day) | (hours/year) | Fuel Consumption (gal/yr) | VOC | NOx | CO | SOx | PM10 | PM2.5 | VOC | NOx | CO | SOx | PM10 | PM2.5 | VOC | NOx | CO | SOx | PM10 | PM2.5 |
| Gilsizer #1 | Gilsizer #1 | Sutter | Diesel | | 162 | T0 | 2,016 | 33% | 267 | 1,300 | 24 | 3,502 | 31,828 | 1.1 | 14.1 | 3.0 | 0.93 | 0.22 | 0.21 | 9.62 | 118.61 | 25.56 | 7.84 | 1.86 | 1.81 | 0.71 | 8.79 | 1.89 | 0.58 | 0.14 | 0.13 |
| Gilsizer #2 | Gilsizer #2 | Sutter | Electric | TBD | 110 | n/a | 2,016 | 33% | 267 | 1,300 | 24 | 3,502 | n/a | | | | | | | | | | | | | | | | | | |
| Gilsizer #3 | Gilsizer #3 | Sutter | Electric | TBD | 110 | n/a | 2,016 | 33% | 267 | 1,300 | 24 | 3,502 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **6,048** | **100%** | **800** | **3,900** | **71** | **10,506** | **31,828** | | | | | | | **9.62** | **118.61** | **25.56** | **7.84** | **1.86** | **1.81** | **0.71** | **8.79** | **1.89** | **0.58** | **0.14** | **0.13** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend
Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | | |
|---|---|---|
| 0.4 | lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 | g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 | lb/gal | |

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## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | |
|---|---|
| Agency | Goose Club Farms and Teichert Aggregates |
| Transfer Volume | 10,000 acre feet/year |
| Location | Sutter County |

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | A | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | N | |

**Table I-35. Goose Club Farms and Teichert Aggregates Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Goose Club1 | 1 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club2 | 2 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club3 | 3 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club4 | 4 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club5 | 5 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club6 | 6 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club7 | 7 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club8 | 8 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club9 | 9 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club10 | 10 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club11 | 11 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club12 | 12 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| Goose Club13 | 13 | Sutter | Electric | TBD | 125 | n/a | 3,000 | 8% | 185 | 769 | 11 | 1,393 |
| | | | | | | **Total** | **39,000** | **100%** | **2,400** | **10,000** | **143** | **18,103** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

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**Groundwater Substitution Air Quality Emissions (Unmitigated)**

| | | | | | |
|---|---|---|---|---|---|
| Agency | Tule Basin Farms | Federal Attainment Status | | | Peak Month |
| Transfer Volume | 7,320 acre feet/year | PM10 | A | *Engines subject to ATCM.* | 1,520 AF/month |
| Location | Sutter County | PM2.5 | N | | 11,095 gallons/minute |
| | | O3 | N | | 96% peak pump rate |

**Table I-36. Tule Basin Farms Criteria Pollutant Emissions**

| | | Well | | | | | Pump Rate | | Transfer Volume | | Operation | | Fuel | Emission Factors (lb/MMBtu) | | | | | | Daily Emissions (lbs/day) | | | | | | Annual Emissions (tons per year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Well | Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | (gpm) | (% of Total) | (AF/month) | (AF/year) | (hours/day) | (hours/year) | Consumption (MMBtu/yr) | VOC | NOx | CO | SOx | PM10 | PM2.5 | VOC | NOx | CO | SOx | PM10 | PM2.5 | VOC | NOx | CO | SOx | PM10 | PM2.5 |
| Tule Basin1 | 1 | Sutter | Electric | | 125 | n/a | 3,050 | 27% | 403 | 1,941 | 24 | 3,457 | n/a | | | | | | | | | | | | | | | | | | |
| Tule Basin2 | 2 | Sutter | Natural Gas | 1985 | 190 | n/a | 3,600 | 31% | 476 | 2,291 | 24 | 3,457 | 4,598 | 0.118 | 4.08 | 0.317 | 0.00059 | 0.00999 | 0.00999 | 3.70 | 128.06 | 9.95 | 0.02 | 0.31 | 0.31 | 0.27 | 9.38 | 0.73 | 0.00 | 0.02 | 0.02 |
| Tule Basin3 | 3 | Sutter | Electric | | 125 | n/a | 4,850 | 42% | 641 | 3,087 | 24 | 3,457 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **11,500** | **100%** | **1,520** | **7,320** | **71** | **10,371** | **4,598** | | | | | | | **3.70** | **128.06** | **9.95** | **0.02** | **0.31** | **0.31** | **0.27** | **9.38** | **0.73** | **0.00** | **0.02** | **0.02** |

Conversion Factors

| | | |
|---|---|---|
| 1 MMBtu = | 1,000,000 | Btu |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Natural Gas Engine Fuel Consumption

| | | | |
|---|---|---|---|
| Estimated BSFC = | 7,000 | Btu/bhp-hr | (Estimated from Waukesha engine specifications) |
| Higher Heating Value | 1,020 | Btu/scf | (AP-42, Chapter 3.2: Natural Gas-fired Reciprocating Engines) |

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## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | |
|---|---|---|
| Agency | Reclamation District 2068 | |
| Transfer Volume | 4,500 | acre feet/year |
| Location | Solano County | |
| | Yolo County | |

Federal Attainment Status

| | *Solano* | *Yolo* | |
|---|---|---|---|
| PM10 | A | A | *Engines subject to ATCM.* |
| PM2.5 | N | N | |
| O3 | N | N | |

**Table I-37. Reclamation District 2068 Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RD-2068TP-1 | TP-1 | Solano | Electric | | 75 | n/a | 1,500 | 25% | 188 | 1,125 | 22 | 4,073 |
| RD-2068GW-2 | GW-2 | Solano | Electric | TBD | 75 | n/a | 1,500 | 25% | 188 | 1,125 | 22 | 4,073 |
| RD-2068GW-3 | GW-3 | Solano | Electric | TBD | 75 | n/a | 1,500 | 25% | 188 | 1,125 | 22 | 4,073 |
| RD-2068GW-4 | GW-4 | Solano | Electric | TBD | 75 | n/a | 1,500 | 25% | 188 | 1,125 | 22 | 4,073 |
| | | | | | | **Total** | **6,000** | **100%** | **750** | **4,500** | **89** | **16,293** |
| | | | | | | **Total (Solano County)** | **6,000** | **100%** | **750** | **4,500** | **89** | **16,293** |
| | | | | | | **Total (Yolo County)** | **0** | **0%** | **0** | **0** | **0** | **0** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## Groundwater Substitution Air Quality Emissions (Unmitigated)

| | | | |
|---|---|---|---|
| Agency | Pope Ranch | | |
| Transfer Volume | 2,800 | acre feet/year | |
| Location | Yolo | County | |

Federal Attainment Status

| | | |
|---|---|---|
| PM10 | A | *Engines subject to ATCM.* |
| PM2.5 | N | |
| O3 | N | |

**Table I-38. Pope Ranch Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pope RanchX1 | X1 | Yolo | Electric | TBD | 110 | n/a | 2,117 | 50% | 280 | 1,400 | 24 | 3,591 |
| Pope RanchX2 | X2 | Yolo | Electric | TBD | 110 | n/a | 2,117 | 50% | 280 | 1,400 | 24 | 3,591 |
| | | | | | | **Total** | **4,234** | **100%** | **560** | **2,800** | **47** | **7,183** |

*Note: Local criteria pollutant emissions not estimated because all engines are electric.*

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

## CARB Airborne Toxic Control Measure (ATCM) for Stationary Compression Ignition Engines

**Table I-39. Summary of the Emission Standards for New Stationary Diesel-Fueled CI Engines > 50 BHP used in Agricultural Operations**

| Horsepower Range | Diesel PM [1] (g/bhp-hr) | HC (g/bhp-hr) | NOx (g/bhp-hr) | NMHC+NOx (g/bhp-hr) | CO (g/bhp-hr) |
|---|---|---|---|---|---|
| 50<HP<100 | 0.3 | | | | |
| 100<=HP<175 | 0.22 | | | | |
| 175<=HP | 0.15 | | | | |

*Source: See Section 93115.8(a)*

Notes:

[1] Less than or equal to the emission standard OR Off-Road CI Engine Certification Standard for an off-road engine of the maximum rated power, whichever is more stringent.

[2] Off-Road CI Engine Certification Standard for an off-road engine of the model year and maximum rated power of the engine installed to meet the applicable PM standard, or Tier 1 standards.

[3] Prior to January 1, 2008, these limits shall not apply to engines sold from one agricultural operation to another and funded under State or federal incentive.

**Table I-40. Emission Standards for Noncertified Greater than 50 BHP In-Use Stationary Diesel-Fueled Engines Used in Agricultural Operations**

| Horsepower (HP) Range | Compliance Date [1] | PM (g/bhp-hr) | HC [2,3] (g/bhp-hr) | NOx [2,3] (g/bhp-hr) | NMHC+NOx [2,3] (g/bhp-hr) | CO [2,3] (g/bhp-hr) |
|---|---|---|---|---|---|---|
| 50<HP<75 | 2011 | 0.3 | | | | |
| 75<=HP<100 | 2011 | 0.3 | | | | |
| 100<=HP<175 | 2010 | 0.22 | | | | |
| 175<=HP<=750 | 2010 | 0.15 | | | | |
| 750<HP | 2014 | 0.075 | | | | |

*Source: See Sections 93115.8(b) (2) and (4)*

Note:

[1] Compliance date on or after December 31

[2] Engine Certification Standards for off-road engine of the model year and maximum rated power of the engine installed to meet the applicable PM standard.

[3] If no limits have been established for an off-road engine of the same model year and maximum rated power, then the in-use stationary diesel-fueled engine used in an agricultural operation shall not exceed Tier 1 standards in Title 13.

**Table I-41. Emission Standards Tier 1- and Tier 2-Certified Greater than 50 BHP In-Use Stationary Diesel-Fueled Engines Used in Agricultural Operations**

| Horsepower Range (hp) | Compliance Date | PM (g/bhp-hr) | HC [2,3] (g/bhp-hr) | NOx [2,3] (g/bhp-hr) | NMHC+NOx [2,3] (g/bhp-hr) | CO [2,3] (g/bhp-hr) |
|---|---|---|---|---|---|---|
| 50<HP<75 | 2015 | 0.02 | | | | |
| 75<=HP<175 | 2015 | 0.01 | | | | |
| 175<=hp<=750 | 2014 | 0.01 | | | | |
| 750<HP | 2014 | 0.075 | | | | |

*Source: See Sections 93115.8(b)(3) and (4)*

Notes:

[1] Compliance date on or after December 31 or 12 years after the date of initial installation, whichever is later.

[2] Off-Road CI Engine Certification Standards for an off-road engine of the model year and maximum rated power of the engine installed to meet the applicable PM standard.

[3] If no limits have been established for an off-road engine of the same model year and maximum rated power, then the in-use stationary diesel-fueled engine used in agricultural operation shall not exceed Tier 1 standards in Tier 13, CCR, section 2423 for an off-road engine of the same maximum rated power irrespective of model year.

**Table I-42. Tier 1, Tier 2, and Tier 3 Exhaust Emission Standards**

| Maximum Rated Power | Tier | Model Year | (g/kW-hr) | | | | | (g/hp-hr) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NOx | HC | NMHC+NOx | CO | PM | NOx | HC | NMHC+NOx | CO | PM |
| kW<8 | T1 | 2000-2004 | - | - | 10.5 | 8.0 | 1 | - | - | 7.8 | 6.0 | 0.75 |
| *hp <11* | T2 | 2005 -2007 | - | - | 7.5 | 8.0 | 0.8 | - | - | 5.6 | 6.0 | 0.60 |
| 8≤kW<19 | T1 | 2000-2004 | - | - | 9.5 | 6.6 | 0.8 | - | - | 7.1 | 4.9 | 0.60 |
| *11<=hp<25* | T2 | 2005 -2007 | - | - | 7.5 | 6.6 | 0.8 | - | - | 5.6 | 4.9 | 0.60 |
| 19≤kW<37 | T1 | 2000-2003 | - | - | 9.5 | 5.5 | 0.8 | - | - | 7.1 | 4.1 | 0.60 |
| *25<=hp<50* | T2 | 2004 -2007 | - | - | 7.5 | 5.5 | 0.6 | - | - | 5.6 | 4.1 | 0.45 |
| 37≤kW<56 | T1 | 2000-2003 | 9.2 | - | - | - | - | 6.9 | - | - | - | - |
| *50<=hp<75* | T2 | 2004-2007 | - | - | 7.5 | 5.0 | 0.4 | - | - | 5.6 | 3.7 | 0.30 |
| | T3 | 2008 -2011 | - | - | 4.7 | 5.0 | 0.4 | - | - | 3.5 | 3.7 | 0.30 |
| 56≤kW<75 | T1 | 2000-2003 | 9.2 | - | - | - | - | 6.9 | - | - | - | - |
| *75<=hp<100* | T2 | 2004-2007 | - | - | 7.5 | 5.0 | 0.4 | - | - | 5.6 | 3.7 | 0.30 |
| | T3 | 2008-2011 | - | - | 4.7 | 5.0 | 0.4 | - | - | 3.5 | 3.7 | 0.30 |
| 75≤kW<130 | T1 | 2000-2002 | 9.2 | - | - | - | - | 6.9 | - | - | - | - |
| *100<=hp<175* | T2 | 2003-2006 | - | - | 6.6 | 5.0 | 0.3 | - | - | 4.9 | 3.7 | 0.22 |
| | T3 | 2007 -2011 | - | - | 4.0 | 5.0 | 0.3 | - | - | 3.0 | 3.7 | 0.22 |
| 130≤kW<225 | T1 | 1996-2002 | 9.2 | 1.3 | - | 11.4 | 0.54 | 6.9 | 1.0 | - | 8.5 | 0.40 |
| *175<=hp<300* | T2 | 2003-2005 | - | - | 6.6 | 3.5 | 0.2 | - | - | 4.9 | 2.6 | 0.15 |
| | T3 | 2006 -2010 | - | - | 4.0 | 3.5 | 0.2 | - | - | 3.0 | 2.6 | 0.15 |
| 225≤kW<450 | T1 | 1996-2000 | 9.2 | 1.3 | - | 11.4 | 0.54 | 6.9 | 1.0 | - | 8.5 | 0.40 |
| *300<=hp<600* | T2 | 2001-2005 | - | - | 6.4 | 3.5 | 0.2 | - | - | 4.8 | 2.6 | 0.15 |
| | T3 | 2006 -2010 | - | - | 4.0 | 3.5 | 0.2 | - | - | 3.0 | 2.6 | 0.15 |
| 450≤kW≤560 | T1 | 1996-2001 | 9.2 | 1.3 | - | 11.4 | 0.54 | 6.9 | 1.0 | - | 8.5 | 0.40 |
| *600<=hp<750* | T2 | 2002-2005 | - | - | 6.4 | 3.5 | 0.2 | - | - | 4.8 | 2.6 | 0.15 |
| | T3 | 2006 -2010 | - | - | 4.0 | 3.5 | 0.2 | - | - | 3.0 | 2.6 | 0.15 |
| kW>560 | T1 | 2000-2005 | 9.2 | 1.3 | - | 11.4 | 0.54 | 6.9 | 1.0 | - | 8.5 | 0.40 |
| *hp>750* | T2 | 2006 -2010 | - | - | 6.4 | 3.5 | 0.2 | - | - | 4.8 | 2.6 | 0.15 |

*Source: Title 13, California Code of Regulations, Division 3, Chapter 9, Article 4, Section 2423, "Off-Road Compression-Ignition Engines and Equipment."*

NOx and NMHC fraction - Table B-26

| | |
|---|---|
| NOx | 95% |
| NMHC | 5% |

http://www.arb.ca.gov/msprog/moyer/guidelines/cmp_guidelines_part4.pdf

PM Size Fractions

| | |
|---|---|
| PM10 | 0.96 |
| PM2.5 | 0.937 |
| Ratio | 0.98 |

CARB PMSIZE Profile No. 116 (STAT. I.C. ENGINE-DIESEL)

**Table I-43. Tier 4 Exhaust Emission Standards**

| MAXIMUM ENGINE POWER | MODEL YEAR | TYPE | PM | NMHC+ | NMHC | NOx | CO |
|---|---|---|---|---|---|---|---|
| | | | grams per horsepower-hour | | | | |
| hp<11 | 2008 and later | FINAL | 0.30 | 5.6 | - | - | 6.0 |
| 11<=hp<25 | | | | | | | 4.9 |
| 25<=hp<50 | 2008-2012 | INTERIM | 0.22 | 5.6 | - | - | 4.1 |
| | 2013 and later | FINAL | 0.02 | 3.5 | | | |
| 50<=hp<75 | 2008-2012 | INTERIM | 0.22 | 3.5 | - | - | 3.7 |
| | 2013 and later | FINAL | 0.02 | | | | |
| 75<=hp<100 | 2012-2014 | PHASE-IN | 0.01 | - | 0.14 | 0.3 | 3.7 |
| | | PHASE-OUT | | 3.5 | - | - | |
| | | or/ ALT NOx | | | 0.14 | 2.5 | |
| | 2015 and later | FINAL | | - | | 0.3 | |
| 100<=hp<175 | 2012-2014 | PHASE-IN | 0.01 | - | 0.14 | 0.3 | 3.7 |
| | | PHASE-OUT | | 3.0 | - | - | |
| | | or/ ALT NOx | | - | 0.14 | 2.5 | |
| | 2015 and later | FINAL | | | 0.14 | 0.3 | |
| 175<=hp<=750 | 2011-2013 | PHASE-IN | 0.01 | - | 0.14 | 0.3 | 2.6 |
| | 2014 and later | PHASE-OUT | | 3.0 | - | - | |
| | | or/ ALT NOx | | - | 0.14 | 1.5 | |
| | | FINAL | | | | 0.3 | |
| 750 hp<GEN<=1205 hp | 2011-2014 | INTERIM | 0.07 | - | 0.30 | 2.6 | 2.6 |
| | 2015 and later | FINAL | 0.02 | | 0.14 | 0.5 | |
| GEN>1205 hp | 2011-2014 | INTERIM | 0.07 | - | 0.30 | | 2.6 |
| | 2015 and later | FINAL | 0.02 | | 0.14 | 0.5 | |
| ELSE>750 hp | 2011-2014 | INTERIM | 0.07 | - | 0.30 | 2.6 | 2.6 |
| | 2015 and later | FINAL | 0.03 | - | 0.14 | | |

*Source: Title 13, California Code of Regulations, Article 4, Section 2423, "Off-Road Compression-Ignition Engines and Equipment."*

**Table I-44. Engine Tier Matrix**

| HP Range | Year | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| hp <11 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T4 | T4 | T4 | T4 | T4 | T4 | T4 | T4 |
| 11<=hp<25 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T4 | T4 | T4 | T4 | T4 | T4 | T4 | T4 |
| 25<=hp<50 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T4I | T4I | T4I | T4I | T4I | T4 | T4 | T4 |
| 50<=hp<75 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T4I | T4I | T4I | T4I | T4I | T4 | T4 | T4 |
| 75<=hp<100 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T3 | T3 | T3 | T3 | T4I | T4I | T4I | T4 |
| 100<=hp<175 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T3 | T3 | T3 | T3 | T3 | T4I | T4I | T4I | T4 |
| 175<=hp<300 | T1 | T1 | T1 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T3 | T3 | T3 | T3 | T3 | T4I | T4I | T4I | T4 | T4 |
| 300<=hp<600 | T1 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T2 | T3 | T3 | T3 | T3 | T3 | T4I | T4I | T4I | T4 | T4 |
| 600<=hp<750 | T1 | T1 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T3 | T3 | T3 | T3 | T3 | T4I | T4I | T4I | T4 | T4 |
| hp>750 | T0 | T0 | T0 | T0 | T1 | T1 | T1 | T1 | T1 | T1 | T2 | T2 | T2 | T2 | T2 | T4I | T4I | T4I | T4I | T4 |

Key:

T0 = Tier 0 (Noncertified)
T1 = Tier 1
T2 = Tier 2
T3 = Tier 3
T4 = Tier 4
T4I = Tier 4 Interim

## AP-42 Emission Factors

**Table I-45. Emission Factors for Uncontrolled Gasoline and Diesel Industrial Engines [a]**

| | Gasoline Fuel | | Diesel Fuel | | | |
|---|---|---|---|---|---|---|
| | Emission Factor | | Emission Factor | | Emission | |
| Pollutant | (lb/hp-hr) (power output) | (lb/MMBtu) (fuel input) | (lb/hp-hr) (power output) | (lb/MMBtu) (fuel input) | Factor Rating | Note |
| NOx | 0.011 | 1.63 | 0.031 | 4.41 | D | |
| CO | 6.96E-03 [d] | 0.99 [d] | 6.68E-03 | 0.95 | D | |
| SOx | 5.91E-04 | 0.084 | 2.05E-03 | 0.29 | D | |
| PM10 | 7.21E-04 | 0.1 | 2.20E-03 | 0.31 | D | [b] |
| CO2 | 1.08 | 154 | 1.15 | 164 | B | [c] |
| Aldehydes | 4.85E-04 | 0.07 | 4.63E-04 | 0.07 | D | |
| TOC | | | | | | |
| Exhaust | 0.015 | 2.1 | 2.47E-03 | 0.35 | D | |
| Evaporative | 6.61E-04 | 0.09 | 0.00 | 0.00 | E | |
| Crankcase | 4.85E-03 | 0.69 | 4.41E-05 | 0.01 | E | |
| Refueling | 1.08E-03 | 0.15 | 0.00 | 0.00 | E | |

*Source: U.S. Environmental Protection Agency. 1996. Compilation of Air Pollutant Emission Factors (AP-42). Chapter 3.3: Gasoline and Diesel Industrial Engines.*

Notes:

[a] References 2,5-6,9-14. When necessary, an average brake-specific fuel consumption (BSFC) of 7,000 Btu/hp-hr was used to convert from lb/MMBtu to lb/hp-hr. To convert from lb/hp-hr to kg/kwhr, multiply by 0.608. To convert from lb/MMBtu to ng/J, multiply by 430. SCC = Source Classification Code. TOC = total organic compounds.

[b] PM-10 = particulate matter less than or equal to 10 :m aerodynamic diameter. All particulate is assumed to be 10 µm in size.

[c] Assumes 99% conversion of carbon in fuel to CO2 with 87 weight % carbon in diesel, 86 weight % carbon in gasoline, average BSFC of 7,000 Btu/hp-hr, diesel heating value of 19,300 Btu/lb, and gasoline heating value of 20,300 Btu/lb.

[d] Instead of 0.439 lb/hp-hr (power output) and 62.7 lb/mmBtu (fuel input), the correct emissions factors values are 6.96 E-03 lb/hp-hr (power output) and 0.99 lb/mmBtu (fuel input), respectively. This is an editorial correction. March 24, 2009

For large stationary diesel engines (greater than 600 horsepower [hp]) see Chapter 3.4: Large Stationary Diesel and All Stationary Dual-Fuel Engines.

**Table I-46. Uncontrolled Emission Factors for 4-Stroke Lean-Burn Engines [a]**

| Pollutant | Emission Factor (lb/MMBtu) [b] (fuel input) | Emission Factor Rating |
|---|---|---|
| NOx [c] 90 - 105% Load | 4.08E+00 | B |
| NOx [c] <90% Load | 8.47E-01 | B |
| CO [c] 90 - 105% Load | 3.17E-01 | C |
| CO [c] <90% Load | 5.57E-01 | B |
| CO2 [d] | 1.10E+02 | A |
| SO2 [e] | 5.88E-04 | A |
| TOC [f] | 1.47E+00 | A |
| Methane[g] | 1.25E+00 | C |
| VOC [h] | 1.18E-01 | C |
| PM10 (filterable) [i] | 7.71E-05 | D |
| PM2.5 (filterable) [i] | 7.71E-05 | D |
| PM Condensable [j] | 9.91E-03 | D |

*Source: U.S. Environmental Protection Agency. 2000. Compilation of Air Pollutant Emission Factors (AP-42). Chapter 3.2: Natural Gas-Fired Reciprocating Engines. July.*
Notes:

[a] Reference 7. Factors represent uncontrolled levels. For NOx, CO, and PM10, "uncontrolled" means no combustion or add-on controls; however, the factor may include turbocharged units. For all other pollutants, the data set may include units with control techniques used for NOx control, such as PCC"uncontrolled" means no oxidation control; and SCR for lean burn engines, and PSC for rich burn engines. Factors are based on large population of engines. Factors are for engines at all loads, except as indicated. SCC = Source Classification Code. TOC = Total Organic Compounds. PM-10 = Particulate Matter ≤ 10 microns (μ) aerodynamic diameter. A "<" sign in front of a factor means that the corresponding emission factor is based on one-half of the method detection limit.

[b] Emission factors were calculated in units of (lb/MMBtu) based on procedures in EPA Method 19. To convert from (lb/MMBtu) to ($lb/10^6$ scf), multiply by the heat content of the fuel. If the heat content is not available, use 1020 Btu/scf. To convert from (lb/MMBtu) to (lb/hp-hr) use the following equation:

lb/hp-hr = (lb/MMBtu) (heat input, MMBtu/hr) (1/operating HP, 1/hp)

[c] Emission tests with unreported load conditions were not included in the data set.

[d] Based on 99.5% conversion of the fuel carbon to CO2. CO2 [lb/MMBtu] = (3.67)(%CON)(C)(D)(1/h), where %CON = percent conversion of fuel carbon to CO2, C = carbon content of fuel by weight (0.75), D = density of fuel, 4.1 E+04 $lb/10^6$ scf, and h = heating value of natural gas (assume 1020 Btu/scf at 60EF).

[e] Based on 100% conversion of fuel sulfur to SO2. Assumes sulfur content in natural gas of 2,000 $gr/10^9$scf.

[f] Emission factor for TOC is based on measured emission levels from 22 source tests.

[g] Emission factor for methane is determined by subtracting the VOC and ethane emission factors from the TOC emission factor. Measured emission factor for methane compares well with the calculated emission factor, 1.31 lb/MMBtu vs. 1.25 lb/MMBtu, respectively.

[h] VOC emission factor is based on the sum of the emission factors for all speciated organic compounds less ethane and methane.

[i] Considered ≤ 1 μ in aerodynamic diameter. Therefore, for filterable PM emissions, PM10(filterable) = PM2.5(filterable).

[j] PM Condensable = PM Condensable Inorganic + PM-Condensable Organic

## Engine Size Summary

**Table I-47. Summary of Average Engine Horsepower by Fuel Type**

| Average of HP | Fuel Type | | | |
|---|---|---|---|---|
| **Agency** | **Diesel** | **Electric** | **Natural Gas** | **Grand Total** |
| Anderson-Cottonwood Irrigation District | | 125 | | 125 |
| Butte Water District | | 325 | | 325 |
| City of Sacramento | | 60 | | 60 |
| Conaway Preservation Group | 227 | 138 | | 147 |
| Cordua Irrigation District | | 82 | | 82 |
| Cranmore Farms | | 125 | | 125 |
| Eastside Mutual Water Company | 215 | | | 215 |
| Goose Club Farms and Teichert Aggregates | | 125 | | 125 |
| Pelger Mutual Water Company | 173 | | | 173 |
| Pleasant Grove-Verona Mutual Water Company | 129 | 118 | | 124 |
| Reclamation District 1004 | 191 | 76 | | 145 |
| Reclamation District 108 | | 200 | | 200 |
| Reclamation District 2068 | | 75 | | 75 |
| Sacramento County Water Agency | | 116 | | 116 |
| Sycamore Mutual Water Company | | 117 | | 117 |
| Te Velde Revocable Family Trust | | 110 | | 110 |
| Tule Basin Farms | | 125 | 190 | 147 |
| **Grand Total** | **162** | **110** | **190** | **117** |

**Table I-48. Summary of Maximum Engine Horsepower by Fuel Type**

| Max of HP | Fuel Type | | | |
|---|---|---|---|---|
| **Agency** | **Diesel** | **Electric** | **Natural Gas** | **Grand Total** |
| Anderson-Cottonwood Irrigation District | | 200 | | 200 |
| Butte Water District | | 350 | | 350 |
| City of Sacramento | | 150 | | 150 |
| Conaway Preservation Group | 227 | 250 | | 250 |
| Cordua Irrigation District | | 125 | | 125 |
| Cranmore Farms | | 125 | | 125 |
| Eastside Mutual Water Company | 215 | | | 215 |
| Goose Club Farms and Teichert Aggregates | | 125 | | 125 |
| Pelger Mutual Water Company | 173 | | | 173 |
| Pleasant Grove-Verona Mutual Water Company | 250 | 250 | | 250 |
| Reclamation District 1004 | 225 | 125 | | 225 |
| Reclamation District 108 | | 250 | | 250 |
| Reclamation District 2068 | | 75 | | 75 |
| Sacramento County Water Agency | | 200 | | 200 |
| Sycamore Mutual Water Company | | 125 | | 125 |
| Te Velde Revocable Family Trust | | 143 | | 143 |
| Tule Basin Farms | | 125 | 190 | 190 |
| **Grand Total** | **250** | **350** | **190** | **350** |

**Table I-49. Summary of Minimum Engine Horsepower by Fuel Type**

| Min of HP | Fuel Type | | | |
|---|---|---|---|---|
| **Agency** | **Diesel** | **Electric** | **Natural Gas** | **Grand Total** |
| Anderson-Cottonwood Irrigation District | | 50 | | 50 |
| Butte Water District | | 300 | | 300 |
| City of Sacramento | | 30 | | 30 |
| Conaway Preservation Group | 227 | 75 | | 75 |
| Cordua Irrigation District | | 50 | | 50 |
| Cranmore Farms | | 125 | | 125 |
| Eastside Mutual Water Company | 215 | | | 215 |
| Goose Club Farms and Teichert Aggregates | | 125 | | 125 |
| Pelger Mutual Water Company | 173 | | | 173 |
| Pleasant Grove-Verona Mutual Water Company | 62 | 30 | | 30 |
| Reclamation District 1004 | 150 | 40 | | 40 |
| Reclamation District 108 | | 100 | | 100 |
| Reclamation District 2068 | | 75 | | 75 |
| Sacramento County Water Agency | | 50 | | 50 |
| Sycamore Mutual Water Company | | 75 | | 75 |
| Te Velde Revocable Family Trust | | 52 | | 52 |
| Tule Basin Farms | | 125 | 190 | 125 |
| **Grand Total** | **62** | **30** | **190** | **30** |

**Table I-50. General Conformity Applicability Evaluation (Mitigated Emissions)**

| County/ Nonattainment Area | Emissions (tons per year) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | VOC | NOx | CO | SOx | | PM10 | PM2.5 | |
| | Sacramento Metro[1,5] | Sacramento Metro[1,5] | Sacramento Area[2] | Sacramento[3,4] | Yuba City-Marysville[6] | Sacramento Co. | Sacramento[4] | Yuba City-Marysville[6] |
| Colusa | -- | -- | -- | -- | -- | -- | -- | -- |
| Glenn | -- | -- | -- | -- | -- | -- | -- | -- |
| Sacramento | 0.1 | 4.9 | 0.4 | 0.001 | -- | 0.01 | 0.01 | -- |
| Shasta | -- | -- | -- | -- | -- | -- | -- | -- |
| Solano | 0.0 | 0.0 | -- | -- | -- | -- | -- | -- |
| Sutter | 0.3 | 3.6 | -- | -- | 3.1 | -- | -- | 0.5 |
| Tehama | -- | -- | -- | -- | -- | -- | -- | -- |
| Yolo | 0.7 | 7.9 | -- | -- | -- | -- | -- | -- |
| Yuba | -- | -- | -- | -- | 0.0 | -- | -- | 0.0 |
| Total | 1.2 | 16.3 | 0.4 | 0.001 | 3.1 | 0.01 | 0.01 | 0.5 |
| Classification | Severe | Severe | Maintenance | PM2.5 Precursor | PM2.5 Precursor | Maintenance | Nonattainment | Nonattainment |
| De Minimis Threshold (tpy) | 25 | 25 | 100 | 100 | 100 | 100 | 100 | 100 |
| Exceed? | No | No | No | No | No | No | No | No |

Note:

[1]The Sacramento Metro 8-hour O3 nonattainment area consists of Sacramento and Yolo Counties and parts of El Dorado, Placer, Solano, and Sutter Counties. Emissions occurring within the attainment area of these counties are excluded from the total emissions.

[2]The Sacramento Area CO maintenance area is based on the Census Bureau Urbanized Area and consists of parts of Placer, Sacramento, and Yolo Counties. The general conformity applicability evaluation is based on emissions that would occur within the entire county to be conservative.

[3]All counties are designated as attainment areas for SO2; however, since SO2 is a precursor to PM2.5, its emissions must be evaluated under general conformity.

[4]The 24-hour PM2.5 nonattainment area for Sacramento includes Sacramento County and parts of El Dorado, Placer, Solano, and Yolo Counties. The general conformity applicability analysis assumes that all emissions that could occur within each county would occur within the Sacramento nonattainment area to be conservative.

[5]VOC and NOx emissions are excluded from Sutter County for Cranmore Farms, Garden Highway Mutual Water Company, Gilsizer Slough Ranch, Pelger Mutual Water Company, Reclamation District 1004, and Tule Basin Farms because they are located in areas designated as attainment for the federal 8-hour O3 NAAQS.

[6]The Yuba City-Marysville PM2.5 nonattainment area contains all of Sutter County and a part of Yuba County.

**Table I-51. Emissions Outside of 8-Hour Ozone Nonattainment Area (tons per year)**

| Water Agency | County | VOC | NOx |
|---|---|---|---|
| Cranmore Farms | Sutter | Electric | Electric |
| Garden Highway Mutual Water Company | Sutter | Electric | Electric |
| Gilsizer Slough Ranch | Sutter | 0.1 | 1.8 |
| Pelger Mutual Water Company | Sutter | 0.1 | 1.2 |
| Reclamation District 1004 | Sutter | n/a | n/a |
| Tule Basin Farms | Sutter | 0.3 | 1.4 |
| Total | | 0.4 | 4.3 |

## Summary of Daily Groundwater Substitution Emissions by County (Mitigated)

**Table I-52. Daily VOC Emissions**

| Water Agency | Daily VOC Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 13.32 | | 13.32 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.55 | | | | | | | | | 1.55 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.92 | | | | 0.92 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 2.21 | | Electric | | 2.21 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 27.07 | 3.98 | | | | n/a | | | | 31.05 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 1.57 | | | | | | | 1.57 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.26 | | | | 1.26 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 3.70 | | | | 3.70 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **28.61** | **3.98** | **1.57** | **0.00** | **0.00** | **8.10** | **0.00** | **13.32** | **0.00** | **55.58** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Mitigated)

**Table I-53. Daily NOx Emissions**

| Water Agency | Daily NOx Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 147.70 | | 147.70 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 29.38 | | | | | | | | | 29.38 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 17.49 | | | | 17.49 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 22.80 | | Electric | | 22.80 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 354.91 | 49.10 | | | | n/a | | | | 404.01 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 54.26 | | | | | | | 54.26 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 23.92 | | | | 23.92 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 19.21 | | | | 19.21 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **384.29** | **49.10** | **54.26** | **0.00** | **0.00** | **83.42** | **0.00** | **147.70** | **0.00** | **718.77** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Mitigated)

**Table I-54. Daily CO Emissions**

| Water Agency | Daily CO Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 125.01 | | 125.01 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 27.06 | | | | | | | | | 27.06 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 23.01 | | | | 23.01 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 48.31 | | Electric | | 48.31 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 118.57 | 10.58 | | | | n/a | | | | 129.15 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 4.22 | | | | | | | 4.22 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 31.47 | | | | 31.47 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 9.95 | | | | 9.95 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **145.63** | **10.58** | **4.22** | **0.00** | **0.00** | **112.75** | **0.00** | **125.01** | **0.00** | **398.18** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Mitigated)

**Table I-55. Daily SOx Emissions**

| Water Agency | Daily SOx Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 25.40 | | 25.40 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 9.63 | | | | | | | | | 9.63 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 5.73 | | | | 5.73 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 13.72 | | Electric | | 13.72 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 36.05 | 3.25 | | | | n/a | | | | 39.29 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.01 | | | | | | | 0.01 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 7.84 | | | | 7.84 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.02 | | | | 0.02 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **45.68** | **3.25** | **0.01** | **0.00** | **0.00** | **27.32** | **0.00** | **25.40** | **0.00** | **101.65** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Mitigated)

**Table I-56. Daily PM10 Emissions**

| Water Agency | Daily PM10 Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 6.39 | | 6.39 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.55 | | | | | | | | | 1.55 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.38 | | | | 1.38 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 1.49 | | Electric | | 1.49 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 6.37 | 0.52 | | | | n/a | | | | 6.90 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.13 | | | | | | | 0.13 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.89 | | | | 1.89 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.31 | | | | 0.31 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **7.92** | **0.52** | **0.13** | **0.00** | **0.00** | **5.07** | **0.00** | **6.39** | **0.00** | **20.04** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Daily Groundwater Substitution Emissions by County (Mitigated)

**Table I-57. Daily PM2.5 Emissions**

| Water Agency | Daily PM2.5 Emissions (lbs/day) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 6.39 | | 6.39 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.55 | | | | | | | | | 1.55 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.38 | | | | 1.38 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 1.47 | | Electric | | 1.47 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 6.30 | 0.51 | | | | n/a | | | | 6.81 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.13 | | | | | | | 0.13 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.89 | | | | 1.89 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.31 | | | | 0.31 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **7.84** | **0.51** | **0.13** | **0.00** | **0.00** | **5.06** | **0.00** | **6.39** | **0.00** | **19.93** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Mitigated)

**Table I-58. Annual VOC Emissions**

| Water Agency | Annual VOC Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 0.71 | | 0.71 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.11 | | | | | | | | | 0.11 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.06 | | | | 0.06 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 0.35 | | Electric | | 0.35 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 1.03 | 0.15 | | | | n/a | | | | 1.18 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.14 | | | | | | | 0.14 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.09 | | | | 0.09 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.27 | | | | 0.27 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **1.14** | **0.15** | **0.14** | **0.00** | **0.00** | **0.77** | **0.00** | **0.71** | **0.00** | **2.92** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Mitigated)

**Table I-59. Annual NOx Emissions**

| Water Agency | Annual NOx Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 7.89 | | 7.89 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 2.14 | | | | | | | | | 2.14 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.16 | | | | 1.16 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 3.56 | | Electric | | 3.56 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 13.49 | 1.87 | | | | n/a | | | | 15.36 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 4.88 | | | | | | | 4.88 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 1.77 | | | | 1.77 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 1.41 | | | | 1.41 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **15.64** | **1.87** | **4.88** | **0.00** | **0.00** | **7.90** | **0.00** | **7.89** | **0.00** | **38.17** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Mitigated)

**Table I-60. Annual CO Emissions**

| Water Agency | Annual CO Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 6.68 | | 6.68 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 1.97 | | | | | | | | | 1.97 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 1.53 | | | | 1.53 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 7.54 | | Electric | | 7.54 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 4.51 | 0.40 | | | | n/a | | | | 4.91 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.38 | | | | | | | 0.38 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 2.33 | | | | 2.33 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.73 | | | | 0.73 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **6.48** | **0.40** | **0.38** | **0.00** | **0.00** | **12.13** | **0.00** | **6.68** | **0.00** | **26.07** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Mitigated)

**Table I-61. Annual SOx Emissions**

| Water Agency | Annual SOx Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 1.36 | | 1.36 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.70 | | | | | | | | | 0.70 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.38 | | | | 0.38 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 2.14 | | Electric | | 2.14 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 1.37 | 0.12 | | | | n/a | | | | 1.49 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.00 | | | | | | | 0.00 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.58 | | | | 0.58 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.00 | | | | 0.00 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **2.07** | **0.12** | **0.00** | **0.00** | **0.00** | **3.10** | **0.00** | **1.36** | **0.00** | **6.66** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Mitigated)

**Table I-62. Annual PM10 Emissions**

| Water Agency | Annual PM10 Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 0.34 | | 0.34 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.11 | | | | | | | | | 0.11 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.09 | | | | 0.09 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 0.23 | | Electric | | 0.23 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 0.24 | 0.02 | | | | n/a | | | | 0.26 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.01 | | | | | | | 0.01 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.14 | | | | 0.14 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.02 | | | | 0.02 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **0.36** | **0.02** | **0.01** | **0.00** | **0.00** | **0.49** | **0.00** | **0.34** | **0.00** | **1.22** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

## Summary of Annual Groundwater Substitution Emissions by County (Mitigated)

**Table I-63. Annual PM2.5 Emissions**

| Water Agency | Annual PM2.5 Emissions (tons per year) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Butte | Colusa | Glenn | Sacramento | Shasta | Solano | Sutter | Tehama | Yolo | Yuba | Total |
| **Sacramento River of Analysis** | | | | | | | | | | | |
| Anderson-Cottonwood Irrigation District | | | | | Electric | | | n/a | | | 0.00 |
| Conaway Preservation Group | | | | | | | | | 0.34 | | 0.34 |
| Cordua Irrigation District | | | | | | | | | | Electric | 0.00 |
| Cranmore Farms | | | | | | | Electric | | | | 0.00 |
| Eastside Mutual Water Company | | 0.11 | | | | | | | | | 0.11 |
| Glenn-Colusa Irrigation District | | n/a | Electric | | | | | | | | 0.00 |
| Natomas Central Mutual Water Company | | | | Electric | | | Electric | | | | 0.00 |
| Pelger Mutual Water Company | | | | | | | 0.09 | | | | 0.09 |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | 0.23 | | Electric | | 0.23 |
| Reclamation District 108 | | Electric | | | | | | | Electric | | 0.00 |
| Reclamation District 1004 | | 0.24 | 0.02 | | | | n/a | | | | 0.26 |
| River Garden Farms | | | | | | | | | Electric | | 0.00 |
| Sycamore Mutual Water Company | | Electric | | | | | | | | | 0.00 |
| Te Velde Revocable Family Trust | | | | | | | | | Electric | | 0.00 |
| **American River Area of Analysis** | | | | | | | | | | | |
| City of Sacramento | | | | Electric | | | | | | | 0.00 |
| Sacramento County Water Agency | | | | Electric | | | | | | | 0.00 |
| Sacramento Suburban Water District | | | | 0.01 | | | | | | | 0.01 |
| **Feather River Area of Analysis** | | | | | | | | | | | |
| Butte Water District | n/a | | | | | | Electric | | | | 0.00 |
| Garden Highway Mutual Water Company | | | | | | | Electric | | | | 0.00 |
| Gilsizer Slough Ranch | | | | | | | 0.14 | | | | 0.14 |
| Goose Club Farms and Teichert Aggregates | | | | | | | Electric | | | | 0.00 |
| Tule Basin Farms | | | | | | | 0.02 | | | | 0.02 |
| **Delta Region Area of Analysis** | | | | | | | | | | | |
| Reclamation District 2068 | | | | | | Electric | | | n/a | | 0.00 |
| Pope Ranch | | | | | | | | | Electric | | 0.00 |
| **Total** | **0.00** | **0.35** | **0.02** | **0.01** | **0.00** | **0.00** | **0.48** | **0.00** | **0.34** | **0.00** | **1.21** |

Note:
Counties designated as "n/a" (not applicable) if water agency is located in the county, but no engines would operate in the county.

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**Groundwater Substitution Air Quality Emissions (Mitigated)**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Agency | Pleasant Grove-Verona Mutual Water Company | | Federal Attainment Status | | | | Peak Month |
| Transfer Volume | 18,000 acre feet/year | | | *Sutter* | *Yolo* | | 4,000 AF/month |
| Location | Sutter County | | PM10 | A | A | *Engines subject to ATCM.* | 29,198 gallons/minute |
| | Yolo County | | PM2.5 | N | N | | 37% peak pump rate |
| | | | O3 | N | N | | |

**Table I-64. Pleasant Grove-Verona Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PGVMWCWill-Lee 4A | Will-Lee 4A | Sutter | Diesel | 2012 | 160 | T4I | 1,500 | 2% | 77 | 345 | 4 | 1,248 | 11,206 | 0.14 | 0.3 | 3.7 | 0.93 | 0.01 | 0.01 | 0.20 | 0.42 | 5.26 | 1.31 | 0.02 | 0.02 | 0.03 | 0.07 | 0.82 | 0.20 | 0.00 | 0.00 |
| PGVMWCRiver Ranch #19 | River Ranch #19 | Sutter | Diesel | 2010 | 200 | T3 | 2,500 | 3% | 128 | 575 | 4 | 1,248 | 14,008 | 0.1 | 2.8 | 2.6 | 0.93 | 0.15 | 0.15 | 0.26 | 5.00 | 4.61 | 1.64 | 0.26 | 0.26 | 0.04 | 0.78 | 0.72 | 0.26 | 0.04 | 0.04 |
| PGVMWCMLF #1 | MLF #1 | Sutter | Electric | | 30 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #2 | MLF #2 | Sutter | Electric | | 250 | n/a | 5,000 | 6% | 255 | 1,149 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF Monster Well | MLF Monster Well | Sutter | Electric | | 60 | n/a | 3,100 | 4% | 158 | 713 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #17/12 | MLF #17/12 | Sutter | Electric | | 50 | n/a | 1,500 | 2% | 77 | 345 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #11 | MLF #11 | Sutter | Diesel | 2011 | 250 | T4I | 4,200 | 5% | 215 | 966 | 4 | 1,248 | 17,510 | 0.14 | 0.3 | 2.6 | 0.93 | 0.01 | 0.01 | 0.31 | 0.66 | 5.76 | 2.05 | 0.03 | 0.03 | 0.05 | 0.10 | 0.90 | 0.32 | 0.01 | 0.01 |
| PGVMWCMLF #13/15 | MLF #13/15 | Sutter | Electric | | 240 | n/a | 4,800 | 6% | 245 | 1,103 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCMLF #16 | MLF #16 | Sutter | Electric | | 240 | n/a | 1,700 | 2% | 87 | 391 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWilley #1 | Willey #1 | Sutter | Diesel | 2012 | 168 | T4I | 3,000 | 4% | 153 | 690 | 4 | 1,248 | 11,767 | 0.14 | 0.3 | 3.7 | 0.93 | 0.01 | 0.01 | 0.21 | 0.44 | 5.53 | 1.38 | 0.02 | 0.02 | 0.03 | 0.07 | 0.86 | 0.21 | 0.00 | 0.00 |
| PGVMWCWilley #2 | Willey #2 | Sutter | Electric | | 250 | n/a | 3,000 | 4% | 153 | 690 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWilley #3 | Willey #3 | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWilley #4 | Willey #4 | Sutter | Diesel | 2010 | 150 | T3 | 3,000 | 4% | 153 | 690 | 4 | 1,248 | 10,506 | 0.1 | 2.8 | 3.7 | 0.93 | 0.22 | 0.22 | 0.20 | 3.75 | 4.94 | 1.23 | 0.30 | 0.30 | 0.03 | 0.59 | 0.77 | 0.19 | 0.05 | 0.05 |
| PGVMWCScheidel&Osterli #18A | Scheidel&Osterli #18A | Sutter | Electric | TBD | 250 | n/a | 2,500 | 3% | 128 | 575 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWill-Lee 30 | Will-Lee 30 | Sutter | Diesel | 2012 | 100 | T4I | 1,500 | 2% | 77 | 345 | 4 | 1,248 | 7,004 | 0.14 | 0.3 | 3.7 | 0.93 | 0.01 | 0.01 | 0.13 | 0.26 | 3.29 | 0.82 | 0.01 | 0.01 | 0.02 | 0.04 | 0.51 | 0.13 | 0.00 | 0.00 |
| PGVMWCWill-Lee 31 | Will-Lee 31 | Sutter | Electric | | 250 | n/a | 2,500 | 3% | 128 | 575 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWill-Lee 32 | Will-Lee 32 | Sutter | Electric | | 250 | n/a | 2,500 | 3% | 128 | 575 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCWill-Lee 33 | Will-Lee 33 | Sutter | Electric | | 250 | n/a | 2,500 | 3% | 128 | 575 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas Sand Field Well | Nicholas Sand Field Well | Sutter | Diesel | 2008 | 62.1 | T4I | 2,000 | 3% | 102 | 460 | 4 | 1,248 | 4,350 | 0.2 | 3.3 | 3.7 | 0.93 | 0.22 | 0.22 | 0.10 | 1.82 | 2.04 | 0.51 | 0.12 | 0.12 | 0.01 | 0.28 | 0.32 | 0.08 | 0.02 | 0.02 |
| PGVMWCNicholas Filipino Camp #2 | Nicholas Filipino Camp #2 | Sutter | Electric | | 40 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas Filipino Camp South | Nicholas Filipino Camp South | Sutter | Diesel | 2008 | 62.1 | T4I | 2,000 | 3% | 102 | 460 | 4 | 1,248 | 4,350 | 0.2 | 3.3 | 3.7 | 0.93 | 0.22 | 0.22 | 0.10 | 1.82 | 2.04 | 0.51 | 0.12 | 0.12 | 0.01 | 0.28 | 0.32 | 0.08 | 0.02 | 0.02 |
| PGVMWCNicholas Johnston Field Well #2 | Nicholas Johnston Field Well #2 | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas Johnston Well | Nicholas Johnston Well | Yolo | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas 72-acre Field South | Nicholas 72-acre Field South | Sutter | Diesel | 2008 | 62.1 | T4I | 2,000 | 3% | 102 | 460 | 4 | 1,248 | 4,350 | 0.2 | 3.3 | 3.7 | 0.93 | 0.22 | 0.22 | 0.10 | 1.82 | 2.04 | 0.51 | 0.12 | 0.12 | 0.01 | 0.28 | 0.32 | 0.08 | 0.02 | 0.02 |
| PGVMWCNicholas 72-Acre Field North | Nicholas 72-Acre Field North | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCNicholas BBC Well | Nicholas BBC Well | Sutter | Electric | | 250 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCKelly 190 Field Well #2 | Kelly 190 Field Well #2 | Sutter | Electric | | 30 | n/a | 2,000 | 3% | 102 | 460 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCKelly Windmill Field Well #2 | Kelly Windmill Field Well #2 | Sutter | Diesel | 2008 | 62.1 | T4I | 2,000 | 3% | 102 | 460 | 4 | 1,248 | 4,350 | 0.2 | 3.3 | 3.7 | 0.93 | 0.22 | 0.22 | 0.10 | 1.82 | 2.04 | 0.51 | 0.12 | 0.12 | 0.01 | 0.28 | 0.32 | 0.08 | 0.02 | 0.02 |
| PGVMWCKelly Windmill North Field Well | Kelly Windmill North Field Well | Sutter | Diesel | 2008 | 62.1 | T4I | 2,000 | 3% | 102 | 460 | 4 | 1,248 | 4,350 | 0.2 | 3.3 | 3.7 | 0.93 | 0.22 | 0.22 | 0.10 | 1.82 | 2.04 | 0.51 | 0.12 | 0.12 | 0.01 | 0.28 | 0.32 | 0.08 | 0.02 | 0.02 |
| PGVMWCKelly 306 Well | Kelly 306 Well | Sutter | Electric | | 250 | n/a | 2,600 | 3% | 133 | 598 | 4 | 1,248 | n/a | | | | | | | | | | | | | | | | | | |
| PGVMWCScheidel&Osterli #16 | Scheidel&Osterli #16 | Sutter | Diesel | 2011 | 234 | T4I | 3,400 | 4% | 174 | 782 | 4 | 1,248 | 16,389 | 0.14 | 0.3 | 2.6 | 0.93 | 0.01 | 0.01 | 0.29 | 0.62 | 5.39 | 1.92 | 0.03 | 0.03 | 0.05 | 0.10 | 0.84 | 0.30 | 0.00 | 0.00 |
| PGVMWCScheidel&Osterli #17 | Scheidel&Osterli #17 | Sutter | Diesel | 2010 | 101 | T3 | 1,500 | 2% | 77 | 345 | 4 | 1,248 | 7,074 | 0.1 | 2.8 | 3.7 | 0.93 | 0.22 | 0.22 | 0.13 | 2.53 | 3.32 | 0.83 | 0.20 | 0.20 | 0.02 | 0.39 | 0.52 | 0.13 | 0.03 | 0.03 |
| | | | | | | **Total** | **78,300** | **100%** | **4,000** | **18,000** | **128** | **39,951** | **117,213** | | | | | | | **2.21** | **22.80** | **48.31** | **13.72** | **1.49** | **1.47** | **0.35** | **3.56** | **7.54** | **2.14** | **0.23** | **0.23** |
| | | | | | | **Total (Sutter County)** | **76,300** | **97%** | **3,898** | **17,540** | **124** | **38,703** | **117,213** | | | | | | | **2.21** | **22.80** | **48.31** | **13.72** | **1.49** | **1.47** | **0.35** | **3.56** | **7.54** | **2.14** | **0.23** | **0.23** |
| | | | | | | **Total (Yolo County)** | **2,000** | **3%** | **102** | **460** | **4** | **1,248** | **0** | | | | | | | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend

| | |
|---|---|
| | Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type |
| | Emission factor based on NMHC+NOx emission standard |
| | Emissions of all pollutants consistent with the applicable tier necessary to control PM emissions under the ATCM for mitigation |

Conversion Factors

| | | | |
|---|---|---|---|
| 1 | lb = | 453.6 | g |
| 1 | ton = | 2,000 | lbs |
| 1 | month = | 30.4 | days |
| 1 | hour = | 60 | minutes |
| 1 | acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption

| | | |
|---|---|---|
| 0.4 | lb/hp-hr | *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)* |
| 0.855 | g/mL | *(Based on MSDS for Hess Diesel Fuel All Types)* |
| 7.13 | lb/gal | |

| | |
|---|---|
| Daily Hours of Operation | 4 |

**Groundwater Substitution Air Quality Emissions (Mitigated)**

Agency Sacramento Suburban Water District
Transfer Volume 30,000 acre feet/year
Location Sacramento County

Federal Attainment Status
PM10 M *Engines subject to ATCM.*
PM2.5 N
O3 N

Peak Month
5,000 AF/month
36,498 gallons/minute
74% peak pump rate

**Table I-65. Sacramento Suburban Water District Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (MMBtu/yr) | Emission Factors (lb/MMBtu) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sacramento Suburban WD5 | 5 | Sacramento | Electric | | 110 | n/a | 330 | 1% | 34 | 201 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD7 | 7 | Sacramento | Electric | | 110 | n/a | 180 | 0% | 18 | 110 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD9 | 9 | Sacramento | Electric | | 110 | n/a | 625 | 1% | 64 | 381 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD12 | 12 | Sacramento | Electric | | 110 | n/a | 540 | 1% | 55 | 329 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD13 | 13 | Sacramento | Electric | | 110 | n/a | 820 | 2% | 83 | 500 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD14 | 14 | Sacramento | Electric | | 110 | n/a | 570 | 1% | 58 | 348 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD18 | 18 | Sacramento | Electric | | 110 | n/a | 840 | 2% | 85 | 512 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD19 | 19 | Sacramento | Electric | | 110 | n/a | 950 | 2% | 97 | 579 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD22 | 22 | Sacramento | Electric | | 110 | n/a | 650 | 1% | 66 | 396 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD23 | 23 | Sacramento | Electric | | 110 | n/a | 550 | 1% | 56 | 335 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD24 | 24 | Sacramento | Electric | | 110 | n/a | 590 | 1% | 60 | 360 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD25 | 25 | Sacramento | Electric | | 110 | n/a | 750 | 2% | 76 | 457 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD26 | 26 | Sacramento | Electric | | 110 | n/a | 650 | 1% | 66 | 396 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD28 | 28 | Sacramento | Electric | | 110 | n/a | 585 | 1% | 59 | 357 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD30 | 30 | Sacramento | Electric | | 110 | n/a | 650 | 1% | 66 | 396 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD35 | 35 | Sacramento | Electric | | 110 | n/a | 1000 | 2% | 102 | 610 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD37 | 37 | Sacramento | Natural Gas | | 190 | n/a | 700 | 1% | 71 | 427 | 2.5 | 450 | 599 | 0.118 | 4.08 | 0.317 | 0.000588 | 0.009987 | 0.009987 | 0.39 | 13.57 | 1.05 | 0.00 | 0.03 | 0.03 | 0.04 | 1.22 | 0.09 | 0.00 | 0.00 | 0.00 |
| Sacramento Suburban WD38 | 38 | Sacramento | Natural Gas | | 190 | n/a | 500 | 1% | 51 | 305 | 2.5 | 450 | 599 | 0.118 | 4.08 | 0.317 | 0.000588 | 0.009987 | 0.009987 | 0.39 | 13.57 | 1.05 | 0.00 | 0.03 | 0.03 | 0.04 | 1.22 | 0.09 | 0.00 | 0.00 | 0.00 |
| Sacramento Suburban WD40 | 40 | Sacramento | Natural Gas | | 190 | n/a | 675 | 1% | 69 | 412 | 2.5 | 450 | 599 | 0.118 | 4.08 | 0.317 | 0.000588 | 0.009987 | 0.009987 | 0.39 | 13.57 | 1.05 | 0.00 | 0.03 | 0.03 | 0.04 | 1.22 | 0.09 | 0.00 | 0.00 | 0.00 |
| Sacramento Suburban WD41 | 41 | Sacramento | Electric | | 110 | n/a | 600 | 1% | 61 | 366 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD43 | 43 | Sacramento | Electric | | 110 | n/a | 850 | 2% | 86 | 518 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD45 | 45 | Sacramento | Natural Gas | | 190 | n/a | 750 | 2% | 76 | 457 | 2.5 | 450 | 599 | 0.118 | 4.08 | 0.317 | 0.000588 | 0.009987 | 0.009987 | 0.39 | 13.57 | 1.05 | 0.00 | 0.03 | 0.03 | 0.04 | 1.22 | 0.09 | 0.00 | 0.00 | 0.00 |
| Sacramento Suburban WD47 | 47 | Sacramento | Electric | | 110 | n/a | 885 | 2% | 90 | 540 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD50 | 50 | Sacramento | Electric | | 110 | n/a | 500 | 1% | 51 | 305 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD51 | 51 | Sacramento | Electric | | 110 | n/a | 285 | 1% | 29 | 174 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD60 | 60 | Sacramento | Electric | | 110 | n/a | 600 | 1% | 61 | 366 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD65 | 65 | Sacramento | Electric | | 110 | n/a | 1250 | 3% | 127 | 762 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD66 | 66 | Sacramento | Electric | | 110 | n/a | 1350 | 3% | 137 | 823 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD69 | 69 | Sacramento | Electric | | 110 | n/a | 450 | 1% | 46 | 274 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD70 | 70 | Sacramento | Electric | | 110 | n/a | 350 | 1% | 36 | 213 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD71 | 71 | Sacramento | Electric | | 110 | n/a | 2675 | 5% | 272 | 1,631 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD72 | 72 | Sacramento | Electric | | 110 | n/a | 1850 | 4% | 188 | 1,128 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD73 | 73 | Sacramento | Electric | | 110 | n/a | 3500 | 7% | 356 | 2,134 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD74 | 74 | Sacramento | Electric | | 110 | n/a | 2700 | 5% | 274 | 1,647 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD75 | 75 | Sacramento | Electric | | 110 | n/a | 1150 | 2% | 117 | 701 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD76 | 76 | Sacramento | Electric | | 110 | n/a | 250 | 1% | 25 | 152 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD77 | 77 | Sacramento | Electric | | 110 | n/a | 400 | 1% | 41 | 244 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD20A | 20A | Sacramento | Electric | | 110 | n/a | 1100 | 2% | 112 | 671 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD2A | 2A | Sacramento | Electric | | 110 | n/a | 995 | 2% | 101 | 607 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD32A | 32A | Sacramento | Electric | | 110 | n/a | 1905 | 4% | 194 | 1,162 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD33A | 33A | Sacramento | Electric | | 110 | n/a | 2675 | 5% | 272 | 1,631 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD3A | 3A | Sacramento | Electric | | 110 | n/a | 370 | 1% | 38 | 226 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD40A | 40A | Sacramento | Electric | | 110 | n/a | 2525 | 5% | 257 | 1,540 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD46R | 46R | Sacramento | Electric | | 110 | n/a | 800 | 2% | 81 | 488 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD4B | 4B | Sacramento | Electric | | 110 | n/a | 2675 | 5% | 272 | 1,631 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD55A | 55A | Sacramento | Electric | | 110 | n/a | 2000 | 4% | 203 | 1,220 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| Sacramento Suburban WD68R | 68R | Sacramento | Electric | | 110 | n/a | 1600 | 3% | 163 | 976 | 18 | 3,312 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **49,195** | **100%** | **5,000** | **30,000** | **790** | **144,209** | **2,394** | | | | | | | **1.57** | **54.26** | **4.22** | **0.01** | **0.13** | **0.13** | **0.14** | **4.88** | **0.38** | **0.00** | **0.01** | **0.01** |

Legend

| | |
|---|---|
| | Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type |
| | Dual-fuel engine (electric and natural gas) required to operate in electric mode to mitigate emissions |
| | Operation of natural gas fired engines will be controlled to reduce emissions less than significance thresholds as mitigation |

Conversion Factors

| | | |
|---|---|---|
| 1 MMBtu = | 1,000,000 | Btu |
| 1 lb = | 453.6 | g |
| 1 ton = | 2,000 | lbs |
| 1 month = | 30.4 | days |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Natural Gas Engine Fuel Consumption

| | | | |
|---|---|---|---|
| Estimated BSFC = | 7,000 | Btu/bhp-hr | (Estimated from Waukesha engine specifications) |
| Higher Heating Value | 1,020 | Btu/scf | (AP-42, Chapter 3.2: Natural Gas-fired Reciprocating Engines) |

**Groundwater Substitution Air Quality Emissions (Mitigated)**

Agency Gilsizer Slough Ranch
Transfer Volume 3,900 acre feet/year
Location Sutter County

Federal Attainment Status
PM10 A *Engines subject to ATCM.*
PM2.5 N
O3 N

Peak Month
800 AF/month
5,840 gallons/minute
97% peak pump rate

**Table I-66. Gilsizer Slough Ranch Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (gal/yr) | Emission Factors (g/bhp-hr) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gilsizer #1 | Gilsizer #1 | Sutter | Diesel | 2011 | 162 | T3 | 2,016 | 33% | 267 | 1,300 | 24 | 3,502 | 31,828 | 0.1 | 2.8 | 3.7 | 0.93 | 0.22 | 0.22 | 1.26 | 23.92 | 31.47 | 7.84 | 1.89 | 1.89 | 0.09 | 1.77 | 2.33 | 0.58 | 0.14 | 0.14 |
| Gilsizer #2 | Gilsizer #2 | Sutter | Electric | TBD | 110 | n/a | 2,016 | 33% | 267 | 1,300 | 24 | 3,502 | n/a | | | | | | | | | | | | | | | | | | |
| Gilsizer #3 | Gilsizer #3 | Sutter | Electric | TBD | 110 | n/a | 2,016 | 33% | 267 | 1,300 | 24 | 3,502 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **6,048** | **100%** | **800** | **3,900** | **71** | **10,506** | **31,828** | | | | | | | **1.26** | **23.92** | **31.47** | **7.84** | **1.89** | **1.89** | **0.09** | **1.77** | **2.33** | **0.58** | **0.14** | **0.14** |

Notes:
If a specific HP and emission tier combination has an emission standard of NMHC+NOx, then 95% of emissions assumed to be NOx and 5% of emissions assumed to be VOC (see CARB Carl Moyer Program Guidelines).
AP-42 emission factors used for SOx in all cases.
If an emission standard is not available for a given pollutant, then AP-42 emission factors used.
PM2.5 assumed to be 98% of PM10 emissions based on size fractions for stationary internal combustion diesel engines.

Legend
Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type
Based on NMHC+NOx standard

Conversion Factors
1 lb = 453.6 g
1 ton = 2,000 lbs
1 month = 30.4 days
1 hour = 60 minutes
1 acre-foot = 325,851 gallons
http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Diesel Engine Fuel Consumption
0.4 lb/hp-hr *(Based on spec sheet for John Deere 6068H, 6.8L Engine, 173 HP)*
0.855 g/mL *(Based on MSDS for Hess Diesel Fuel All Types)*
7.13 lb/gal

**Groundwater Substitution Air Quality Emissions (Mitigated)**

Agency Tule Basin Farms
Transfer Volume 7,320 acre feet/year
Location Sutter County

Federal Attainment Status
PM10 A *Engines subject to ATCM.*
PM2.5 N
O3 N

Peak Month
1,520 AF/month
11,095 gallons/minute
96% peak pump rate

**Table I-67. Tule Basin Farms Criteria Pollutant Emissions**

| Description | Well | Well Location (County) | Fuel Type | Model Year | Power Rating (hp) | Emission Tier | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/month) | Transfer Volume (AF/year) | Operation (hours/day) | Operation (hours/year) | Fuel Consumption (MMBtu/yr) | Emission Factors (lb/MMBtu) VOC | NOx | CO | SOx | PM10 | PM2.5 | Daily Emissions (lbs/day) VOC | NOx | CO | SOx | PM10 | PM2.5 | Annual Emissions (tons per year) VOC | NOx | CO | SOx | PM10 | PM2.5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tule Basin1 | 1 | Sutter | Electric | | 125 | n/a | 3,050 | 27% | 403 | 1,941 | 24 | 3,457 | n/a | | | | | | | | | | | | | | | | | | |
| Tule Basin2 | 2 | Sutter | Natural Gas | 1985 | 190 | n/a | 3,600 | 31% | 476 | 2,291 | 24 | 3,457 | 4,598 | 0.118 | 0.61 | 0.317 | 0.000588 | 0.009987 | 0.009987 | 3.70 | 19.21 | 9.95 | 0.02 | 0.31 | 0.31 | 0.27 | 1.41 | 0.73 | 0.00 | 0.02 | 0.02 |
| Tule Basin3 | 3 | Sutter | Electric | | 125 | n/a | 4,850 | 42% | 641 | 3,087 | 24 | 3,457 | n/a | | | | | | | | | | | | | | | | | | |
| | | | | | | **Total** | **11,500** | **100%** | **1,520** | **7,320** | **71** | **10,371** | **4,598** | | | | | | | **3.70** | **19.21** | **9.95** | **0.02** | **0.31** | **0.31** | **0.27** | **1.41** | **0.73** | **0.00** | **0.02** | **0.02** |

Conversion Factors
1 MMBtu = 1,000,000 Btu
1 ton = 2,000 lbs
1 month = 30.4 days
1 hour = 60 minutes
1 acre-foot = 325,851 gallons
http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Natural Gas Engine Fuel Consumption
Estimated BSFC = 7,000 Btu/bhp-hr (Estimated from Waukesha engine specifications)
Higher Heating Value 1,020 Btu/scf (AP-42, Chapter 3.2: Natural Gas-fired Reciprocating Engines)

SCR control efficiency 85%

**Table I-68. Summary of Cropland Idling Emissions by Water Agency**

| | Daily Emissions (lbs per day) | | | | | | Annual Emissions (tons per year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Agency** | **VOC** | **NOx** | **CO** | **SOx** | **PM10** | **PM2.5** | **VOC** | **NOx** | **CO** | **SOx** | **PM10** | **PM2.5** |
| Butte Water District | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (13) | (17) | (4) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (142) | (21) | -- | -- | -- | -- | (13) | (2) |
| Harvesting | -- | -- | -- | -- | (17) | (2) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 6 | 1 | -- | -- | -- | -- | 1 | 0 |
| Butte Water District Subtotal | (1) | (13) | (17) | (4) | (153) | (23) | (0) | (1) | (1) | (0) | (14) | (2) |
| Conaway Preservation Group | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (23) | (31) | (8) | (2) | (2) | (0) | (2) | (2) | (1) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (205) | (31) | -- | -- | -- | -- | (18) | (3) |
| Harvesting | -- | -- | -- | -- | (40) | (6) | -- | -- | -- | -- | (4) | (1) |
| Wind Erosion | -- | -- | -- | -- | 18 | 4 | -- | -- | -- | -- | 2 | 0 |
| Conaway Preservation Group Subtotal | (1) | (23) | (31) | (8) | (228) | (35) | (0) | (2) | (2) | (1) | (21) | (3) |
| Cranmore Farms | | | | | | | | | | | | |
| Exhaust Emissions | (0) | (3) | (4) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (61) | (9) | -- | -- | -- | -- | (6) | (1) |
| Harvesting | -- | -- | -- | -- | (4) | (1) | -- | -- | -- | -- | (0) | (0) |
| Wind Erosion | -- | -- | -- | -- | 1 | 0 | -- | -- | -- | -- | 0 | 0 |
| Cranmore Farms Subtotal | (0) | (3) | (4) | (1) | (64) | (10) | (0) | (0) | (0) | (0) | (6) | (1) |
| Glenn-Colusa Irrigation District | | | | | | | | | | | | |
| Exhaust Emissions | (4) | (72) | (95) | (24) | (6) | (6) | (0) | (5) | (6) | (2) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (1,550) | (232) | -- | -- | -- | -- | (140) | (21) |
| Harvesting | -- | -- | -- | -- | (96) | (14) | -- | -- | -- | -- | (9) | (1) |
| Wind Erosion | -- | -- | -- | -- | 416 | 83 | -- | -- | -- | -- | 37 | 7 |
| Glenn-Colusa Irrigation District Subtotal | (4) | (72) | (95) | (24) | (1,236) | (169) | (0) | (5) | (6) | (2) | (111) | (15) |
| Goose Club Farms and Teichert Aggregates | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (11) | (14) | (4) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (245) | (37) | -- | -- | -- | -- | (22) | (3) |
| Harvesting | -- | -- | -- | -- | (15) | (2) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 6 | 1 | -- | -- | -- | -- | 1 | 0 |
| Goose Club Farms and Teichert Aggregates Subtotal | (1) | (11) | (14) | (4) | (255) | (39) | (0) | (1) | (1) | (0) | (23) | (3) |
| Pelger Mutual Water Company | | | | | | | | | | | | |
| Exhaust Emissions | (0) | (3) | (4) | (1) | (0) | (0) | (0) | (0) | (0) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (62) | (9) | -- | -- | -- | -- | (6) | (1) |
| Harvesting | -- | -- | -- | -- | (4) | (1) | -- | -- | -- | -- | (0) | (0) |
| Wind Erosion | -- | -- | -- | -- | 1 | 0 | -- | -- | -- | -- | 0 | 0 |
| Pelger Mutual Water Company Subtotal | (0) | (3) | (4) | (1) | (65) | (10) | (0) | (0) | (0) | (0) | (6) | (1) |

**Table I-68. Summary of Cropland Idling Emissions by Water Agency**

| | Daily Emissions (lbs per day) | | | | | | Annual Emissions (tons per year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Agency** | **VOC** | **NOx** | **CO** | **SOx** | **PM10** | **PM2.5** | **VOC** | **NOx** | **CO** | **SOx** | **PM10** | **PM2.5** |
| Pleasant Grove-Verona Mutual Water Company | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (10) | (13) | (3) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (221) | (33) | -- | -- | -- | -- | (20) | (3) |
| Harvesting | -- | -- | -- | -- | (13) | (2) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 5 | 1 | -- | -- | -- | -- | 0 | 0 |
| Pleasant Grove-Verona Mutual Water Company Subtotal | (1) | (10) | (13) | (3) | (230) | (35) | (0) | (1) | (1) | (0) | (21) | (3) |
| Reclamation District 108 | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (22) | (29) | (7) | (2) | (2) | (0) | (1) | (2) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (338) | (51) | -- | -- | -- | -- | (30) | (5) |
| Harvesting | -- | -- | -- | -- | (33) | (5) | -- | -- | -- | -- | (3) | (0) |
| Wind Erosion | -- | -- | -- | -- | 75 | 15 | -- | -- | -- | -- | 7 | 1 |
| Reclamation District 108 Subtotal | (1) | (22) | (29) | (7) | (298) | (42) | (0) | (1) | (2) | (0) | (27) | (4) |
| Reclamation District 1004 | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (11) | (14) | (4) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (238) | (36) | -- | -- | -- | -- | (21) | (3) |
| Harvesting | -- | -- | -- | -- | (15) | (2) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 44 | 9 | -- | -- | -- | -- | 4 | 1 |
| Reclamation District 1004 Subtotal | (1) | (11) | (14) | (4) | (210) | (30) | (0) | (1) | (1) | (0) | (19) | (3) |
| Reclamation District 2068 | | | | | | | | | | | | |
| Exhaust Emissions | (0) | (8) | (11) | (3) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (39) | (6) | -- | -- | -- | -- | (4) | (1) |
| Harvesting | -- | -- | -- | -- | (7) | (1) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 5 | 1 | -- | -- | -- | -- | 0 | 0 |
| Reclamation District 2068 Subtotal | (0) | (8) | (11) | (3) | (41) | (6) | (0) | (1) | (1) | (0) | (4) | (1) |
| Sycamore Mutual Water Company | | | | | | | | | | | | |
| Exhaust Emissions | (1) | (11) | (14) | (4) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (242) | (36) | -- | -- | -- | -- | (22) | (3) |
| Harvesting | -- | -- | -- | -- | (15) | (2) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 66 | 13 | -- | -- | -- | -- | 6 | 1 |
| Sycamore Mutual Water Company Subtotal | (1) | (11) | (14) | (4) | (191) | (26) | (0) | (1) | (1) | (0) | (17) | (2) |

**Table I-68. Summary of Cropland Idling Emissions by Water Agency**

| | Daily Emissions (lbs per day) | | | | | | Annual Emissions (tons per year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Water Agency** | **VOC** | **NOx** | **CO** | **SOx** | **PM10** | **PM2.5** | **VOC** | **NOx** | **CO** | **SOx** | **PM10** | **PM2.5** |
| Te Velde Revocable Family Trust | | | | | | | | | | | | |
| Exhaust Emissions | (0) | (8) | (10) | (3) | (1) | (1) | (0) | (1) | (1) | (0) | (0) | (0) |
| Land Preparation | -- | -- | -- | -- | (67) | (10) | -- | -- | -- | -- | (6) | (1) |
| Harvesting | -- | -- | -- | -- | (13) | (2) | -- | -- | -- | -- | (1) | (0) |
| Wind Erosion | -- | -- | -- | -- | 6 | 1 | -- | -- | -- | -- | 1 | 0 |
| Te Velde Revocable Family Trust Subtotal | (0) | (8) | (10) | (3) | (75) | (11) | (0) | (1) | (1) | (0) | (7) | (1) |
| Exhaust Emissions Total | (10) | (195) | (256) | (64) | (15) | (15) | (1) | (13) | (17) | (4) | (1) | (1) |
| Land Preparation Total | 0 | 0 | 0 | 0 | (3,409) | (511) | 0 | 0 | 0 | 0 | (307) | (46) |
| Harvesting Total | 0 | 0 | 0 | 0 | (271) | (41) | 0 | 0 | 0 | 0 | (24) | (4) |
| Wind Erosion Total | 0 | 0 | 0 | 0 | 651 | 130 | 0 | 0 | 0 | 0 | 59 | 12 |
| **GRAND TOTAL** | **(10)** | **(195)** | **(256)** | **(64)** | **(3,045)** | **(437)** | **(1)** | **(13)** | **(17)** | **(4)** | **(274)** | **(39)** |

Size Fractions

| Description | PM10 | PM2.5 | Ratio |
|---|---|---|---|
| PM Profile ID No. 411, Windblown Dust - Agricultural | 0.5 | 0.1 | 0.2 |
| PM Profile ID No. 417, Agricultural Tilling Dust | 0.4543 | 0.0681 | 0.1499 |

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**Table I-69. Reduced Exhaust Emissions from Cropland Idling**

| Water Agency | Groundwater Substitution | Cropland Idling/ Crop Shifting | GW Pumping Equivalent | Reduced Daily Emissions (lbs/day) | | | | | | Reduced Annual Emissions (tons/year) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (acre-feet/year) | (acre-feet/year) | (acre-feet/year) | VOC | NOx | CO | SOx | PM10 | PM2.5 | VOC | NOx | CO | SOx | PM10 | PM2.5 |
| Butte Water District | 5,500 | 11,500 | 2,706 | 1 | 13 | 17 | 4 | 1 | 1 | 0.0 | 0.8 | 1.1 | 0.3 | 0.1 | 0.1 |
| Conaway Preservation Group | 35,000 | 21,349 | 5,023 | 1 | 23 | 31 | 8 | 2 | 2 | 0.1 | 1.6 | 2.0 | 0.5 | 0.1 | 0.1 |
| Cranmore Farms | 8,000 | 2,500 | 588 | 0 | 3 | 4 | 1 | 0 | 0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 |
| Glenn-Colusa Irrigation District | 25,000 | 66,000 | 15,529 | 4 | 72 | 95 | 24 | 6 | 6 | 0.3 | 4.8 | 6.3 | 1.6 | 0.4 | 0.4 |
| Goose Club Farms and Teichert Aggregates | 10,000 | 10,000 | 2,353 | 1 | 11 | 14 | 4 | 1 | 1 | 0.0 | 0.7 | 1.0 | 0.2 | 0.1 | 0.1 |
| Pelger Mutual Water Company | 3,750 | 2,538 | 597 | 0 | 3 | 4 | 1 | 0 | 0 | 0.0 | 0.2 | 0.2 | 0.1 | 0.0 | 0.0 |
| Pleasant Grove-Verona Mutual Water Company | 18,000 | 9,000 | 2,118 | 1 | 10 | 13 | 3 | 1 | 1 | 0.0 | 0.7 | 0.9 | 0.2 | 0.1 | 0.1 |
| Reclamation District 108 | 15,000 | 20,000 | 4,706 | 1 | 22 | 29 | 7 | 2 | 2 | 0.1 | 1.5 | 1.9 | 0.5 | 0.1 | 0.1 |
| Reclamation District 1004 | 7,175 | 10,000 | 2,353 | 1 | 11 | 14 | 4 | 1 | 1 | 0.0 | 0.7 | 1.0 | 0.2 | 0.1 | 0.1 |
| Reclamation District 2068 | 4,500 | 7,500 | 1,765 | 0 | 8 | 11 | 3 | 1 | 1 | 0.0 | 0.5 | 0.7 | 0.2 | 0.0 | 0.0 |
| Sycamore Mutual Water Company | 15,000 | 10,000 | 2,353 | 1 | 11 | 14 | 4 | 1 | 1 | 0.0 | 0.7 | 1.0 | 0.2 | 0.1 | 0.1 |
| Te Velde Revocable Family Trust | 7,094 | 6,975 | 1,641 | 0 | 8 | 10 | 3 | 1 | 1 | 0.0 | 0.5 | 0.7 | 0.2 | 0.0 | 0.0 |
| **Total** | **154,019** | **177,362** | **41,732** | **10** | **195** | **256** | **64** | **15** | **15** | **0.7** | **12.9** | **17.0** | **4.2** | **1.0** | **1.0** |

Notes:

Pelger Mutual Water Company used to estimate emissions for other water agencies.

Engine power rating equal to 250 hp for Pelger Mutual Water Company engines.

The Byron Buck memo is based on diesel-fueled engines with sizes ranging from 121 to 225 hp; all engines are noncertified (Tier 0).

Pelger Mutual Water Company engines are therefore determined to be a sufficient proxy to estimate the difference in emissions between groundwater substitution and cropland idling.

1 acre-foot of groundwater pumped = 4.25 acre-feet produced by fallowing

*Source: Byron Buck & Associates. 2009. "Comparison of Summertime Emission Credits from Land Fallowing Versus Groundwater Pumping."*

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**Fugitive Dust Emissions from Cropland Idling**

**Table I-70. Land Preparation (Reduced Emissions)**

| District | County | Acres | Daily PM10 Emissions (lbs/day) | Annual PM10 Emissions (tons per year) |
|---|---|---|---|---|
| | | Rice | Rice | Rice |
| **Sacramento River Area of Analysis** | | | | |
| Anderson-Cottonwood Irrigation District | Shasta/Tehama | 0 | 0 | 0 |
| Conaway Preservation Group | Yolo | 6,469 | 205 | 18 |
| Cordua Irrigation District | Yuba | 0 | 0 | 0 |
| Cranmore Farms | Sutter | 758 | 61 | 6 |
| Eastside Mutual Water Company | Colusa | 0 | 0 | 0 |
| Glenn-Colusa Irrigation District | Glenn/Colusa | 20,000 | 1,550 | 140 |
| Natomas Central Mutual Water Company | Sacramento/Sutter | 0 | 0 | 0 |
| Pelger Mutual Water Company | Sutter | 769 | 62 | 6 |
| Pleasant Grove-Verona Mutual Water Company | Sutter | 2,727 | 221 | 20 |
| Reclamation District 108 | Colusa/Yolo | 6,061 | 338 | 30 |
| Reclamation District 1004 | Colusa/Glenn/Sutter | 3,030 | 238 | 21 |
| River Garden Farms | Yolo | 0 | 0 | 0 |
| Sycamore Mutual Water Company | Colusa | 3,030 | 242 | 22 |
| Te Velde Revocable Family Trust | Yolo | 2,114 | 67 | 6 |
| **American River Area of Analysis** | | | | |
| City of Sacramento | Sacramento | 0 | 0 | 0 |
| Placer County Water Agency | Placer | 0 | 0 | 0 |
| Sacramento County Water Agency | Sacramento | 0 | 0 | 0 |
| Sacramento Suburban Water District | Sacramento | 0 | 0 | 0 |
| **Yuba River Area of Analysis** | | | | |
| Browns Valley Irrigation District | Yuba | 0 | 0 | 0 |
| **Feather River Area of Analysis** | | | | |
| Butte Water District | Butte/Sutter | 3,485 | 142 | 13 |
| Garden Highway Mutual Water Company | Sutter | 0 | 0 | 0 |
| Gilsizer Slough Ranch | Sutter | 0 | 0 | 0 |
| Goose Club Farms and Teichert Aggregates | Sutter | 3,030 | 245 | 22 |
| South Sutter Water District | Sutter/Placer | 0 | 0 | 0 |
| Tule Basin Farms | Sutter | 0 | 0 | 0 |
| **Merced River Area of Analysis** | | | | |
| Merced Irrigation District | Merced | 0 | 0 | 0 |
| **Delta Region Area of Analysis** | | | | |
| Reclamation District 2068 | Solano/Yolo | 2,273 | 39 | 4 |
| Pope Ranch | Yolo | 0 | 0 | 0 |
| **Total** | | **53,746** | **3,409** | **307** |

**Table I-71. Harvesting (Reduced Emissions)**

| District | County | Acres<br>Rice | Daily PM10 Emissions (lbs/day)<br>Rice | Annual PM10 Emissions (tons per year)<br>Rice |
|---|---|---|---|---|
| **Sacramento River Area of Analysis** | | | | |
| Anderson-Cottonwood Irrigation District | Shasta/Tehama | 0 | 0 | 0 |
| Conaway Preservation Group | Yolo | 6,469 | 40 | 4 |
| Cordua Irrigation District | Yuba | 0 | 0 | 0 |
| Cranmore Farms | Sutter | 758 | 4 | 0 |
| Eastside Mutual Water Company | Colusa | 0 | 0 | 0 |
| Glenn-Colusa Irrigation District | Glenn/Colusa | 20,000 | 96 | 9 |
| Natomas Central Mutual Water Company | Sacramento/Sutter | 0 | 0 | 0 |
| Pelger Mutual Water Company | Sutter | 769 | 4 | 0 |
| Pleasant Grove-Verona Mutual Water Company | Sutter | 2,727 | 13 | 1 |
| Reclamation District 108 | Colusa/Yolo | 6,061 | 33 | 3 |
| Reclamation District 1004 | Colusa/Glenn/Sutter | 3,030 | 15 | 1 |
| River Garden Farms | Yolo | 0 | 0 | 0 |
| Sycamore Mutual Water Company | Colusa | 3,030 | 15 | 1 |
| Te Velde Revocable Family Trust | Yolo | 2,114 | 13 | 1 |
| **American River Area of Analysis** | | | | |
| City of Sacramento | Sacramento | 0 | 0 | 0 |
| Placer County Water Agency | Placer | 0 | 0 | 0 |
| Sacramento County Water Agency | Sacramento | 0 | 0 | 0 |
| Sacramento Suburban Water District | Sacramento | 0 | 0 | 0 |
| **Yuba River Area of Analysis** | | | | |
| Browns Valley Irrigation District | Yuba | 0 | 0 | 0 |
| **Feather River Area of Analysis** | | | | |
| Butte Water District | Butte/Sutter | 3,485 | 17 | 1 |
| Garden Highway Mutual Water Company | Sutter | 0 | 0 | 0 |
| Gilsizer Slough Ranch | Sutter | 0 | 0 | 0 |
| Goose Club Farms and Teichert Aggregates | Sutter | 3,030 | 15 | 1 |
| South Sutter Water District | Sutter/Placer | 0 | 0 | 0 |
| Tule Basin Farms | Sutter | 0 | 0 | 0 |
| **Merced River Area of Analysis** | | | | |
| Merced Irrigation District | Merced | 0 | 0 | 0 |
| **Delta Region Area of Analysis** | | | | |
| Reclamation District 2068 | Solano/Yolo | 2,273 | 7 | 1 |
| Pope Ranch | Yolo | 0 | 0 | 0 |
| **Total** | | **53,746** | **271** | **24** |

**Table I-72. Windblown Dust (Increased Emissions)**

| District | County | Acres<br>Rice | Daily PM10 Emissions (lbs/day)<br>Rice | Annual PM10 Emissions (tons per year)<br>Rice |
|---|---|---|---|---|
| **Sacramento River Area of Analysis** | | | | |
| Anderson-Cottonwood Irrigation District | Shasta/Tehama | 0 | -- | -- |
| Conaway Preservation Group | Yolo | 6,469 | 18 | 2 |
| Cordua Irrigation District | Yuba | 0 | -- | -- |
| Cranmore Farms | Sutter | 758 | 1 | 0 |
| Eastside Mutual Water Company | Colusa | 0 | -- | -- |
| Glenn-Colusa Irrigation District | Glenn/Colusa | 20,000 | 416 | 37 |
| Natomas Central Mutual Water Company | Sacramento/Sutter | 0 | -- | -- |
| Pelger Mutual Water Company | Sutter | 769 | 1 | 0 |
| Pleasant Grove-Verona Mutual Water Company | Sutter | 2,727 | 5 | 0 |
| Reclamation District 108 | Colusa/Yolo | 6,061 | 75 | 7 |
| Reclamation District 1004 | Colusa/Glenn/Sutter | 3,030 | 44 | 4 |
| River Garden Farms | Yolo | 0 | -- | -- |
| Sycamore Mutual Water Company | Colusa | 3,030 | 66 | 6 |
| Te Velde Revocable Family Trust | Yolo | 2,114 | 6 | 1 |
| **American River Area of Analysis** | | | | |
| City of Sacramento | Sacramento | 0 | -- | -- |
| Placer County Water Agency | Placer | 0 | -- | -- |
| Sacramento County Water Agency | Sacramento | 0 | -- | -- |
| Sacramento Suburban Water District | Sacramento | 0 | -- | -- |
| **Yuba River Area of Analysis** | | | | |
| Browns Valley Irrigation District | Yuba | 0 | -- | -- |
| **Feather River Area of Analysis** | | | | |
| Butte Water District | Butte/Sutter | 3,485 | 6 | 1 |
| Garden Highway Mutual Water Company | Sutter | 0 | -- | -- |
| Gilsizer Slough Ranch | Sutter | 0 | -- | -- |
| Goose Club Farms and Teichert Aggregates | Sutter | 3,030 | 6 | 1 |
| South Sutter Water District | Sutter/Placer | 0 | -- | -- |
| Tule Basin Farms | Sutter | 0 | -- | -- |
| **Merced River Area of Analysis** | | | | |
| Merced Irrigation District | Merced | 0 | -- | -- |
| **Delta Region Area of Analysis** | | | | |
| Reclamation District 2068 | Solano/Yolo | 2,273 | 5 | 0 |
| Pope Ranch | Yolo | 0 | -- | -- |
| **Total** | | **53,746** | **651** | **59** |

Note:
Fraction of PM10 (FRPM10) from wind erosion: 0.50
(PM10 Emissions = PM x FRPM10)

Conversions

| | | | |
|---|---|---|---|
| 1 ton = | 2,000 | pounds | |
| Project duration = | 180 | days | (assumes 6-month crop idling season) |

Legend

| | |
|---|---|
| | Windblown dust emission factor for pasture land used because emission factor for agricultural lands not available. |
| | Windblown dust emission factor for pasture land used because emission factor for agricultural lands not available (for Yolo County only). |
| | Windblown dust emission factor for pasture land used because emission factor for agricultural lands not available (for Sutter County only). |

## Agricultural Land Preparation

**Table I-73. Summary of Crop Profile, Acre-Pass, and Emission Factor**

| Crop profile | Land Preparation Operations | Category | Acre-Pass | Emission Factor | |
|---|---|---|---|---|---|
| | | | | Operation (lbs PM10/Acre-pass) | Crop (lbs PM10/Acre/year) |
| Alfalfa | Unspecified | Discing | 1.25 | 1.2 | 4 |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| Almonds | Float | Land Planing | 0.25 | 12.5 | 3.13 |
| Citrus | Unspecified | Discing | 0.06 | 1.2 | 0.07 |
| Corn | List & Fertilize | Weeding | 1 | 0.8 | 6.9 |
| | Mulch Beds | Discing | 1 | 1.2 | |
| | Finish Disc | Discing | 1 | 1.2 | |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| | Stubble Disc | Discing | 1 | 1.2 | |
| Cotton | Land Preparation | Discing | 4 | 1.2 | 8.9 |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| | Seed Bed Preparation | Weeding | 2 | 0.8 | |
| DryBeans | Land Maintenance | Land Planing | 0.2 | 12.5 | 7.7 |
| | Chisel | Discing | 1 | 1.2 | |
| | Shaping | Weeding | 1 | 0.8 | |
| | Disc | Discing | 2 | 1.2 | |
| | Listing | Weeding | 1 | 0.8 | |
| Garbanzo | Chisel | Discing | 1 | 1.2 | 7.7 |
| | Listing | Weeding | 1 | 0.8 | |
| | Shaping | Weeding | 1 | 0.8 | |
| | Disc | Discing | 2 | 1.2 | |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| Garlic | Land Maintenance | Land Planing | 0.2 | 12.5 | 6.5 |
| | Disc & Roll | Discing | 1 | 1.2 | |
| | Chisel | Discing | 1 | 1.2 | |
| | List | Weeding | 1 | 0.8 | |
| | Shape Beds | Weeding | 1 | 0.8 | |
| Grapes-Raisin | Terrace | Weeding | 1 | 0.8 | 2.6 |
| | Spring Tooth | Weeding | 0.2 | 0.8 | |
| | Subsoil | Ripping | 0.05 | 4.6 | |
| | Disc & Furrow-out | Discing | 1 | 1.2 | |
| | Level (new vineyard) | Land Planing | 0.02 | 12.5 | |
| Grapes-Table | Subsoil | Ripping | 0.05 | 4.6 | 0.83 |
| | Disc & Furrow-out | Discing | 0.5 | 1.2 | |
| Grapes-Wine | Level (new vineyard) | Land Planing | 0.02 | 12.5 | 1.5 |
| | Spring Tooth | Weeding | 0.2 | 0.8 | |
| | Subsoil | Ripping | 0.05 | 4.6 | |
| | Disc & Furrow-out | Discing | 0.75 | 1.2 | |
| Lettuce* | Land Maintenance | Land Planing | 0.2 | 12.5 | 12.75 |
| | Disc & Roll | Discing | 2/2 | 1.2 | |
| | Chisel | Discing | 2/2 | 1.2 | |
| | List | Weeding | 2/2 | 0.8 | |
| | Plane | Land Planing | ½ | 12.5 | |
| | Shape Beds & Roll | Weeding | 2/2 | 0.8 | |
| Melon | Plow | Discing | 1 | 1.2 | 5.7 |
| | Shape Beds | Weeding | 1 | 0.8 | |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| | Disc | Discing | 1 | 1.2 | |
| No Land Prep. | Unspecified | Discing | 0 | 1.2 | 0 |
| Onions | List | Weeding | 1 | 0.8 | 6.5 |
| | Shape Beds | Weeding | 1 | 0.8 | |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| | Chisel | Discing | 1 | 1.2 | |
| | Disc & Roll | Discing | 1 | 1.2 | |

## Agricultural Land Preparation

**Table I-73. Summary of Crop Profile, Acre-Pass, and Emission Factor**

| Crop profile | Land Preparation Operations | Category | Acre-Pass | Emission Factor | |
|---|---|---|---|---|---|
| | | | | Operation (lbs PM10/Acre-pass) | Crop (lbs PM10/Acre/year) |
| Rice | Chisel | Discing | 1 | 1.2 | 20 |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| | Post Burn/Harvest Disc | Discing | 0.5 | 1.2 | |
| | Roll | Weeding | 1 | 0.8 | |
| | 3 Wheel Plane | Land Planing | 1 | 12.5 | |
| | Harrow Disc | Discing | 1 | 1.2 | |
| | Stubble Disc | Discing | 1 | 1.2 | |
| Safflower | List | Weeding | 1 | 0.8 | 4.5 |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| | Stubble Disc | Discing | 1 | 1.2 | |
| Sugar Beets | Disc | Discing | 1 | 1.2 | 22.8 |
| | Land Plane | Land Planing | 1 | 12.5 | |
| | Subsoil-deep chisel | Ripping | 1 | 4.6 | |
| | Stubble Disc | Discing | 1 | 1.2 | |
| | List | Weeding | 1 | 0.8 | |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| Tomatoes | Bed Preparation | Weeding | 2 | 0.8 | 10.1 |
| | Land Preparation | Discing | 5 | 1.2 | |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |
| Vegetables | Land Maintenance | Land Planing | 0.2 | 12.5 | 8.5 |
| | Unspecified | Discing | 5 | 1.2 | |
| Wheat | Stubble Disc | Discing | 1 | 1.2 | 3.7 |
| | Land Maintenance | Land Planing | 0.2 | 12.5 | |

Source:

CARB. 2003. Emission Inventory Documentation, Section 7.4: Agricultural Land Preparation. January.

Accessed on: May 5, 2012. Available at: http://www.arb.ca.gov/ei/areasrc/arbmiscprocresfarmop.htm

## Agricultural Harvest Operations

**Table I-74. Summary of Crop Emission Factor Assumptions**

| CDFA Crop Code | CDFA Crop Description | Crop Profile | Assumption | Emission Factor (lbs PM10/acre/yr) |
|---|---|---|---|---|
| 101999 | WHEAT ALL | Wheat | Wheat/1 | 5.8 |
| 104999 | RYE FOR GRAIN | Wheat | Wheat/1 | 5.8 |
| 106199 | RICE, FOR MILLING | Rice | Cotton/2 | 1.68 |
| 106269 | FIELD CROP BY PRODUCTS | Cotton | Cotton/20 | 0.17 |
| 108999 | FOOD GRAINS, MISC | Corn | Cotton/2 | 1.68 |
| 111559 | CORN, WHITE | Corn | Cotton/40 | 0.08 |
| 111991 | CORN FOR GRAIN | Corn | Cotton/2 | 1.68 |
| 111992 | CORN FOR SILAGE | Corn | Cotton/20 | 0.17 |
| 112999 | OATS FOR GRAIN | Wheat | Wheat/1 | 5.8 |
| 113994 | BARLEY, MALTING | Wheat | Wheat/1 | 5.8 |
| 113995 | BARLEY, FEED | Wheat | Wheat/1 | 5.8 |
| 113999 | BARLEY, UNSPECIFIED | Wheat | Wheat/1 | 5.8 |
| 114991 | SORGHUM, GRAIN | Wheat | Wheat/1 | 5.8 |
| 121219 | COTTON LINT, UPLAND | Cotton | Cotton/1 | 3.37 |
| 121229 | COTTON LINT, PIMA | Cotton | Cotton/1 | 3.37 |
| 121299 | COTTON LINT, UNSPEC | Cotton | Cotton/1 | 3.37 |
| 132999 | SUGAR BEETS | Sugar Beets | Cotton/2 | 1.68 |
| 151999 | COTTONSEED | Cotton | Cotton/1 | 3.37 |
| 153999 | PEANUTS, ALL | Safflower | Cotton/2 | 1.68 |
| 158269 | SAFFLOWER | Safflower | Wheat/1 | 5.8 |
| 158316 | SUNFLOWER SEED, PLANTING | Corn | Wheat/1 | 5.8 |
| 158319 | SUNFLOWER SEED | Corn | Wheat/1 | 5.8 |
| 158499 | JOJOBA | Melon | Cotton/40 | 0.08 |
| 161131 | BEANS, LIMAS, LG. DRY | DryBeans | Cotton/2 | 1.68 |
| 161132 | BEANS, LIMAS, BABY DRY | DryBeans | Cotton/2 | 1.68 |
| 161199 | LIMA BEANS, UNSPECIFIED | DryBeans | Cotton/2 | 1.68 |
| 161717 | BEANS, RED KIDNEY | DryBeans | Cotton/2 | 1.68 |
| 161721 | BEANS, PINK | DryBeans | Cotton/2 | 1.68 |
| 161741 | BEANS, BLACKEYE (PEAS) | DryBeans | Cotton/2 | 1.68 |
| 161742 | BEANS, GARBANZO | Garbanzo | Cotton/2 | 1.68 |
| 162399 | BEANS, FAVA | DryBeans | Cotton/2 | 1.68 |
| 163999 | PEAS, DRY EDIBLE | DryBeans | Cotton/20 | 0.17 |
| 169999 | BEANS,UNSPEC. DRY EDIBLE | DryBeans | Cotton/2 | 1.68 |
| 171019 | SEED WHEAT | Wheat | Wheat/1 | 5.8 |
| 171049 | SEED RYE | Wheat | Wheat/1 | 5.8 |
| 171069 | SEED RICE | Rice | Cotton/2 | 1.68 |
| 171129 | SEED OATS | Wheat | Wheat/1 | 5.8 |
| 171139 | SEED BARLEY | Wheat | Wheat/1 | 5.8 |
| 171519 | SEED, COTTON FOR PLANTING | Cotton | Cotton/1 | 3.37 |
| 171582 | SEED, SAFFLOWER, PLANTING | Safflower | Wheat/1 | 5.8 |
| 171619 | SEED BEANS | DryBeans | Cotton/2 | 1.68 |
| 171639 | SEED PEAS | DryBeans | Cotton/20 | 0.17 |
| 171949 | SEED, MISC FIELD CROP | Corn | Cotton/20 | 0.17 |
| 171959 | SEED, VEG & VINECROP | Vegetables | Cotton/20 | 0.17 |
| 172119 | SEED, ALFALFA | Alfalfa | Zero/1 | 0 |
| 172289 | CLOVER, UNSPECIFIED SEED | Alfalfa | Zero/1 | 0 |
| 173079 | SEED, BERMUDA GRASS | Alfalfa | Zero/1 | 0 |
| 173669 | SEED, SUDAN GRASS | Alfalfa | Zero/1 | 0 |
| 173999 | SEED, GRASS, UNSPECIFIED | Alfalfa | Zero/1 | 0 |
| 178999 | SEED, OTHER (NO FLOWERS) | Alfalfa | Cotton/20 | 0.17 |
| 181999 | HAY, ALFALFA | Alfalfa | Zero/1 | 0 |
| 188499 | HAY, GRAIN | Alfalfa | Cotton/2 | 1.68 |
| 188799 | HAY, WILD | Alfalfa | Cotton/2 | 1.68 |
| 188899 | HAY, SUDAN | Alfalfa | Zero/1 | 0 |
| 188999 | HAY, OTHER UNSPECIFIED | Alfalfa | Cotton/2 | 1.68 |

## Agricultural Harvest Operations

**Table I-74. Summary of Crop Emission Factor Assumptions**

| CDFA Crop Code | CDFA Crop Description | Crop Profile | Assumption | Emission Factor (lbs PM10/acre/yr) |
|---|---|---|---|---|
| 194599 | PASTURE, IRRIGATED | No Land | Zero/1 | 0 |
| 194699 | PASTURE, RANGE | No Land | Zero/1 | 0 |
| 194799 | PASTURE, MISC. FORAGE | No Land | Zero/1 | 0 |
| 195199 | SILAGE | Wheat | Cotton/20 | 0.17 |
| 195299 | HAY, GREEN CHOP | Alfalfa | Zero/1 | 0 |
| 195399 | STRAW | Alfalfa | Wheat/1 | 5.8 |
| 198199 | RICE, WILD | Rice | Cotton/2 | 1.68 |
| 198999 | FIELD CROPS, UNSPEC. | Corn | Cotton/20 | 0.17 |
| 201119 | ORANGES, NAVEL | Citrus | Cotton/40 | 0.08 |
| 201519 | ORANGES, VALENCIAS | Citrus | Cotton/40 | 0.08 |
| 201999 | ORANGES, UNSPECIFIED | Citrus | Cotton/40 | 0.08 |
| 202999 | GRAPEFRUIT, ALL | Citrus | Cotton/40 | 0.08 |
| 203999 | TANGERINES & MANDARINS | Citrus | Cotton/40 | 0.08 |
| 204999 | LEMONS, ALL | Citrus | Cotton/40 | 0.08 |
| 205999 | LIMES, ALL | Citrus | Cotton/40 | 0.08 |
| 206999 | TANGELOS | Citrus | Cotton/40 | 0.08 |
| 207999 | KUMQUATS | Citrus | Cotton/40 | 0.08 |
| 208059 | CITRUS, MISC BY-PROD | Citrus | Cotton/40 | 0.08 |
| 209999 | CITRUS, UNSPECIFIED | Citrus | Cotton/40 | 0.08 |
| 211999 | APPLES, ALL | Citrus | Cotton/40 | 0.08 |
| 212199 | PEACHES, FREESTONE | Citrus | Cotton/40 | 0.08 |
| 212399 | PEACHES, CLINGSTONE | Citrus | Cotton/40 | 0.08 |
| 212999 | PEACHES, UNSPECIFIED | Citrus | Cotton/40 | 0.08 |
| 213199 | CHERRIES, SWEET | Citrus | Cotton/40 | 0.08 |
| 214199 | PEARS, BARLETT | Citrus | Cotton/40 | 0.08 |
| 214899 | PEARS, ASIAN | Citrus | Cotton/40 | 0.08 |
| 214999 | PEARS, UNSPECIFIED | Citrus | Cotton/40 | 0.08 |
| 215199 | PLUMS | Citrus | Cotton/40 | 0.08 |
| 215399 | PLUMCOTS | Citrus | Cotton/40 | 0.08 |
| 215999 | PRUNES, DRIED | Citrus | Cotton/40 | 0.08 |
| 216199 | GRAPES, TABLE | Grapes-Table | Cotton/20 | 0.17 |
| 216299 | GRAPES, WINE | Grapes-Wine | Cotton/20 | 0.17 |
| 216399 | GRAPES, RAISIN | Grapes-Raisin | Cotton/20 | 0.17 |
| 216999 | GRAPES, UNSPECIFIED | Grapes-Wine | Cotton/20 | 0.17 |
| 217999 | APRICOTS, ALL | Citrus | Cotton/40 | 0.08 |
| 218199 | NECTARINES | Citrus | Cotton/40 | 0.08 |
| 218299 | PERSIMMONS | Citrus | Cotton/40 | 0.08 |
| 218399 | POMEGRANATES | Citrus | Cotton/40 | 0.08 |
| 218499 | QUINCE | Citrus | Cotton/40 | 0.08 |
| 218839 | CHERIMOYAS | Citrus | Cotton/40 | 0.08 |
| 218889 | ORCHARD BIOMASS | Almonds | Cotton/40 | 0.08 |
| 218899 | FRUITS & NUTS, UNSPEC. | Citrus | Cotton/40 | 0.08 |
| 221999 | AVOCADOS, ALL | Citrus | Cotton/40 | 0.08 |
| 224999 | DATES | Citrus | Almonds/20 | 2.04 |
| 225999 | FIGS, DRIED | Citrus | Almonds/20 | 2.04 |
| 226999 | OLIVES | Citrus | Cotton/40 | 0.08 |
| 228019 | GUAVAS | Citrus | Cotton/40 | 0.08 |
| 229999 | KIWIFRUIT | Citrus | Cotton/40 | 0.08 |
| 230639 | BERRIES, BLACKBERRIES | Grapes-Table | Cotton/40 | 0.08 |
| 230869 | BERRIES, BOYSENBERRIES | Grapes-Table | Cotton/40 | 0.08 |
| 234799 | BERRIES, LOGANBERRIES | Grapes-Table | Cotton/40 | 0.08 |
| 236199 | BERRIES, RASPBERRIES | Grapes-Table | Cotton/40 | 0.08 |
| 237199 | STRAWBERRIES, FRESH MKT | Melon | Cotton/40 | 0.08 |
| 237299 | STRAWBERRIES, PROC | Melon | Cotton/40 | 0.08 |
| 237999 | STRAWBERRIES, UNSPECIFIED | Melon | Cotton/40 | 0.08 |

## Agricultural Harvest Operations

**Table I-74. Summary of Crop Emission Factor Assumptions**

| CDFA Crop Code | CDFA Crop Description | Crop Profile | Assumption | Emission Factor (lbs PM10/acre/yr) |
|---|---|---|---|---|
| 239999 | BERRIES, BUSH, UNSPECIFIED | Grapes-Table | Cotton/40 | 0.08 |
| 261999 | ALMONDS, ALL | Almonds | Almonds/1 | 40.77 |
| 263999 | WALNUTS, ENGLISH | Almonds | Almonds/1 | 40.77 |
| 264999 | PECANS | Almonds | Almonds/10 | 4.08 |
| 265999 | WALNUTS, BLACK | Almonds | Almonds/1 | 40.77 |
| 266999 | CHESTNUTS | Almonds | Almonds/10 | 4.08 |
| 267999 | MACADAMIA NUT | Almonds | Almonds/10 | 4.08 |
| 268079 | PISTACHIOS | Almonds | Almonds/10 | 4.08 |
| 268099 | ALMOND HULLS | Almonds | Almonds/1 | 40.77 |
| 301999 | ARTICHOKES | Melon | Cotton/40 | 0.08 |
| 302199 | ASPARAGUS, FRESH MKT | Melon | Cotton/2 | 1.68 |
| 302299 | ASPARAGUS, PROC | Melon | Cotton/2 | 1.68 |
| 302999 | ASPARAGUS, UNSPECIFIED | Melon | Cotton/2 | 1.68 |
| 303999 | BEANS, GREEN LIMAS | DryBeans | Cotton/2 | 1.68 |
| 304199 | BEANS, SNAP FR MKT | DryBeans | Cotton/20 | 0.17 |
| 304299 | BEANS, SNAP PROC | DryBeans | Cotton/20 | 0.17 |
| 304399 | BEANS FRESH UNSPECIFIED | DryBeans | Cotton/20 | 0.17 |
| 304999 | BEANS, UNSPECIFIED SNAP | DryBeans | Cotton/20 | 0.17 |
| 305999 | BEETS, GARDEN | Sugar Beets | Cotton/2 | 1.68 |
| 306999 | RAPINI | Sugar Beets | Cotton/40 | 0.08 |
| 307189 | BROCCOLI,FOOD SERV | Vegetables | Cotton/40 | 0.08 |
| 307199 | BROCCOLI, FR MKT | Vegetables | Cotton/40 | 0.08 |
| 307299 | BROCCOLI, PROC | Vegetables | Cotton/40 | 0.08 |
| 307919 | BROCCOLI, UNSPECIFIED | Vegetables | Cotton/40 | 0.08 |
| 308999 | BRUSSELS SPROUTS | Melon | Cotton/40 | 0.08 |
| 309999 | CABBAGE, CH. & SPECIALTY | Lettuce | Cotton/40 | 0.08 |
| 310999 | CABBAGE, HEAD | Lettuce | Cotton/40 | 0.08 |
| 313189 | CARROTS, FOOD SERV | Sugar Beets | Cotton/20 | 0.17 |
| 313199 | CARROTS, FR MKT | Sugar Beets | Cotton/20 | 0.17 |
| 313299 | CARROTS, PROC | Sugar Beets | Cotton/20 | 0.17 |
| 313999 | CARROTS, UNSPECIFIED | Sugar Beets | Cotton/20 | 0.17 |
| 314189 | CAULIFLOWER, FOOD SERV | Vegetables | Cotton/40 | 0.08 |
| 314199 | CAULIFLOWER, FR MKT | Vegetables | Cotton/40 | 0.08 |
| 314299 | CAULIFLOWER, PROC | Vegetables | Cotton/40 | 0.08 |
| 314999 | CAULIFLOWER, UNSPECIFIED | Vegetables | Cotton/40 | 0.08 |
| 316189 | CELERY, FOOD SERV | Lettuce | Cotton/40 | 0.08 |
| 316199 | CELERY, FR MKT | Lettuce | Cotton/40 | 0.08 |
| 316299 | CELERY, PROC | Lettuce | Cotton/40 | 0.08 |
| 316999 | CELERY, UNSPECIFIED | Lettuce | Cotton/40 | 0.08 |
| 318999 | RADICCHIO | Lettuce | Cotton/40 | 0.08 |
| 320999 | CHIVES | Lettuce | Cotton/40 | 0.08 |
| 322999 | COLLARD GREENS | Lettuce | Cotton/40 | 0.08 |
| 323999 | CORN, SWEET ALL | Corn | Cotton/40 | 0.08 |
| 325999 | CUCUMBERS | Vegetables | Cotton/40 | 0.08 |
| 330999 | EGGPLANT, ALL | Vegetables | Cotton/40 | 0.08 |
| 331999 | ENDIVE, ALL | Lettuce | Cotton/40 | 0.08 |
| 332999 | ESCAROLE, ALL | Lettuce | Cotton/40 | 0.08 |
| 333999 | ANISE (FENNEL) | Lettuce | Cotton/2 | 1.68 |
| 335999 | GARLIC, ALL | Garlic | Cotton/2 | 1.68 |
| 337999 | KALE | Lettuce | Cotton/40 | 0.08 |
| 338999 | KOHLRABI | Lettuce | Cotton/40 | 0.08 |
| 339196 | LETTUCE, BULK SALAD PRODS. | Lettuce | Cotton/40 | 0.08 |
| 339999 | LETTUCE, UNSPECIFIED | Lettuce | Cotton/40 | 0.08 |
| 340999 | LETTUCE, HEAD | Lettuce | Cotton/40 | 0.08 |
| 341999 | LETTUCE, ROMAINE | Lettuce | Cotton/40 | 0.08 |

## Agricultural Harvest Operations

**Table I-74. Summary of Crop Emission Factor Assumptions**

| CDFA Crop Code | CDFA Crop Description | Crop Profile | Assumption | Emission Factor (lbs PM10/acre/yr) |
|---|---|---|---|---|
| 342999 | LETTUCE, LEAF | Lettuce | Cotton/40 | 0.08 |
| 343999 | MELON, CANTALOUPE | Melon | Cotton/40 | 0.08 |
| 348999 | MELON, HONEYDEW | Melon | Cotton/40 | 0.08 |
| 354299 | MELON, UNSPECIFIED | Melon | Cotton/40 | 0.08 |
| 354999 | MELON, WATER MELONS | Melon | Cotton/40 | 0.08 |
| 355999 | MUSHROOMS | No Land Prep. | Zero/1 | 0 |
| 356999 | MUSTARD | Lettuce | Cotton/40 | 0.08 |
| 357999 | OKRA | Lettuce | Cotton/40 | 0.08 |
| 358999 | ONIONS | Onions | Cotton/2 | 1.68 |
| 359999 | PARSLEY | Lettuce | Cotton/40 | 0.08 |
| 361299 | PEAS, GREEN, PROCESSING | DryBeans | Cotton/20 | 0.17 |
| 361999 | PEAS, GREEN, UNSPECIFIED | DryBeans | Cotton/20 | 0.17 |
| 363999 | PEPPERS, BELL | Tomatoes | Cotton/40 | 0.08 |
| 364999 | PEPPERS, CHILI, HOT | Tomatoes | Cotton/40 | 0.08 |
| 366999 | PUMPKINS | Melon | Cotton/20 | 0.17 |
| 367999 | RADISHES | Sugar Beets | Cotton/40 | 0.08 |
| 368999 | RHUBARB | Lettuce | Cotton/40 | 0.08 |
| 370999 | RUTABAGAS | Sugar Beets | Cotton/2 | 1.68 |
| 372999 | ONIONS, GREEN & SHALLOTS | Onions | Cotton/40 | 0.08 |
| 374189 | SPINACH, FOOD SERV | Lettuce | Cotton/40 | 0.08 |
| 374199 | SPINACH, FR MKT | Lettuce | Cotton/40 | 0.08 |
| 374299 | SPINACH, PROC | Lettuce | Cotton/40 | 0.08 |
| 374999 | SPINACH UNSPECIFIED | Lettuce | Cotton/40 | 0.08 |
| 375999 | SQUASH | Melon | Cotton/20 | 0.17 |
| 376999 | SWISSCHARD | Lettuce | Cotton/40 | 0.08 |
| 378199 | TOMATOES, FRESH MARKET | Tomatoes | Cotton/40 | 0.08 |
| 378299 | TOMATOES, PROCESSING | Tomatoes | Cotton/20 | 0.17 |
| 378999 | TOMATOES, UNSPECIFIED | Tomatoes | Cotton/20 | 0.17 |
| 380999 | TURNIPS, ALL | Sugar Beets | Cotton/2 | 1.68 |
| 381999 | GREENS, TURNIP & MUSTARD | Lettuce | Cotton/40 | 0.08 |
| 387999 | LEEKS | Onions | Cotton/40 | 0.08 |
| 391999 | POTATOES, IRISH ALL | Sugar Beets | Cotton/2 | 1.68 |
| 392999 | SWEET POTATOES | Sugar Beets | Cotton/2 | 1.68 |
| 393999 | HORSERADISH | Onions | Cotton/40 | 0.08 |
| 394199 | SALAD GREENS NEC | Lettuce | Cotton/40 | 0.08 |
| 394999 | PEAS, EDIBLE POD (SNOW) | DryBeans | Cotton/20 | 0.17 |
| 395999 | VEGETABLES, ORIENTAL, ALL | Vegetables | Cotton/40 | 0.08 |
| 396999 | SPROUTS, ALFALFA & BEAN | Lettuce | Cotton/40 | 0.08 |
| 398199 | CUCUMBERS, GREENHOUSE | No Land Prep. | Zero/1 | 0 |
| 398299 | TOMATOES, GREENHOUSE | No Land Prep. | Zero/1 | 0 |
| 398399 | TOMATOES, CHERRY | Tomatoes | Cotton/40 | 0.08 |
| 398499 | TOMATILLO | Tomatoes | Cotton/40 | 0.08 |
| 398559 | CILANTRO | Lettuce | Cotton/40 | 0.08 |
| 398599 | SPICES AND HERBS | Lettuce | Cotton/40 | 0.08 |
| 398899 | VEGETABLES, BABY | Vegetables | Cotton/40 | 0.08 |
| 398999 | VEGETABLES, UNSPECIFIED | Vegetables | Cotton/20 | 0.17 |
| 832919 | POTATOES SEED | Sugar Beets | Cotton/2 | 1.68 |
| 892999 | NURSERY TURF | No Land Prep. | Zero 1 | 0 |

Source:

CARB. 2003. Emission Inventory Documentation, Section 7.5: Agricultural Harvest Operations. January. Accessed on: May 5, 2012. Available at: http://www.arb.ca.gov/ei/areasrc/arbmiscprocresfarmop.htm.

## Windblown Dust - Agricultural Lands

**Table I-75. Windblown Dust - Agricultural Lands**

| Air Basin Code | County Name | Emission Factor (tons/acre/yr) | Process Rate (acres) | PM Emissions (tons/year) |
|---|---|---|---|---|
| NCC | Monterey | 0.020478 | 279,178.00 | 5,717.07 |
| | San Benito | 0.015936 | 50,009.00 | 796.96 |
| | Santa Cruz | 0.002485 | 14,873.00 | 36.97 |
| SCC | San Luis Obispo | 0.006876 | 109,694.00 | 754.2 |
| | Santa Barbara | 0.00319 | 80,732.00 | 257.56 |
| | Ventura | 0.018418 | 54,568.00 | 1,005.02 |
| SED | Imperial | 0.141666 | 490,409.00 | 69,474.43 |
| SJV | Fresno | 0.013761 | 864,164.00 | 11,891.35 |
| | Kern | 0.008662 | 408,313.48 | 3,536.73 |
| | Kings | 0.012856 | 473,817.00 | 6,091.62 |
| | Madera | 0.008032 | 141,617.00 | 1,137.47 |
| | Merced | 0.013659 | 364,804.00 | 4,982.86 |
| | San Joaquin | 0.003527 | 387,278.00 | 1,365.96 |
| | Stanislaus | 0.009052 | 229,805.00 | 2,080.26 |
| | Tulare | 0.004693 | 471,664.00 | 2,213.29 |
| SV | Butte | 0.001154 | 116,869.00 | 134.87 |
| | Colusa | 0.004702 | 229,747.00 | 1,080.31 |
| | Glenn | 0.004957 | 186,067.00 | 922.39 |
| | Placer | 0.002172 | 6,962.90 | 15.12 |
| | Sacramento | 0.002479 | 117,770.00 | 291.92 |

Note:
Fraction of PM10 (FRPM10): 0.50
(PM10 Emissions = PM x FRPM10)

**Table I-76. Windblown Dust - Pasture Lands**

| Air Basin Code | County Name | Emission Factor (tons/acre/yr) | Process Rate (acres) | PM Emissions (tons/year) |
|---|---|---|---|---|
| NCC | Monterey | 0.00110562 | 1,108,000 | 1,225.03 |
| | San Benito | 0.00109336 | 512,000 | 559.8 |
| | Santa Cruz | 0.0001605 | 8,000 | 1.28 |
| SCC | Santa Barbara | 0.00021801 | 602,913 | 131.44 |
| | San Luis Obispo | 0.00046964 | 1,102,500 | 517.78 |
| | Ventura | 0.00050356 | 210,918 | 106.21 |
| SED | Imperial | 0.00867346 | 158,449 | 1,374.30 |
| SJV | Fresno | 0.00149089 | 907,300 | 1,352.69 |
| | Kern | 0.00082834 | 1,527,603 | 1,265.37 |
| | Kings | 0.00146875 | 142,777 | 209.7 |
| | Madera | 0.00116178 | 421,000 | 489.11 |
| | Merced | 0.00155578 | 642,700 | 999.9 |
| | San Joaquin | 0.0005228 | 167,700 | 87.67 |
| | Stanislaus | 0.00107875 | 434,300 | 468.5 |
| | Tulare | 0.00063424 | 713,400 | 452.47 |
| SV | Butte | 0.00014292 | 288,500 | 41.23 |
| | Colusa | 0.00046444 | 181,900 | 84.48 |
| | Glenn | 0.00048846 | 256,575 | 125.33 |
| | Placer | 0.00026499 | 65,656 | 17.4 |
| | Sacramento | 0.00019538 | 118,000 | 23.05 |
| | Shasta | 0.00034146 | 459,000 | 156.73 |
| | Solano | 0.00039453 | 131,360 | 51.83 |
| | Sutter | 0.00037084 | 71,500 | 26.51 |
| | Tehama | 0.00035146 | 955,350 | 335.76 |
| | Yolo | 0.00061919 | 136,870 | 84.75 |
| | Yuba | 0.00023892 | 207,600 | 49.6 |

Note:
Fraction of PM10 (FRPM10): 0.50
(PM10 Emissions = PM x FRPM10)

Source:
CARB. 1997. Emission Inventory Documentation, Section 7.12: Windblown Dust - Agricultural Lands. July.
Accessed on: May 5, 2012. Available at: http://www.arb.ca.gov/ei/areasrc/arbmiscprocfugwbdst.htm.

## Seasonal Profiles

**Table I-77. Agricultural Land Preparation Seasonal Profile for Land Preparation**

| AB | ID # | County | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SV | 4 | BUTTE | 0.005 | 0.004 | 0.081 | 0.387 | 0.387 | 0.001 | 0.001 | 0.001 | 0.001 | 0.015 | 0.06 | 0.058 |
| | 6 | COLUSA | 0.009 | 0.016 | 0.079 | 0.355 | 0.355 | 0.002 | 0.002 | 0.002 | 0.002 | 0.035 | 0.074 | 0.07 |
| | 11 | GLENN | 0.018 | 0.013 | 0.094 | 0.331 | 0.331 | 0.003 | 0.004 | 0.004 | 0.004 | 0.028 | 0.087 | 0.082 |
| | 31 | PLACER | 0.005 | 0 | 0.076 | 0.415 | 0.415 | 0 | 0 | 0 | 0 | 0.026 | 0.031 | 0.031 |
| | 34 | SACRAMENTO | 0.078 | 0.014 | 0.123 | 0.117 | 0.123 | 0.016 | 0.016 | 0.016 | 0.016 | 0.071 | 0.205 | 0.205 |
| | 45 | SHASTA | 0.051 | 0 | 0.028 | 0.152 | 0.152 | 0 | 0.039 | 0 | 0 | 0.208 | 0.188 | 0.182 |
| | 48 | SOLANO | 0.075 | 0.039 | 0.089 | 0.003 | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 | 0.128 | 0.328 | 0.318 |
| | 51 | SUTTER | 0.011 | 0.012 | 0.086 | 0.362 | 0.362 | 0.001 | 0.001 | 0.001 | 0.001 | 0.028 | 0.071 | 0.067 |
| | 52 | TEHAMA | 0.051 | 0.024 | 0.083 | 0.054 | 0.054 | 0 | 0 | 0 | 0 | 0.083 | 0.331 | 0.32 |
| | 57 | YOLO | 0.062 | 0.021 | 0.088 | 0.136 | 0.137 | 0.003 | 0.003 | 0.003 | 0.003 | 0.095 | 0.223 | 0.223 |
| | 58 | YUBA | 0.006 | 0 | 0.082 | 0.405 | 0.405 | 0 | 0 | 0 | 0 | 0.015 | 0.043 | 0.043 |

Source:

CARB. 2003. Emission Inventory Documentation, Section 7.4: Agricultural Land Preparation. January.

Accessed on: May 5, 2012. Available at: http://www.arb.ca.gov/ei/areasrc/arbmiscprocresfarmop.htm

**Table I-78. Seasonal Profile for Agricultural Harvest Emissions**

| AB | ID # | County | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SV | 4 | BUTTE | 0 | 0 | 0 | 0 | 0 | 0.003 | 0.004 | 0.001 | 0.483 | 0.484 | 0.025 | 0 |
| | 6 | COLUSA | 0 | 0 | 0.001 | 0.001 | 0.001 | 0.037 | 0.052 | 0.016 | 0.408 | 0.411 | 0.073 | 0 |
| | 11 | GLENN | 0 | 0 | 0.001 | 0.001 | 0.001 | 0.03 | 0.032 | 0.002 | 0.446 | 0.45 | 0.036 | 0 |
| | 31 | PLACER | 0 | 0 | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 | 0.409 | 0.395 | 0.112 | 0 |
| | 34 | SACRAMENTO | 0.002 | 0.002 | 0.009 | 0.009 | 0.009 | 0.222 | 0.284 | 0.071 | 0.206 | 0.137 | 0.044 | 0.002 |
| | 45 | SHASTA | 0 | 0 | 0.059 | 0.059 | 0.059 | 0.083 | 0.083 | 0.059 | 0.316 | 0.258 | 0.025 | 0 |
| | 48 | SOLANO | 0 | 0 | 0.003 | 0.003 | 0.003 | 0.196 | 0.229 | 0.035 | 0.274 | 0.247 | 0.01 | 0 |
| | 51 | SUTTER | 0 | 0 | 0.001 | 0.001 | 0.001 | 0.025 | 0.05 | 0.026 | 0.427 | 0.407 | 0.059 | 0 |
| | 52 | TEHAMA | 0 | 0 | 0.002 | 0.002 | 0.002 | 0.005 | 0.006 | 0.002 | 0.489 | 0.489 | 0.002 | 0 |
| | 57 | YOLO | 0 | 0 | 0.002 | 0.002 | 0.002 | 0.111 | 0.155 | 0.046 | 0.348 | 0.308 | 0.026 | 0 |
| | 58 | YUBA | 0 | 0 | 0.002 | 0.002 | 0.002 | 0.005 | 0.005 | 0.002 | 0.471 | 0.469 | 0.042 | 0 |

Source:

CARB. 2003. Emission Inventory Documentation, Section 7.5: Agricultural Harvest Operations. January.

Accessed on: May 5, 2012. Available at: http://www.arb.ca.gov/ei/areasrc/arbmiscprocresfarmop.htm.

**Table I-79. Final Normalized Monthly Emission Profiles: Nonpasture**

| Basin | County | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SV | Butte | 0.0114 | 0.0316 | 0.0333 | 0.2697 | 0.2156 | 0.0556 | 0.1253 | 0.0977 | 0.0498 | 0.0721 | 0.0227 | 0.0152 |
| | Colusa | 0.0037 | 0.0075 | 0.0171 | 0.1868 | 0.1818 | 0.1461 | 0.0998 | 0.1141 | 0.1099 | 0.1169 | 0.0106 | 0.0059 |
| | Glenn | 0.004 | 0.0116 | 0.0162 | 0.2311 | 0.0859 | 0.2114 | 0.0773 | 0.0466 | 0.0623 | 0.1652 | 0.0764 | 0.0122 |
| | Placer | 0.0052 | 0.0081 | 0.013 | 0.2733 | 0.261 | 0.0962 | 0.0877 | 0.0964 | 0.1024 | 0.0411 | 0.0107 | 0.0049 |
| | Sacramento | 0.0015 | 0.0025 | 0.0046 | 0.1199 | 0.1443 | 0.3286 | 0.13 | 0.1012 | 0.1297 | 0.0306 | 0.0046 | 0.0024 |
| | Shasta | 0.0019 | 0.0071 | 0.0082 | 0.0756 | 0.0984 | 0.3371 | 0.2219 | 0.1439 | 0.0436 | 0.055 | 0.0055 | 0.0018 |
| | Solano | 0.0008 | 0.0011 | 0.0021 | 0.0461 | 0.0884 | 0.1865 | 0.1423 | 0.145 | 0.1875 | 0.1902 | 0.0087 | 0.0013 |
| | Sutter | 0.0038 | 0.0057 | 0.0088 | 0.1846 | 0.2083 | 0.2042 | 0.0906 | 0.099 | 0.1433 | 0.0397 | 0.0084 | 0.0036 |
| | Tehama | 0.0021 | 0.0055 | 0.0059 | 0.0528 | 0.0666 | 0.3714 | 0.2149 | 0.157 | 0.0664 | 0.0505 | 0.0047 | 0.0021 |
| | Yolo | 0.0015 | 0.0022 | 0.0036 | 0.0787 | 0.1309 | 0.2377 | 0.1079 | 0.1054 | 0.1682 | 0.1528 | 0.0091 | 0.0019 |
| | Yuba | 0.0076 | 0.012 | 0.0182 | 0.2745 | 0.2564 | 0.1158 | 0.0768 | 0.0478 | 0.0804 | 0.066 | 0.0372 | 0.0073 |

**Table I-80. Final Normalized Monthly Emission Profiles: Pasture**

| Basin | County | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SV | Butte | 0.001 | 0.0029 | 0.0031 | 0.0294 | 0.0515 | 0.094 | 0.3024 | 0.2379 | 0.2041 | 0.0688 | 0.0034 | 0.0015 |
| | Colusa | 0.0005 | 0.0009 | 0.0022 | 0.0291 | 0.0582 | 0.218 | 0.1974 | 0.161 | 0.2281 | 0.1018 | 0.0019 | 0.0008 |
| | Glenn | 0.0006 | 0.0018 | 0.0025 | 0.0412 | 0.0287 | 0.2338 | 0.1275 | 0.0827 | 0.2331 | 0.2277 | 0.0185 | 0.002 |
| | Placer | 0.0005 | 0.0008 | 0.0013 | 0.0314 | 0.0677 | 0.2348 | 0.1734 | 0.1379 | 0.3101 | 0.0399 | 0.0017 | 0.0005 |
| | Sacramento | 0.0004 | 0.0006 | 0.0012 | 0.036 | 0.0571 | 0.2216 | 0.1705 | 0.1299 | 0.331 | 0.0495 | 0.0016 | 0.0006 |
| | Shasta | 0.0007 | 0.0019 | 0.0021 | 0.0214 | 0.0365 | 0.3573 | 0.2451 | 0.144 | 0.1219 | 0.0665 | 0.0018 | 0.0007 |
| | Solano | 0.0002 | 0.0003 | 0.0007 | 0.0182 | 0.0447 | 0.1497 | 0.148 | 0.1119 | 0.2964 | 0.2266 | 0.0028 | 0.0004 |
| | Sutter | 0.0005 | 0.0007 | 0.0012 | 0.0286 | 0.0617 | 0.2125 | 0.1566 | 0.1249 | 0.3636 | 0.0477 | 0.0016 | 0.0005 |
| | Tehama | 0.0007 | 0.0019 | 0.0021 | 0.0217 | 0.037 | 0.3624 | 0.2488 | 0.1461 | 0.1147 | 0.0621 | 0.0018 | 0.0007 |
| | Yolo | 0.0003 | 0.0005 | 0.0009 | 0.0226 | 0.0528 | 0.1794 | 0.1598 | 0.1228 | 0.2924 | 0.1656 | 0.0025 | 0.0004 |
| | Yuba | 0.0004 | 0.0006 | 0.001 | 0.0169 | 0.0356 | 0.1527 | 0.1783 | 0.1611 | 0.4092 | 0.0405 | 0.0033 | 0.0004 |

# Appendix J

# Climate Change Analysis Emission Calculations

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## Summary of Annual Groundwater Substitution GHG Emissions by County

**Table J-1. GHG Emissions from Groundwater Substitution**

| Water Agency | Emissions (MTCO2e per year) | | | |
|---|---|---|---|---|
| | CO2 | CH4 | N2O | Total |
| **Sacramento River of Analysis** | | | | |
| Anderson-Cottonwood Irrigation District | 164 | 0.26 | 0.66 | 165 |
| Conaway Preservation Group | 2,360 | 3.33 | 8.30 | 2,371 |
| Cordua Irrigation District | 496 | 0.79 | 2.00 | 499 |
| Cranmore Farms | 272 | 0.44 | 1.10 | 274 |
| Eastside Mutual Water Company | 392 | 0.40 | 0.95 | 394 |
| Glenn-Colusa Irrigation District | 785 | 1.26 | 3.17 | 789 |
| Natomas Central Mutual Water Company | 376 | 0.51 | 1.29 | 378 |
| Pelger Mutual Water Company | 283 | 0.33 | 0.80 | 285 |
| Pleasant Grove-Verona Mutual Water Company | 1,890 | 2.32 | 5.69 | 1,898 |
| Reclamation District 108 | 642 | 1.03 | 2.59 | 646 |
| Reclamation District 1004 | 900 | 0.95 | 2.28 | 903 |
| River Garden Farms | 326 | 0.52 | 1.32 | 327 |
| Sycamore Mutual Water Company | 490 | 0.79 | 1.98 | 493 |
| Te Velde Revocable Family Trust | 202 | 0.32 | 0.82 | 203 |
| **American River Area of Analysis** | | | | |
| City of Sacramento | 483 | 0.66 | 1.66 | 485 |
| Sacramento County Water Agency | 1,427 | 1.95 | 4.92 | 1,434 |
| Sacramento Suburban Water District | 4,379 | 4.31 | 9.69 | 4,393 |
| **Feather River Area of Analysis** | | | | |
| Butte Water District | 356 | 0.57 | 1.44 | 358 |
| Garden Highway Mutual Water Company | 452 | 0.72 | 1.83 | 454 |
| Gilsizer Slough Ranch | 441 | 0.52 | 1.25 | 443 |
| Goose Club Farms and Teichert Aggregates | 341 | 0.55 | 1.38 | 342 |
| Tule Basin Farms | 374 | 0.32 | 0.66 | 375 |
| **Delta Region Area of Analysis** | | | | |
| Reclamation District 2068 | 184 | 0.29 | 0.74 | 185 |
| Pope Ranch | 119 | 0.19 | 0.48 | 120 |
| **Total** | **18,134** | **23.34** | **57.03** | **18,215** |

## Groundwater Substitution GHG Emissions

| | | |
|---|---|---|
| Agency | Anderson-Cottonwood Irrigation District | |
| Transfer Volume | 5,226 | acre feet/year |
| Location | Shasta | County |
| | Tehama | County |

**Table J-2. Anderson-Cottonwood Irrigation District Criteria Pollutant Emissions**

| | | | | | | | | | | GHG Emissions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | (metric tons per year) | | | (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Barney Street | Barney Street | Electric | 200 | 5,500 | 85% | 4,422 | 4,366 | 651,702 | n/a | 131 | 0.0084 | 0.0018 | 131 | 0.21 | 0.53 | 132 |
| Crowley Gulch | Crowley Gulch | Electric | 50 | 1,000 | 15% | 804 | 4,366 | 162,926 | n/a | 33 | 0.0021 | 0.0004 | 33 | 0.05 | 0.13 | 33 |
| | | | **Total** | **6,500** | **100%** | **5,226** | **8,733** | **814,628** | **0** | **164** | **0.0105** | **0.0022** | **164** | **0.26** | **0.66** | **165** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Conaway Preservation Group
Transfer Volume 35,000 acre feet/year
Location Yolo County

**Table J-3. Conaway Preservation Group Criteria Pollutant Emissions**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Fuel | GHG Emissions | | | | | | |
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Consumption | (metric tons per year) | | | (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| ConawayPG12W-1 | 12W-1 | Electric | 250 | 3,500 | 4% | 1,253 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG12W-2 | 12W-2 | Electric | 250 | 2,500 | 3% | 895 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG12W-5 | 12W-5 | Electric | 250 | 3,500 | 4% | 1,253 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG13W-3 | 13W-3 | Electric | 200 | 3,500 | 4% | 1,253 | 1,944 | 290,083 | n/a | 59 | 0.0037 | 0.0008 | 59 | 0.09 | 0.24 | 59 |
| ConawayPG16W-2 | 16W-2 | Diesel | 227 | 1,600 | 2% | 573 | 1,944 | n/a | 24,751 | 253 | 0.0102 | 0.0020 | 253 | 0.26 | 0.61 | 254 |
| ConawayPG17W-3 | 17W-3 | Diesel | 227 | 1,700 | 2% | 608 | 1,944 | n/a | 24,751 | 253 | 0.0102 | 0.0020 | 253 | 0.26 | 0.61 | 254 |
| ConawayPG1W-3 | 1W-3 | Electric | 250 | 3,500 | 4% | 1,253 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG20W-1 | 20W-1 | Electric | 100 | 2,500 | 3% | 895 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG21W-1 | 21W-1 | Electric | 250 | 2,500 | 3% | 895 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG21W-3 | 21W-3 | Electric | 100 | 2,500 | 3% | 895 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG24W-1 | 24W-1 | Electric | 250 | 2,500 | 3% | 895 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG31W-1 | 31W-1 | Electric | 100 | 2,300 | 2% | 823 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG32NW-1 | 32NW-1 | Electric | 100 | 3,300 | 3% | 1,181 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG32NW-2 | 32NW-2 | Electric | 250 | 3,500 | 4% | 1,253 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG32W-3 | 32W-3 | Electric | 250 | 2,500 | 3% | 895 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG33NW-1 | 33NW-1 | Electric | 100 | 2,300 | 2% | 823 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-2 | 33NW-2 | Electric | 100 | 2,200 | 2% | 787 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-3 | 33NW-3 | Electric | 100 | 2,100 | 2% | 752 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-4 | 33NW-4 | Electric | 100 | 3,400 | 3% | 1,217 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-5 | 33NW-5 | Electric | 100 | 1,800 | 2% | 644 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-6 | 33NW-6 | Electric | 100 | 2,100 | 2% | 752 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-7 | 33NW-7 | Electric | 100 | 1,400 | 1% | 501 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG33NW-8 | 33NW-8 | Electric | 100 | 2,200 | 2% | 787 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG5W-2 | 5W-2 | Electric | 250 | 3,500 | 4% | 1,253 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG5W-3 | 5W-3 | Electric | 250 | 2,700 | 3% | 966 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG6W-2 | 6W-2 | Electric | 100 | 3,500 | 4% | 1,253 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPG7W-1 | 7W-1 | Electric | 75 | 1,800 | 2% | 644 | 1,944 | 108,781 | n/a | 22 | 0.0014 | 0.0003 | 22 | 0.04 | 0.09 | 22 |
| ConawayPG7W-2 | 7W-2 | Electric | 250 | 3,500 | 4% | 1,253 | 1,944 | 362,604 | n/a | 73 | 0.0047 | 0.0010 | 73 | 0.12 | 0.30 | 74 |
| ConawayPG7W-4 | 7W-4 | Electric | 200 | 3,500 | 4% | 1,253 | 1,944 | 290,083 | n/a | 59 | 0.0037 | 0.0008 | 59 | 0.09 | 0.24 | 59 |
| ConawayPG7W-4S | 7W-4S | Electric | 200 | 3,500 | 4% | 1,253 | 1,944 | 290,083 | n/a | 59 | 0.0037 | 0.0008 | 59 | 0.09 | 0.24 | 59 |
| ConawayPG8W-2 | 8W-2 | Diesel | 227 | 2,300 | 2% | 823 | 1,944 | n/a | 24,751 | 253 | 0.0102 | 0.0020 | 253 | 0.26 | 0.61 | 254 |
| ConawayPG8W-2N | 8W-2N | Electric | 200 | 1,500 | 2% | 537 | 1,944 | 290,083 | n/a | 59 | 0.0037 | 0.0008 | 59 | 0.09 | 0.24 | 59 |
| ConawayPGOW-1 | OW-1 | Electric | 100 | 2,600 | 3% | 930 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPGOW-2 | OW-2 | Electric | 100 | 3,400 | 3% | 1,217 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPGOW-3 | OW-3 | Electric | 125 | 3,400 | 3% | 1,217 | 1,944 | 181,302 | n/a | 37 | 0.0023 | 0.0005 | 37 | 0.06 | 0.15 | 37 |
| ConawayPGOW-4 | OW-4 | Electric | 100 | 1,700 | 2% | 608 | 1,944 | 145,041 | n/a | 29 | 0.0019 | 0.0004 | 29 | 0.05 | 0.12 | 29 |
| ConawayPGOW-5 | OW-5 | Electric | 125 | 2,000 | 2% | 716 | 1,944 | 181,302 | n/a | 37 | 0.0023 | 0.0005 | 37 | 0.06 | 0.15 | 37 |
| | | | **Total** | **97,800** | **100%** | **35,000** | **71,912** | **7,941,021** | **74,253** | **2,360** | **0.1334** | **0.0279** | **2,360** | **3.33** | **8.30** | **2,371** |

Legend

Assumed to be electric (similar to 32W-2)

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Cordua Irrigation District
Transfer Volume 12,000 acre feet/year
Location Yuba County

**Table J-4. Cordua Irrigation District Criteria Pollutant Emissions**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| COR1 | COR1 | Electric | 60 | 1,000 | 3% | 323 | 1,757 | 78,654 | n/a | 16 | 0.0010 | 0.0002 | 16 | 0.03 | 0.06 | 16 |
| COR2 | COR2 | Electric | 50 | 900 | 2% | 291 | 1,757 | 65,545 | n/a | 13 | 0.0008 | 0.0002 | 13 | 0.02 | 0.05 | 13 |
| COR3 | COR3 | Electric | 60 | 1,000 | 3% | 323 | 1,757 | 78,654 | n/a | 16 | 0.0010 | 0.0002 | 16 | 0.03 | 0.06 | 16 |
| COR4 | COR4 | Electric | 75 | 1,400 | 4% | 453 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR5 | COR5 | Electric | 75 | 1,300 | 4% | 420 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR8 | COR8 | Electric | 75 | 2,000 | 5% | 647 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR9 | COR9 | Electric | 60 | 1,000 | 3% | 323 | 1,757 | 78,654 | n/a | 16 | 0.0010 | 0.0002 | 16 | 0.03 | 0.06 | 16 |
| COR10 | COR10 | Electric | 75 | 1,300 | 4% | 420 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR11 | COR11 | Electric | 60 | 1,800 | 5% | 582 | 1,757 | 78,654 | n/a | 16 | 0.0010 | 0.0002 | 16 | 0.03 | 0.06 | 16 |
| COR12 | COR12 | Electric | 100 | 1,400 | 4% | 453 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR13 | COR13 | Electric | 100 | 2,100 | 6% | 679 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR14 | COR14 | Electric | 75 | 1,800 | 5% | 582 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR18 | COR18 | Electric | 100 | 2,000 | 5% | 647 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR20 | COR20 | Electric | 125 | 2,150 | 6% | 695 | 1,757 | 163,863 | n/a | 33 | 0.0021 | 0.0004 | 33 | 0.05 | 0.13 | 33 |
| COR21 | COR21 | Electric | 75 | 1,250 | 3% | 404 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR22 | COR22 | Electric | 60 | 1,750 | 5% | 566 | 1,757 | 78,654 | n/a | 16 | 0.0010 | 0.0002 | 16 | 0.03 | 0.06 | 16 |
| COR23 | COR23 | Electric | 75 | 1,150 | 3% | 372 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR25 | COR25 | Electric | 75 | 1,600 | 4% | 518 | 1,757 | 98,318 | n/a | 20 | 0.0013 | 0.0003 | 20 | 0.03 | 0.08 | 20 |
| COR26 | COR26 | Electric | 100 | 1,800 | 5% | 582 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR27 | COR27 | Electric | 100 | 1,700 | 5% | 550 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR16 | COR16 | Electric | 100 | 2,300 | 6% | 744 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR17 | COR17 | Electric | 100 | 2,400 | 6% | 776 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| COR24 | COR24 | Electric | 100 | 2,000 | 5% | 647 | 1,757 | 131,090 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 27 |
| | | | **Total** | **37,100** | **100%** | **12,000** | **40,402** | **2,457,942** | **0** | **496** | **0.0318** | **0.0067** | **496** | **0.79** | **2.00** | **499** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Cranmore Farms
Transfer Volume 8,000 acre feet/year
Location Sutter County

**Table J-5. Cranmore Farms Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (gal/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cranmore Farms1 | 1 | Electric | 125 | 3,000 | 17% | 1,333 | 2,414 | 225,160 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 46 |
| Cranmore Farms2 | 2 | Electric | 125 | 3,000 | 17% | 1,333 | 2,414 | 225,160 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 46 |
| Cranmore Farms3 | 3 | Electric | 125 | 3,000 | 17% | 1,333 | 2,414 | 225,160 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 46 |
| Cranmore Farms4 | 4 | Electric | 125 | 3,000 | 17% | 1,333 | 2,414 | 225,160 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 46 |
| Cranmore Farms5 | 5 | Electric | 125 | 3,000 | 17% | 1,333 | 2,414 | 225,160 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 46 |
| Cranmore Farms6 | 6 | Electric | 125 | 3,000 | 17% | 1,333 | 2,414 | 225,160 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 46 |
| | | | **Total** | **18,000** | **100%** | **8,000** | **14,482** | **1,350,958** | **0** | **272** | **0.0175** | **0.0037** | **272** | **0.44** | **1.10** | **274** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

| | | |
|---|---|---|
| Agency | Eastside Mutual Water Company | |
| Transfer Volume | 2,230 | acre feet/year |
| Location | Colusa County | |

**Table J-6. Eastside Mutual Water Company Criteria Pollutant Emissions**

| | | | | | | | | | | GHG Emissions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | (metric tons per year) | | | (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| 7631T | 7631T | Diesel | 215 | 3,800 | 100% | 2,230 | 3,187 | n/a | 38,441 | 392 | 0.0159 | 0.0032 | 392 | 0.40 | 0.95 | 394 |
| | | | **Total** | **3,800** | **100%** | **2,230** | **3,187** | **0** | **38,441** | **392** | **0.0159** | **0.0032** | **392** | **0.40** | **0.95** | **394** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

## Groundwater Substitution GHG Emissions

| | | |
|---|---|---|
| Agency | Glenn-Colusa Irrigation District | |
| Transfer Volume | 25,000 | acre feet/year |
| Location | Glenn | County |
| | Colusa | County |

**Table J-7. Glenn-Colusa Irrigation District Criteria Pollutant Emissions**

| | | | | | | | | | | GHG Emissions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | (metric tons per year) | | | (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| GCID 1 | GCID 1 | Electric | 110 | 3,305 | 10% | 2,622 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID 2 | GCID 2 | Electric | 110 | 3,305 | 10% | 2,622 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID 3 | GCID 3 | Electric | 110 | 3,305 | 10% | 2,622 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID 4 | GCID 4 | Electric | 110 | 3,305 | 10% | 2,622 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID 5 | GCID 5 | Electric | 110 | 2,605 | 8% | 2,067 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID X1 | GCID X1 | Electric | 110 | 2,389 | 8% | 1,896 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID X2 | GCID X2 | Electric | 110 | 3,305 | 10% | 2,622 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID X3 | GCID X3 | Electric | 110 | 2,605 | 8% | 2,067 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID X4 | GCID X4 | Electric | 110 | 2,389 | 8% | 1,896 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| GCID X5 | GCID X5 | Electric | 110 | 2,605 | 8% | 2,067 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| Test Hole 7 | Test Hole 7 | Electric | 110 | 2,389 | 8% | 1,896 | 4,309 | 353,744 | n/a | 71 | 0.0046 | 0.0010 | 71 | 0.11 | 0.29 | 72 |
| | | | **Total** | **31,507** | **100%** | **25,000** | **47,402** | **3,891,180** | **0** | **785** | **0.0503** | **0.0106** | **785** | **1.26** | **3.17** | **789** |

Legend

| | |
|---|---|
| | Assumed to be electric (similar to other wells operated by water agency) |
| | Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency: Natomas Central Mutual Water Company
Transfer Volume: 30,000 acre feet/year
Location: Sacramento County, Sutter County

**Table J-8. Natomas Central Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Natomas Central MWCWilley, Ed | Willey, Ed | Electric | 250 | 5,500 | 2% | 698 | 689 | 128,527 | n/a | 30 | 0.0017 | 0.0004 | 30 | 0.04 | 0.10 | 31 |
| Natomas Central MWCOse, Mary-site 8, well 1 | Ose, Mary-site 8, well 1 | Electric | 200 | 5,500 | 2% | 698 | 689 | 102,821 | n/a | 24 | 0.0013 | 0.0003 | 24 | 0.03 | 0.08 | 24 |
| Natomas Central MWCOse, Mary-site 9, well 2 | Ose, Mary-site 9, well 2 | Electric | 150 | 5,500 | 2% | 698 | 689 | 77,116 | n/a | 18 | 0.0010 | 0.0002 | 18 | 0.02 | 0.06 | 18 |
| Natomas Central MWCLeal, Robert-site 1 well 2 | Leal, Robert-site 1 well 2 | Electric | 100 | 5,500 | 2% | 698 | 689 | 51,411 | n/a | 12 | 0.0007 | 0.0001 | 12 | 0.02 | 0.04 | 12 |
| Natomas Central MWCDeWitt, Jack-1 | DeWitt, Jack-1 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCDeWitt, Jack-2 | DeWitt, Jack-2 | Electric | 80 | 5,500 | 2% | 698 | 689 | 41,129 | n/a | 10 | 0.0005 | 0.0001 | 10 | 0.01 | 0.03 | 10 |
| Natomas Central MWCDeWitt, Jack-3 | DeWitt, Jack-3 | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Natomas Central MWCDeWitt, Jack-4 | DeWitt, Jack-4 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCDeWitt, Jack-5 | DeWitt, Jack-5 | Electric | 20 | 5,500 | 2% | 698 | 689 | 10,282 | n/a | 2 | 0.0001 | 0.0000 | 2 | 0.00 | 0.01 | 2 |
| Natomas Central MWCDeWitt, Jack-6 | DeWitt, Jack-6 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCDeWitt, Jack-7 | DeWitt, Jack-7 | Electric | 25 | 5,500 | 2% | 698 | 689 | 12,853 | n/a | 3 | 0.0002 | 0.0000 | 3 | 0.00 | 0.01 | 3 |
| Natomas Central MWCDeWitt, Jack-7 | DeWitt, Jack-7 | Electric | 25 | 5,500 | 2% | 698 | 689 | 12,853 | n/a | 3 | 0.0002 | 0.0000 | 3 | 0.00 | 0.01 | 3 |
| Natomas Central MWCDeWitt, Jack--8 | DeWitt, Jack--8 | Electric | 250 | 5,500 | 2% | 698 | 689 | 128,527 | n/a | 30 | 0.0017 | 0.0004 | 30 | 0.04 | 0.10 | 31 |
| Natomas Central MWCMorrison, Phil #2-site 5 well 14 | Morrison, Phil #2-site 5 well 14 | Electric | 40 | 5,500 | 2% | 698 | 689 | 20,564 | n/a | 5 | 0.0003 | 0.0001 | 5 | 0.01 | 0.02 | 5 |
| Natomas Central MWCBianchi, John- site 2, well 10 | Bianchi, John- site 2, well 10 | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Natomas Central MWCBianchi, John-site 2 well 11 | Bianchi, John-site 2 well 11 | Electric | 80 | 5,500 | 2% | 698 | 689 | 41,129 | n/a | 10 | 0.0005 | 0.0001 | 10 | 0.01 | 0.03 | 10 |
| Natomas Central MWCLauppe and Sons | Lauppe and Sons | Electric | 40 | 5,500 | 2% | 698 | 689 | 20,564 | n/a | 5 | 0.0003 | 0.0001 | 5 | 0.01 | 0.02 | 5 |
| Natomas Central MWCWiley, Wane-site 7 , well 18 | Wiley, Wane-site 7 , well 18 | Electric | 40 | 5,500 | 2% | 698 | 689 | 20,564 | n/a | 5 | 0.0003 | 0.0001 | 5 | 0.01 | 0.02 | 5 |
| Natomas Central MWCLeal, Robert L-1 (rice box) | Leal, Robert L-1 (rice box) | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCLeal, Robert L-3 | Leal, Robert L-3 | Electric | 50 | 5,500 | 2% | 698 | 689 | 25,705 | n/a | 6 | 0.0003 | 0.0001 | 6 | 0.01 | 0.02 | 6 |
| Natomas Central MWCLeal, Robert L-4 | Leal, Robert L-4 | Electric | 110 | 5,500 | 2% | 698 | 689 | 56,552 | n/a | 13 | 0.0007 | 0.0002 | 13 | 0.02 | 0.05 | 13 |
| Natomas Central MWCLeal, Robert L-5 | Leal, Robert L-5 | Electric | 110 | 5,500 | 2% | 698 | 689 | 56,552 | n/a | 13 | 0.0007 | 0.0002 | 13 | 0.02 | 0.05 | 13 |
| Natomas Central MWCLeal, Robert L-6 | Leal, Robert L-6 | Electric | 110 | 5,500 | 2% | 698 | 689 | 56,552 | n/a | 13 | 0.0007 | 0.0002 | 13 | 0.02 | 0.05 | 13 |
| Natomas Central MWCLeal, Robert L-7 | Leal, Robert L-7 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCLeal, Robert L-8 | Leal, Robert L-8 | Electric | 200 | 5,500 | 2% | 698 | 689 | 102,821 | n/a | 24 | 0.0013 | 0.0003 | 24 | 0.03 | 0.08 | 24 |
| Natomas Central MWCLeal, Robert L-9 | Leal, Robert L-9 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCLeal, Robert L-2 | Leal, Robert L-2 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCLeal, Robert #1 | Leal, Robert #1 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCLeal, Robert #2 | Leal, Robert #2 | Electric | 40 | 5,500 | 2% | 698 | 689 | 20,564 | n/a | 5 | 0.0003 | 0.0001 | 5 | 0.01 | 0.02 | 5 |
| Natomas Central MWCSpangler, Dan-site 4 well 13 | Spangler, Dan-site 4 well 13 | Electric | 80 | 5,500 | 2% | 698 | 689 | 41,129 | n/a | 10 | 0.0005 | 0.0001 | 10 | 0.01 | 0.03 | 10 |
| Natomas Central MWCVestal, Sid | Vestal, Sid | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Natomas Central MWCVestal, Sid-1 | Vestal, Sid-1 | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Dewitt, Jack-9 Housley N | Dewitt, Jack-9 Housley N | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Dewitt, Jack-10 Housley | Dewitt, Jack-10 Housley | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Dewitt, Jack-11 Housley | Dewitt, Jack-11 Housley | Electric | 20 | 5,500 | 2% | 698 | 689 | 10,282 | n/a | 2 | 0.0001 | 0.0000 | 2 | 0.00 | 0.01 | 2 |
| Natomas Central MWCMorrison, Phil-#3 site 5 well 15 | Morrison, Phil-#3 site 5 well 15 | Electric | 40 | 5,500 | 2% | 698 | 689 | 20,564 | n/a | 5 | 0.0003 | 0.0001 | 5 | 0.01 | 0.02 | 5 |
| Natomas Central MWCMorrison, Phil-#4 site 5 well 16 | Morrison, Phil-#4 site 5 well 16 | Electric | 40 | 5,500 | 2% | 698 | 689 | 20,564 | n/a | 5 | 0.0003 | 0.0001 | 5 | 0.01 | 0.02 | 5 |
| Natomas Central MWCNBC-Frazer | NBC-Frazer | Electric | 50 | 5,500 | 2% | 698 | 689 | 25,705 | n/a | 6 | 0.0003 | 0.0001 | 6 | 0.01 | 0.02 | 6 |
| Natomas Central MWCNBC-Lucich North | NBC-Lucich North | Electric | 75 | 5,500 | 2% | 698 | 689 | 38,558 | n/a | 9 | 0.0005 | 0.0001 | 9 | 0.01 | 0.03 | 9 |
| Natomas Central MWCNBC- Natomas Farm#1 | NBC- Natomas Farm#1 | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Natomas Central MWCNBC-Cummings | NBC-Cummings | Electric | 20 | 5,500 | 2% | 698 | 689 | 10,282 | n/a | 2 | 0.0001 | 0.0000 | 2 | 0.00 | 0.01 | 2 |
| Natomas Central MWCMorrison, Phillip-#5 | Morrison, Phillip-#5 | Electric | 60 | 5,500 | 2% | 698 | 689 | 30,846 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.03 | 7 |
| Natomas Central MWCPerry, Joe | Perry, Joe | Electric | 125 | 5,500 | 2% | 698 | 689 | 64,263 | n/a | 15 | 0.0008 | 0.0002 | 15 | 0.02 | 0.05 | 15 |
| Natomas Central MWCNBC-Kismat-2 | NBC-Kismat-2 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCNBC-Kismat-3 | NBC-Kismat-3 | Electric | 30 | 5,500 | 2% | 698 | 689 | 15,423 | n/a | 4 | 0.0002 | 0.0000 | 4 | 0.00 | 0.01 | 4 |
| Natomas Central MWCNBC-Kismat-4 | NBC-Kismat-4 | Electric | 110 | 5,500 | 2% | 698 | 689 | 56,552 | n/a | 13 | 0.0007 | 0.0002 | 13 | 0.02 | 0.05 | 13 |
| Natomas Central MWCNBC-Sliva | NBC-Sliva | Electric | 50 | 5,500 | 2% | 698 | 689 | 25,705 | n/a | 6 | 0.0003 | 0.0001 | 6 | 0.01 | 0.02 | 6 |
| | | | **Total** | **236,500** | **100%** | **30,000** | **29,623** | **1,588,589** | **0** | **376** | **0.0205** | **0.0043** | **376** | **0.51** | **1.29** | **378** |

Legend

| | |
|---|---|
| | Assumed to be electric |
| | Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

| | | |
|---|---|---|
| Agency | Pelger Mutual Water Company | |
| Transfer Volume | 3,750 | acre feet/year |
| Location | Sutter County | |

**Table J-9. Pelger Mutual Water Company Criteria Pollutant Emissions**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Pelger MWCWell 1 Tucker | Well 1 Tucker | Electric | 110 | 3,100 | 33% | 1,224 | 2,144 | 175,980 | n/a | 35 | 0.0023 | 0.0005 | 35 | 0.06 | 0.14 | 36 |
| Pelger MWCWell 2 Flopet | Well 2 Flopet | Diesel | 173 | 2,100 | 22% | 829 | 2,144 | n/a | 20,806 | 212 | 0.0086 | 0.0017 | 212 | 0.22 | 0.51 | 213 |
| Pelger MWCWell 3 Klein | Well 3 Klein | Electric | 110 | 4,300 | 45% | 1,697 | 2,144 | 175,980 | n/a | 35 | 0.0023 | 0.0005 | 35 | 0.06 | 0.14 | 36 |
| | | | **Total** | **9,500** | **100%** | **3,750** | **6,431** | **351,960** | **20,806** | **283** | **0.0132** | **0.0027** | **283** | **0.33** | **0.80** | **285** |

Legend

| | |
|---|---|
| | Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency: Pleasant Grove-Verona Mutual Water Company
Transfer Volume: 18,000 acre feet/year
Location: Sutter County

**Table J-10. Pleasant Grove-Verona Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| PGVMWCWill-Lee 4A | Will-Lee 4A | Diesel | 160 | 1,500 | 2% | 345 | 1,248 | n/a | 11,206 | 114 | 0.0046 | 0.0009 | 114 | 0.12 | 0.28 | 115 |
| PGVMWCRiver Ranch #19 | River Ranch #19 | Diesel | 200 | 2,500 | 3% | 575 | 1,248 | n/a | 14,008 | 143 | 0.0058 | 0.0012 | 143 | 0.14 | 0.35 | 144 |
| PGVMWCMLF #1 | MLF #1 | Electric | 30 | 2,000 | 3% | 460 | 1,248 | 27,951 | n/a | 6 | 0.0004 | 0.0001 | 6 | 0.01 | 0.02 | 6 |
| PGVMWCMLF #2 | MLF #2 | Electric | 250 | 5,000 | 6% | 1,149 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCMLF Monster Well | MLF Monster Well | Electric | 60 | 3,100 | 4% | 713 | 1,248 | 55,902 | n/a | 11 | 0.0007 | 0.0002 | 11 | 0.02 | 0.05 | 11 |
| PGVMWCMLF #17/12 | MLF #17/12 | Electric | 50 | 1,500 | 2% | 345 | 1,248 | 46,585 | n/a | 9 | 0.0006 | 0.0001 | 9 | 0.02 | 0.04 | 9 |
| PGVMWCMLF #11 | MLF #11 | Diesel | 250 | 4,200 | 5% | 966 | 1,248 | n/a | 17,510 | 179 | 0.0072 | 0.0014 | 179 | 0.18 | 0.43 | 179 |
| PGVMWCMLF #13/15 | MLF #13/15 | Electric | 240 | 4,800 | 6% | 1,103 | 1,248 | 223,607 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 45 |
| PGVMWCMLF #16 | MLF #16 | Electric | 240 | 1,700 | 2% | 391 | 1,248 | 223,607 | n/a | 45 | 0.0029 | 0.0006 | 45 | 0.07 | 0.18 | 45 |
| PGVMWCWilley #1 | Willey #1 | Diesel | 168 | 3,000 | 4% | 690 | 1,248 | n/a | 11,767 | 120 | 0.0049 | 0.0010 | 120 | 0.12 | 0.29 | 121 |
| PGVMWCWilley #2 | Willey #2 | Electric | 250 | 3,000 | 4% | 690 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCWilley #3 | Willey #3 | Electric | 250 | 2,000 | 3% | 460 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCWilley #4 | Willey #4 | Diesel | 150 | 3,000 | 4% | 690 | 1,248 | n/a | 10,506 | 107 | 0.0043 | 0.0009 | 107 | 0.11 | 0.26 | 108 |
| PGVMWCScheidel&Osterli #18A | Scheidel&Osterli #18A | Electric | 250 | 2,500 | 3% | 575 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCWill-Lee 30 | Will-Lee 30 | Diesel | 100 | 1,500 | 2% | 345 | 1,248 | n/a | 7,004 | 72 | 0.0029 | 0.0006 | 72 | 0.07 | 0.17 | 72 |
| PGVMWCWill-Lee 31 | Will-Lee 31 | Electric | 250 | 2,500 | 3% | 575 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCWill-Lee 32 | Will-Lee 32 | Electric | 250 | 2,500 | 3% | 575 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCWill-Lee 33 | Will-Lee 33 | Electric | 250 | 2,500 | 3% | 575 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCNicholas Sand Field Well | Nicholas Sand Field Well | Diesel | 62.1 | 2,000 | 3% | 460 | 1,248 | n/a | 4,350 | 44 | 0.0018 | 0.0004 | 44 | 0.05 | 0.11 | 45 |
| PGVMWCNicholas Filipino Camp #2 | Nicholas Filipino Camp #2 | Electric | 40 | 2,000 | 3% | 460 | 1,248 | 37,268 | n/a | 8 | 0.0005 | 0.0001 | 8 | 0.01 | 0.03 | 8 |
| PGVMWCNicholas Filipino Camp South | Nicholas Filipino Camp South | Diesel | 62.1 | 2,000 | 3% | 460 | 1,248 | n/a | 4,350 | 44 | 0.0018 | 0.0004 | 44 | 0.05 | 0.11 | 45 |
| PGVMWCNicholas Johnston Field Well #2 | Nicholas Johnston Field Well #2 | Electric | 250 | 2,000 | 3% | 460 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCNicholas Johnston Well | Nicholas Johnston Well | Electric | 250 | 2,000 | 3% | 460 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCNicholas 72-acre Field South | Nicholas 72-acre Field South | Diesel | 62.1 | 2,000 | 3% | 460 | 1,248 | n/a | 4,350 | 44 | 0.0018 | 0.0004 | 44 | 0.05 | 0.11 | 45 |
| PGVMWCNicholas 72-Acre Field North | Nicholas 72-Acre Field North | Electric | 250 | 2,000 | 3% | 460 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCNicholas BBC Well | Nicholas BBC Well | Electric | 250 | 2,000 | 3% | 460 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCKelly 190 Field Well #2 | Kelly 190 Field Well #2 | Electric | 30 | 2,000 | 3% | 460 | 1,248 | 27,951 | n/a | 6 | 0.0004 | 0.0001 | 6 | 0.01 | 0.02 | 6 |
| PGVMWCKelly Windmill Field Well #2 | Kelly Windmill Field Well #2 | Diesel | 62.1 | 2,000 | 3% | 460 | 1,248 | n/a | 4,350 | 44 | 0.0018 | 0.0004 | 44 | 0.05 | 0.11 | 45 |
| PGVMWCKelly Windmill North Field Well | Kelly Windmill North Field Well | Diesel | 62.1 | 2,000 | 3% | 460 | 1,248 | n/a | 4,350 | 44 | 0.0018 | 0.0004 | 44 | 0.05 | 0.11 | 45 |
| PGVMWCKelly 306 Well | Kelly 306 Well | Electric | 250 | 2,600 | 3% | 598 | 1,248 | 232,924 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.08 | 0.19 | 47 |
| PGVMWCScheidel&Osterli #16 | Scheidel&Osterli #16 | Diesel | 234 | 3,400 | 4% | 782 | 1,248 | n/a | 16,389 | 167 | 0.0068 | 0.0014 | 167 | 0.17 | 0.40 | 168 |
| PGVMWCScheidel&Osterli #17 | Scheidel&Osterli #17 | Diesel | 101 | 1,500 | 2% | 345 | 1,248 | n/a | 7,074 | 72 | 0.0029 | 0.0006 | 72 | 0.07 | 0.17 | 72 |
| | | | **Total** | **78,300** | **100%** | **18,000** | **39,951** | **3,437,954** | **117,213** | **1,890** | **0.0930** | **0.0191** | **1,890** | **2.32** | **5.69** | **1,898** |

Legend

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | |
|---|---|
| 1 lb = | 453.6 g |
| 1 tonne = | 1,000 kg |
| 1 tonne = | 1,000,000 g |
| 1 MWh = | 1,000 kWh |
| 1 GWh = | 1,000,000 kWh |
| 1 kW = | 1.34 hp |
| 1 hour = | 60 minutes |
| 1 acre-foot = | 325,851 gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

| | |
|---|---|
| Agency | Reclamation District 108 |
| Transfer Volume | 15,000 acre feet/year |
| Location | Colusa County |
| | Yolo County |

**Table J-11. Reclamation District 108 Criteria Pollutant Emissions**

| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| RD 108Well#1 Heidrick | Well#1 Heidrick | Electric | 100 | 3,500 | 18% | 2,749 | 4,265 | 318,288 | n/a | 64 | 0.0041 | 0.0009 | 64 | 0.10 | 0.26 | 65 |
| RD 108Well #5 RiggsRanch | Well #5 RiggsRanch | Electric | 150 | 1,700 | 9% | 1,335 | 4,265 | 477,433 | n/a | 96 | 0.0062 | 0.0013 | 96 | 0.15 | 0.39 | 97 |
| RD 108Well #6 CountyLine | Well #6 CountyLine | Electric | 250 | 5,900 | 31% | 4,634 | 4,265 | 795,721 | n/a | 160 | 0.0103 | 0.0022 | 160 | 0.26 | 0.65 | 161 |
| RD 108Well#7 Tract 6 | Well#7 Tract 6 | Electric | 250 | 4,000 | 21% | 3,141 | 4,265 | 795,721 | n/a | 160 | 0.0103 | 0.0022 | 160 | 0.26 | 0.65 | 161 |
| RD 108Well #4 Huff | Well #4 Huff | Electric | 250 | 4,000 | 21% | 3,141 | 4,265 | 795,721 | n/a | 160 | 0.0103 | 0.0022 | 160 | 0.26 | 0.65 | 161 |
| | | | **Total** | **19,100** | **100%** | **15,000** | **21,325** | **3,182,885** | **0** | **642** | **0.0411** | **0.0087** | **642** | **1.03** | **2.59** | **646** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Reclamation District 1004
Transfer Volume 7,175 acre feet/year
Location Colusa County
Glenn County
Sutter County

**Table J-12. Reclamation District 1004 Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Gardener No. 374672 | Gardener No. 374672 | Diesel | 215 | 3,500 | 5% | 345 | 535 | n/a | 6,456 | 66 | 0.0027 | 0.0005 | 66 | 0.07 | 0.16 | 66 |
| Gardener No. 498178 | Gardener No. 498178 | Diesel | 215 | 3,500 | 5% | 345 | 535 | n/a | 6,456 | 66 | 0.0027 | 0.0005 | 66 | 0.07 | 0.16 | 66 |
| Stonewell #6 No. 11334 | Stone Well #6 No.11334 | Electric | 40 | 1,800 | 2% | 177 | 535 | 15,978 | n/a | 3 | 0.0002 | 0.0000 | 3 | 0.01 | 0.01 | 3 |
| Drumheller Well #7 | Drumheller Well No.7 | Diesel | 225 | 4,000 | 5% | 394 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| Myers Well #1 No. 3457 | Myers Well #1 No.3457 | Electric | 40 | 2,200 | 3% | 217 | 535 | 15,978 | n/a | 3 | 0.0002 | 0.0000 | 3 | 0.01 | 0.01 | 3 |
| Myers Well #2 No. 340884 | Myers Well #2 No. 340884 | Electric | 100 | 4,100 | 6% | 404 | 535 | 39,944 | n/a | 8 | 0.0005 | 0.0001 | 8 | 0.01 | 0.03 | 8 |
| Sikes & Parachini #1 No. 93124 | Sikes & Parachini Well #1 WS No.93124 | Diesel | 173 | 4,000 | 5% | 394 | 535 | n/a | 5,195 | 53 | 0.0022 | 0.0004 | 53 | 0.05 | 0.13 | 53 |
| Sikes & Parachini #2 No. 374682 | Sikes & Parachini Well #2 WS No. 374682 | Diesel | 150 | 4,000 | 5% | 394 | 535 | n/a | 4,504 | 46 | 0.0019 | 0.0004 | 46 | 0.05 | 0.11 | 46 |
| Rancho Caleta No. 726883 | Rancho Caleta No. 726883 | Diesel | 170 | 4,500 | 6% | 444 | 535 | n/a | 5,105 | 52 | 0.0021 | 0.0004 | 52 | 0.05 | 0.13 | 52 |
| Behring Ranch Club House No. 496461 | Behring Ranch Club House Well No.496461 | Electric | 125 | 3,400 | 5% | 335 | 535 | 49,930 | n/a | 10 | 0.0006 | 0.0001 | 10 | 0.02 | 0.04 | 10 |
| Behring Ranch West Well No. 97863 | Behring Ranch West Well No.97863 | Electric | 125 | 2,300 | 3% | 227 | 535 | 49,930 | n/a | 10 | 0.0006 | 0.0001 | 10 | 0.02 | 0.04 | 10 |
| Behring Ranch 10 Field Well No. 496441 | Behring Ranch 10 Field Well No. 496441 | Diesel | 225 | 5,800 | 8% | 572 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| Behring Ranch Pearl 20094 | Behring Ranch Pearl Well No. 20094 | Diesel | 225 | 2,500 | 3% | 246 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| Behring Ranch Nursery Well No. 17N1W10H1 | Behring Ranch Nursery Well No. 17N1W10H1 | Diesel | 225 | 1,000 | 1% | 99 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| Hall Well No. X | Hall Well No. X | Electric | 125 | 4,500 | 6% | 444 | 535 | 49,930 | n/a | 10 | 0.0006 | 0.0001 | 10 | 0.02 | 0.04 | 10 |
| Hall Well No. 369428 | Hall Well No.369428 | Electric | 125 | 4,500 | 6% | 444 | 535 | 49,930 | n/a | 10 | 0.0006 | 0.0001 | 10 | 0.02 | 0.04 | 10 |
| East Morgan Well | East Morgan Well #1 No. 374667 17N01W14N001M | Diesel | 225 | 2,600 | 4% | 256 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| ast Morgan Well | East Morgan Well#2 No. 498195 17N01W15Q001M | Diesel | 225 | 1,300 | 2% | 128 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| Mohammad No. | Mohammad No.e0084085 17N01W02D001M | Electric | 125 | 4,500 | 6% | 444 | 535 | 49,930 | n/a | 10 | 0.0006 | 0.0001 | 10 | 0.02 | 0.04 | 10 |
| Southam Sartain | Southam Sartain Well 18N01W26D001M | Diesel | 225 | 4,800 | 7% | 473 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| Barale Well | Barale Well | Diesel | 225 | 4,000 | 5% | 394 | 535 | n/a | 6,756 | 69 | 0.0028 | 0.0006 | 69 | 0.07 | 0.17 | 69 |
| | | | **Total** | **72,800** | **100%** | **7,175** | **11,240** | **321,551** | **81,767** | **900** | **0.0380** | **0.0076** | **900** | **0.95** | **2.28** | **903** |

Legend

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

| | | |
|---|---|---|
| Agency | River Garden Farms | |
| Transfer Volume | 9,000 | acre feet/year |
| Location | Yolo | County |

**Table J-13. River Garden Farms Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| River Garden FarmsField 65 PW | Field 65 PW | Electric | 110 | 2,500 | 14% | 1,293 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| River Garden FarmsField 71 PW | Field 71 PW | Electric | 110 | 1,700 | 10% | 880 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| River Garden FarmsField 98 PW | Field 98 PW | Electric | 110 | 2,900 | 17% | 1,500 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| River Garden FarmsField 104 PW | Field 104 PW | Electric | 110 | 2,500 | 14% | 1,293 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| River Garden FarmsField 104-09 PW | Field 104-09 PW | Electric | 110 | 2,990 | 17% | 1,547 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| River Garden FarmsField 91-09 PW | Field 91-09 PW | Electric | 110 | 2,840 | 16% | 1,469 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| River Garden FarmsField 117 PW | Field 117 PW | Electric | 110 | 1,965 | 11% | 1,017 | 2,810 | 230,661 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| | | | **Total** | **17,395** | **100%** | **9,000** | **19,669** | **1,614,626** | **0** | **326** | **0.0209** | **0.0044** | **326** | **0.52** | **1.32** | **327** |

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

| | |
|---|---|
| Agency | Sycamore Mutual Water Company |
| Transfer Volume | 15,000 acre feet/year |
| Location | Colusa County |

**Table J-14. Sycamore Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Sycamore Family Trust1 | 1 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust2 | 2 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust3 | 3 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust4 | 4 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust5 | 5 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust6 | 6 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust7 | 7 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust8 | 8 | Electric | 125 | 3,000 | 9% | 1,286 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| Sycamore Family Trust11 | 11 | Electric | 100 | 2,500 | 7% | 1,071 | 2,328 | 173,695 | n/a | 35 | 0.0022 | 0.0005 | 35 | 0.06 | 0.14 | 35 |
| Sycamore Family Trust14 | 14 | Electric | 100 | 2,500 | 7% | 1,071 | 2,328 | 173,695 | n/a | 35 | 0.0022 | 0.0005 | 35 | 0.06 | 0.14 | 35 |
| Sycamore Family Trust15 | 15 | Electric | 75 | 2,500 | 7% | 1,071 | 2,328 | 130,271 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Sycamore Family Trust17 | 17 | Electric | 125 | 3,500 | 10% | 1,500 | 2,328 | 217,118 | n/a | 44 | 0.0028 | 0.0006 | 44 | 0.07 | 0.18 | 44 |
| | | | **Total** | **35,000** | **100%** | **15,000** | **27,930** | **2,431,724** | **0** | **490** | **0.0314** | **0.0067** | **490** | **0.79** | **1.98** | **493** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Te Velde Revocable Family Trust
Transfer Volume 7,094 acre feet/year
Location Yolo County

**Table J-15. Te Velde Revocable Family Trust Criteria Pollutant Emissions**

| | | | | | | | | | | GHG Emissions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | (metric tons per year) | | | (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Te VeldeGW1 | GW1 | Electric | 127 | 4,656 | 29% | 2,090 | 2,438 | 231,042 | n/a | 47 | 0.0030 | 0.0006 | 47 | 0.07 | 0.19 | 47 |
| Te VeldeGW10 | GW10 | Electric | 143 | 2,833 | 18% | 1,272 | 2,438 | 260,150 | n/a | 52 | 0.0034 | 0.0007 | 52 | 0.08 | 0.21 | 53 |
| Te VeldeGW9 | GW9 | Electric | 104 | 2,200 | 14% | 988 | 2,438 | 189,200 | n/a | 38 | 0.0024 | 0.0005 | 38 | 0.06 | 0.15 | 38 |
| Te VeldeGW4 | GW4 | Electric | 125 | 3,715 | 24% | 1,668 | 2,438 | 227,404 | n/a | 46 | 0.0029 | 0.0006 | 46 | 0.07 | 0.19 | 46 |
| Te VeldeGW3 | GW3 | Electric | 52 | 2,400 | 15% | 1,077 | 2,438 | 94,600 | n/a | 19 | 0.0012 | 0.0003 | 19 | 0.03 | 0.08 | 19 |
| | | | **Total** | **15,804** | **100%** | **7,094** | **12,189** | **1,002,395** | **0** | **202** | **0.0130** | **0.0027** | **202** | **0.32** | **0.82** | **203** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency City of Sacramento
Transfer Volume 5,000 acre feet/year
Location Sacramento County

**Table J-16. City of Sacramento Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| City of Sacramento WSA83 | WELL83 | electric | 30 | 373 | 2% | 88 | 1,278 | 28,615 | n/a | 7 | 0.0004 | 0.0001 | 7 | 0.01 | 0.02 | 7 |
| City of Sacramento WSA92 | WELL92 | electric | 50 | 785 | 4% | 185 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA93 | WELL93 | electric | 50 | 411 | 2% | 97 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA94 | WELL94 | electric | 50 | 879 | 4% | 207 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA107 | WELL107 | electric | 50 | 727 | 3% | 171 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA116 | WELL116 | electric | 75 | 673 | 3% | 158 | 1,278 | 71,538 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| City of Sacramento WSA120 | WELL120 | electric | 50 | 572 | 3% | 135 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA122 | WELL122 | electric | 50 | 470 | 2% | 111 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA124 | WELL124 | electric | 50 | 541 | 3% | 127 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA126 | WELL126 | electric | 50 | 433 | 2% | 102 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA127 | WELL127 | electric | 50 | 592 | 3% | 139 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA129 | WELL129 | electric | 50 | 466 | 2% | 110 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA131 | WELL131 | electric | 50 | 431 | 2% | 101 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA133 | WELL133 | electric | 150 | 757 | 4% | 178 | 1,278 | 143,076 | n/a | 34 | 0.0018 | 0.0004 | 34 | 0.05 | 0.12 | 34 |
| City of Sacramento WSA134 | WELL134 | electric | 60 | 676 | 3% | 159 | 1,278 | 57,230 | n/a | 14 | 0.0007 | 0.0002 | 14 | 0.02 | 0.05 | 14 |
| City of Sacramento WSA137 | WELL137 | electric | 75 | 541 | 3% | 127 | 1,278 | 71,538 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| City of Sacramento WSA138 | WELL138 | electric | 75 | 505 | 2% | 119 | 1,278 | 71,538 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| City of Sacramento WSA139 | WELL139 | electric | 50 | 818 | 4% | 193 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA142 | WELL142 | electric | 75 | 940 | 4% | 221 | 1,278 | 71,538 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| City of Sacramento WSA143 | WELL143 | electric | 50 | 379 | 2% | 89 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA144 | WELL144 | electric | 50 | 549 | 3% | 129 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA153 | WELL153 | electric | 100 | 1027 | 5% | 242 | 1,278 | 95,384 | n/a | 23 | 0.0012 | 0.0003 | 23 | 0.03 | 0.08 | 23 |
| City of Sacramento WSA154 | WELL154 | electric | 50 | 502 | 2% | 118 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA155 | WELL155 | electric | 50 | 675 | 3% | 159 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA156 | WELL156 | electric | 75 | 525 | 2% | 124 | 1,278 | 71,538 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| City of Sacramento WSA157 | WELL157 | electric | 50 | 781 | 4% | 184 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA158 | WELL158 | electric | 50 | 781 | 4% | 184 | 1,278 | 47,692 | n/a | 11 | 0.0006 | 0.0001 | 11 | 0.02 | 0.04 | 11 |
| City of Sacramento WSA159 | WELL159 | electric | 75 | 535 | 3% | 126 | 1,278 | 71,538 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| City of Sacramento WSA164 | WELL164 | electric | 150 | 1101 | 5% | 259 | 1,278 | 143,076 | n/a | 34 | 0.0018 | 0.0004 | 34 | 0.05 | 0.12 | 34 |
| City of Sacramento WSAX1 | WELLX1 | electric | 150 | 1400 | 7% | 329 | 1,278 | 143,076 | n/a | 34 | 0.0018 | 0.0004 | 34 | 0.05 | 0.12 | 34 |
| City of Sacramento WSAX2 | WELLX2 | electric | 150 | 1400 | 7% | 329 | 1,278 | 143,076 | n/a | 34 | 0.0018 | 0.0004 | 34 | 0.05 | 0.12 | 34 |
| | | | **Total** | **21,245** | **100%** | **5,000** | **39,623** | **2,041,221** | **0** | **483** | **0.0264** | **0.0056** | **483** | **0.66** | **1.66** | **485** |

Legend

Assumed to be electric (similar to other wells operated by water agency)
Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Sacramento County Water Agency
Transfer Volume 15,000 acre feet/year
Location Sacramento County

**Table J-17. Sacramento County Water Agency Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating | Pump Rate | | Transfer Volume | Operation | | Fuel Consumption | GHG Emissions (metric tons per year) | | | GHG Emissions (metric tons CO2e per year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Sacramento County WAW 040 | W 040 | Electric | 115 | 1,160 | 2% | 312 | 1,463 | 126,082 | n/a | 30 | 0.0016 | 0.0003 | 30 | 0.04 | 0.10 | 30 |
| Sacramento County WAW 041 | W 041 | Electric | 65 | 676 | 1% | 182 | 1,463 | 71,349 | n/a | 17 | 0.0009 | 0.0002 | 17 | 0.02 | 0.06 | 17 |
| Sacramento County WAW 042 | W 042 | Electric | 77 | 727 | 1% | 196 | 1,463 | 83,960 | n/a | 20 | 0.0011 | 0.0002 | 20 | 0.03 | 0.07 | 20 |
| Sacramento County WAW 043 | W 043 | Electric | 94 | 918 | 2% | 247 | 1,463 | 103,064 | n/a | 24 | 0.0013 | 0.0003 | 24 | 0.03 | 0.08 | 25 |
| Sacramento County WAW 044 | W 044 | Electric | 73 | 515 | 1% | 139 | 1,463 | 79,808 | n/a | 19 | 0.0010 | 0.0002 | 19 | 0.03 | 0.07 | 19 |
| Sacramento County WAW 047 | W 047 | Electric | 88 | 1,030 | 2% | 277 | 1,463 | 95,585 | n/a | 23 | 0.0012 | 0.0003 | 23 | 0.03 | 0.08 | 23 |
| Sacramento County WAW 049 | W 049 | Electric | 92 | 853 | 2% | 230 | 1,463 | 100,474 | n/a | 24 | 0.0013 | 0.0003 | 24 | 0.03 | 0.08 | 24 |
| Sacramento County WAW 052 | W 052 | Electric | 120 | 1,192 | 2% | 321 | 1,463 | 130,941 | n/a | 31 | 0.0017 | 0.0004 | 31 | 0.04 | 0.11 | 31 |
| Sacramento County WAW 056 | W 056 | Electric | 200 | 3,000 | 5% | 808 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 061 | W 061 | Electric | 145 | 1,570 | 3% | 423 | 1,463 | 158,061 | n/a | 37 | 0.0020 | 0.0004 | 37 | 0.05 | 0.13 | 38 |
| Sacramento County WAW 062 | W 062 | Electric | 100 | 455 | 1% | 123 | 1,463 | 109,181 | n/a | 26 | 0.0014 | 0.0003 | 26 | 0.04 | 0.09 | 26 |
| Sacramento County WAW 063 | W 063 | Electric | 100 | 1,119 | 2% | 301 | 1,463 | 109,181 | n/a | 26 | 0.0014 | 0.0003 | 26 | 0.04 | 0.09 | 26 |
| Sacramento County WAW 064 | W 064 | Electric | 141 | 1,205 | 2% | 325 | 1,463 | 153,945 | n/a | 36 | 0.0020 | 0.0004 | 36 | 0.05 | 0.13 | 37 |
| Sacramento County WAW 065 | W 065 | Electric | 57 | 589 | 1% | 159 | 1,463 | 62,670 | n/a | 15 | 0.0008 | 0.0002 | 15 | 0.02 | 0.05 | 15 |
| Sacramento County WAW 066 | W 066 | Electric | 125 | 1,700 | 3% | 458 | 1,463 | 136,476 | n/a | 32 | 0.0018 | 0.0004 | 32 | 0.04 | 0.11 | 32 |
| Sacramento County WAW 067 | W 067 | Electric | 135 | 1,425 | 3% | 384 | 1,463 | 147,820 | n/a | 35 | 0.0019 | 0.0004 | 35 | 0.05 | 0.12 | 35 |
| Sacramento County WAW 068 | W 068 | Electric | 141 | 1,624 | 3% | 437 | 1,463 | 153,836 | n/a | 36 | 0.0020 | 0.0004 | 36 | 0.05 | 0.13 | 37 |
| Sacramento County WAW 069 | W 069 | Electric | 154 | 1,663 | 3% | 448 | 1,463 | 168,019 | n/a | 40 | 0.0022 | 0.0005 | 40 | 0.05 | 0.14 | 40 |
| Sacramento County WAW 070 | W 070 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 073 | W 073 | Electric | 175 | 2,000 | 4% | 539 | 1,463 | 191,067 | n/a | 45 | 0.0025 | 0.0005 | 45 | 0.06 | 0.16 | 45 |
| Sacramento County WAW 074 | W 074 | Electric | 50 | 500 | 1% | 135 | 1,463 | 54,591 | n/a | 13 | 0.0007 | 0.0001 | 13 | 0.02 | 0.04 | 13 |
| Sacramento County WAW 076 | W 076 | Electric | 150 | 1,500 | 3% | 404 | 1,463 | 163,772 | n/a | 39 | 0.0021 | 0.0004 | 39 | 0.05 | 0.13 | 39 |
| Sacramento County WAW 077 | W 077 | Electric | 125 | 2,000 | 4% | 539 | 1,463 | 136,476 | n/a | 32 | 0.0018 | 0.0004 | 32 | 0.04 | 0.11 | 32 |
| Sacramento County WAW 078 | W 078 | Electric | 125 | 2,400 | 4% | 647 | 1,463 | 136,476 | n/a | 32 | 0.0018 | 0.0004 | 32 | 0.04 | 0.11 | 32 |
| Sacramento County WAW 087 | W 087 | Electric | 150 | 1,900 | 3% | 512 | 1,463 | 163,772 | n/a | 39 | 0.0021 | 0.0004 | 39 | 0.05 | 0.13 | 39 |
| Sacramento County WAW 092 | W 092 | Electric | 75 | 1,160 | 2% | 312 | 1,463 | 81,886 | n/a | 19 | 0.0011 | 0.0002 | 19 | 0.03 | 0.07 | 19 |
| Sacramento County WAW 095 | W 095 | Electric | 200 | 2,200 | 4% | 593 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 096 | W 096 | Electric | 150 | 1,500 | 3% | 404 | 1,463 | 163,772 | n/a | 39 | 0.0021 | 0.0004 | 39 | 0.05 | 0.13 | 39 |
| Sacramento County WAW 105 | W 105 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 106 | W 106 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 109 | W 109 | Electric | 200 | 2,600 | 5% | 700 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 110 | W 110 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 112 | W 112 | Electric | 100 | 1,500 | 3% | 404 | 1,463 | 109,181 | n/a | 26 | 0.0014 | 0.0003 | 26 | 0.04 | 0.09 | 26 |
| Sacramento County WAW 114 | W 114 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 129 | W 129 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 130 | W 130 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 122 | W 122 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 123 | W 123 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| Sacramento County WAW 124 | W 124 | Electric | 200 | 1,500 | 3% | 404 | 1,463 | 218,362 | n/a | 52 | 0.0028 | 0.0006 | 52 | 0.07 | 0.18 | 52 |
| | | | **Total** | **55,681** | **100%** | **15,000** | **57,058** | **6,030,151** | **0** | **1,427** | **0.0779** | **0.0165** | **1,427** | **1.95** | **4.92** | **1,434** |

Legend

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Sacramento Suburban Water District
Transfer Volume 30,000 acre feet/year
Location Sacramento County

**Table J-18. Sacramento Suburban Water District Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (MMBtu/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sacramento Suburban WD5 | 5 | Electric | 110 | 330 | 1% | 201 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD7 | 7 | Electric | 110 | 180 | 0% | 110 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD9 | 9 | Electric | 110 | 625 | 1% | 381 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD12 | 12 | Electric | 110 | 540 | 1% | 329 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD13 | 13 | Electric | 110 | 820 | 2% | 500 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD14 | 14 | Electric | 110 | 570 | 1% | 348 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD18 | 18 | Electric | 110 | 840 | 2% | 512 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD19 | 19 | Electric | 110 | 950 | 2% | 579 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD22 | 22 | Electric | 110 | 650 | 1% | 396 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD23 | 23 | Electric | 110 | 550 | 1% | 335 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD24 | 24 | Electric | 110 | 590 | 1% | 360 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD25 | 25 | Electric | 110 | 750 | 2% | 457 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD26 | 26 | Electric | 110 | 650 | 1% | 396 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD28 | 28 | Electric | 110 | 585 | 1% | 357 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD30 | 30 | Electric | 110 | 650 | 1% | 396 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD35 | 35 | Electric | 110 | 1000 | 2% | 610 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD37 | 37 | Natural Gas | 190 | 700 | 1% | 427 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD38 | 38 | Natural Gas | 190 | 500 | 1% | 305 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD40 | 40 | Natural Gas | 190 | 675 | 1% | 412 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD41 | 41 | Electric/Natural Gas | 190 | 600 | 1% | 366 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD43 | 43 | Electric/Natural Gas | 190 | 850 | 2% | 518 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD45 | 45 | Natural Gas | 190 | 750 | 2% | 457 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD47 | 47 | Electric/Natural Gas | 190 | 885 | 2% | 540 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD50 | 50 | Electric | 110 | 500 | 1% | 305 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD51 | 51 | Electric | 110 | 285 | 1% | 174 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD60 | 60 | Electric | 110 | 600 | 1% | 366 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD65 | 65 | Electric | 110 | 1250 | 3% | 762 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD66 | 66 | Electric | 110 | 1350 | 3% | 823 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD69 | 69 | Electric | 110 | 450 | 1% | 274 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD70 | 70 | Electric | 110 | 350 | 1% | 213 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD71 | 71 | Electric | 110 | 2675 | 5% | 1,631 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD72 | 72 | Electric | 110 | 1850 | 4% | 1,128 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD73 | 73 | Electric | 110 | 3500 | 7% | 2,134 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD74 | 74 | Electric | 110 | 2700 | 5% | 1,647 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD75 | 75 | Electric | 110 | 1150 | 2% | 701 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD76 | 76 | Electric | 110 | 250 | 1% | 152 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD77 | 77 | Electric | 110 | 400 | 1% | 244 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD20A | 20A | Electric | 110 | 1100 | 2% | 671 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD2A | 2A | Electric | 110 | 995 | 2% | 607 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD32A | 32A | Electric | 110 | 1905 | 4% | 1,162 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD33A | 33A | Electric | 110 | 2675 | 5% | 1,631 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD3A | 3A | Electric | 110 | 370 | 1% | 226 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD40A | 40A | Electric | 110 | 2525 | 5% | 1,540 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD46R | 46R | Electric/Natural Gas | 190 | 800 | 2% | 488 | 3,312 | n/a | 4,405 | 234 | 0.004 | 0.000 | 234 | 0.11 | 0.13 | 234 |
| Sacramento Suburban WD4B | 4B | Electric | 110 | 2675 | 5% | 1,631 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD55A | 55A | Electric | 110 | 2000 | 4% | 1,220 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| Sacramento Suburban WD68R | 68R | Electric | 110 | 1600 | 3% | 976 | 3,312 | 271,867 | n/a | 64 | 0.004 | 0.001 | 64 | 0.09 | 0.22 | 65 |
| | | | **Total** | **49,195** | **100%** | **30,000** | **155,656** | **10,602,801** | **35,238** | **4,379** | **0.1723** | **0.0325** | **4,379** | **4.31** | **9.69** | **4,393** |

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Natural Gas Engine Fuel Consumption

| | | |
|---|---|---|
| Estimated BSFC = | 7,000 | Btu/bhp-hr |
| Higher Heating Valu | 1,020 | Btu/scf |

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

## Groundwater Substitution GHG Emissions

| | | |
|---|---|---|
| Agency | Butte Water District | |
| Transfer Volume | 5,500 | acre feet/year |
| Location | Butte | County |
| | Sutter | County |

**Table J-19. Butte Water District Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (gal/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Butte Water District#1 | #1 | Electric | 300 | 4,000 | 49% | 2,683 | 3,643 | 815,517 | n/a | 164 | 0.0105 | 0.0022 | 164 | 0.26 | 0.66 | 165 |
| Butte Water District#2 | #2 | Electric | 350 | 4,200 | 51% | 2,817 | 3,643 | 951,437 | n/a | 192 | 0.0123 | 0.0026 | 192 | 0.31 | 0.78 | 193 |
| | | | **Total** | **8,200** | **100%** | **5,500** | **7,285** | **1,766,954** | **0** | **356** | **0.0228** | **0.0048** | **356** | **0.57** | **1.44** | **358** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Garden Highway Mutual Water Company
Transfer Volume 14,000 acre feet/year
Location Sutter County

**Table J-20. Garden Highway Mutual Water Company Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (gal/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Garden Highway MWC4 | #4 | Electric | 110 | 2,300 | 12% | 1,651 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| Garden Highway MWC17 | #17 | Electric | 110 | 3,100 | 16% | 2,226 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| Garden Highway MWC19 | #19 | Electric | 110 | 2,800 | 14% | 2,010 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| Garden Highway MWC22 | #22 | Electric | 110 | 2,700 | 14% | 1,938 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| Garden Highway MWC23 | #23 | Electric | 110 | 2,200 | 11% | 1,579 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| Garden Highway MWC24 | #24 | Electric | 110 | 3,200 | 16% | 2,297 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| Garden Highway MWC25 | #25 | Electric | 110 | 3,200 | 16% | 2,297 | 3,899 | 320,073 | n/a | 65 | 0.0041 | 0.0009 | 65 | 0.10 | 0.26 | 65 |
| | | | **Total** | **19,500** | **100%** | **14,000** | **27,294** | **2,240,511** | **0** | **452** | **0.0290** | **0.0061** | **452** | **0.72** | **1.83** | **454** |

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

## Groundwater Substitution GHG Emissions

Agency Gilsizer Slough Ranch
Transfer Volume 3,900 acre feet/year
Location Sutter County

**Table J-21. Gilsizer Slough Ranch Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (gal/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gilsizer #1 | Gilsizer #1 | Diesel | 162 | 2,016 | 33% | 1,300 | 3,502 | n/a | 31,828 | 325 | 0.0132 | 0.0026 | 325 | 0.33 | 0.79 | 326 |
| Gilsizer #2 | Gilsizer #2 | Electric | 110 | 2,016 | 33% | 1,300 | 3,502 | 287,481 | n/a | 58 | 0.0037 | 0.0008 | 58 | 0.09 | 0.23 | 58 |
| Gilsizer #3 | Gilsizer #3 | Electric | 110 | 2,016 | 33% | 1,300 | 3,502 | 287,481 | n/a | 58 | 0.0037 | 0.0008 | 58 | 0.09 | 0.23 | 58 |
| | | | **Total** | **6,048** | **100%** | **3,900** | **10,506** | **574,961** | **31,828** | **441** | **0.0206** | **0.0042** | **441** | **0.52** | **1.25** | **443** |

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

Agency Goose Club Farms and Teichert Aggregates
Transfer Volume 10,000 acre feet/year
Location Sutter County

**Table J-22. Goose Club Farms and Teichert Aggregates Criteria Pollutant Emissions**

| | | | | | | | | | Fuel | GHG Emissions | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Power Rating | Pump Rate | | Transfer Volume | Operation | | Consumption | (metric tons per year) | | | (metric tons CO2e per year) | | | |
| Description | Well | Fuel Type | (hp) | (gpm) | (% of Total) | (AF/year) | (hours/year) | (kWh/yr) | (gal/yr) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Goose Club1 | 1 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club2 | 2 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club3 | 3 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club4 | 4 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club5 | 5 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club6 | 6 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club7 | 7 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club8 | 8 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club9 | 9 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club10 | 10 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club11 | 11 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club12 | 12 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| Goose Club13 | 13 | Electric | 125 | 3,000 | 8% | 769 | 1,393 | 129,900 | n/a | 26 | 0.0017 | 0.0004 | 26 | 0.04 | 0.11 | 26 |
| | | | **Total** | **39,000** | **100%** | **10,000** | **18,103** | **1,688,697** | **0** | **341** | **0.0218** | **0.0046** | **341** | **0.55** | **1.38** | **342** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

**Groundwater Substitution GHG Emissions**

| | | |
|---|---|---|
| Agency | Tule Basin Farms | |
| Transfer Volume | 7,320 | acre feet/year |
| Location | Sutter | County |

**Table J-23. Tule Basin Farms Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (MMBtu/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tule Basin1 | 1 | Electric | 125 | 3,050 | 27% | 1,941 | 3,457 | 322,468 | n/a | 65 | 0.004 | 0.001 | 65 | 0.10 | 0.26 | 65 |
| Tule Basin2 | 2 | Natural Gas | 190 | 3,600 | 31% | 2,291 | 3,457 | n/a | 4,598 | 244 | 0.005 | 0.000 | 244 | 0.11 | 0.14 | 244 |
| Tule Basin3 | 3 | Electric | 125 | 4,850 | 42% | 3,087 | 3,457 | 322,468 | n/a | 65 | 0.004 | 0.001 | 65 | 0.10 | 0.26 | 65 |
| | | | **Total** | **11,500** | **100%** | **7,320** | **10,371** | **644,935** | **4,598** | **374** | **0.0129** | **0.0022** | **374** | **0.32** | **0.66** | **375** |

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Natural Gas Engine Fuel Consumption

| | | |
|---|---|---|
| Estimated BSFC = | 7,000 | Btu/bhp-hr |
| Higher Heating Value | 1,020 | Btu/scf |

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

## Groundwater Substitution GHG Emissions

| | |
|---|---|
| Agency | Reclamation District 2068 |
| Transfer Volume | 4,500 acre feet/year |
| Location | Solano County |
| | Yolo County |

**Table J-24. Reclamation District 2068 Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (gal/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | GHG Emissions (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RD-2068TP-1 | TP-1 | Electric | 75 | 1,500 | 25% | 1,125 | 4,073 | 227,974 | n/a | 46 | 0.0029 | 0.0006 | 46 | 0.07 | 0.19 | 46 |
| RD-2068GW-2 | GW-2 | Electric | 75 | 1,500 | 25% | 1,125 | 4,073 | 227,974 | n/a | 46 | 0.0029 | 0.0006 | 46 | 0.07 | 0.19 | 46 |
| RD-2068GW-3 | GW-3 | Electric | 75 | 1,500 | 25% | 1,125 | 4,073 | 227,974 | n/a | 46 | 0.0029 | 0.0006 | 46 | 0.07 | 0.19 | 46 |
| RD-2068GW-4 | GW-4 | Electric | 75 | 1,500 | 25% | 1,125 | 4,073 | 227,974 | n/a | 46 | 0.0029 | 0.0006 | 46 | 0.07 | 0.19 | 46 |
| | | | **Total** | **6,000** | **100%** | **4,500** | **16,293** | **911,896** | **0** | **184** | **0.0118** | **0.0025** | **184** | **0.29** | **0.74** | **185** |

Legend

Engine power rating not provided; assumed to be equal to maximum horsepower for all engines operating at the water agency with the same fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

## Groundwater Substitution GHG Emissions

Agency Pope Ranch
Transfer Volume 2,800 acre feet/year
Location Yolo County

**Table J-25. Pope Ranch Criteria Pollutant Emissions**

| Description | Well | Fuel Type | Power Rating (hp) | Pump Rate (gpm) | Pump Rate (% of Total) | Transfer Volume (AF/year) | Operation (hours/year) | Operation (kWh/yr) | Fuel Consumption (gal/yr) | GHG Emissions (metric tons per year) CO2 | CH4 | N2O | GHG Emissions (metric tons CO2e per year) CO2 | CH4 | N2O | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pope RanchX1 | X1 | Electric | 110 | 2,117 | 50% | 1,400 | 3,591 | 294,824 | n/a | 59 | 0.0038 | 0.0008 | 59 | 0.10 | 0.24 | 60 |
| Pope RanchX2 | X2 | Electric | 110 | 2,117 | 50% | 1,400 | 3,591 | 294,824 | n/a | 59 | 0.0038 | 0.0008 | 59 | 0.10 | 0.24 | 60 |
| | | | **Total** | **4,234** | **100%** | **2,800** | **7,183** | **589,648** | **0** | **119** | **0.0076** | **0.0016** | **119** | **0.19** | **0.48** | **120** |

Legend

Engine power rating not provided; assumed to be equal to average horsepower for all engines operating in the study area for fuel type

Conversion Factors

| | | |
|---|---|---|
| 1 lb = | 453.6 | g |
| 1 tonne = | 1,000 | kg |
| 1 tonne = | 1,000,000 | g |
| 1 MWh = | 1,000 | kWh |
| 1 GWh = | 1,000,000 | kWh |
| 1 kW = | 1.34 | hp |
| 1 hour = | 60 | minutes |
| 1 acre-foot = | 325,851 | gallons |

http://www.water.ca.gov/pubs/dwrnews/california_water_facts_card/waterfactscard.pdf

Global Warming Potential

| | |
|---|---|
| CO2 | 1 |
| CH4 | 25 |
| N2O | 298 |

## Engine Size Summary

**Table J-26. Summary of Average Engine Horsepower by Fuel Type**

| Average of HP | Fuel Type | | | |
|---|---|---|---|---|
| **Agency** | **Diesel** | **Electric** | **Natural Gas** | **Grand Total** |
| Anderson-Cottonwood Irrigation District | | 125 | | 125 |
| Butte Water District | | 325 | | 325 |
| City of Sacramento | | 60 | | 60 |
| Conaway Preservation Group | 227 | 138 | | 147 |
| Cordua Irrigation District | | 82 | | 82 |
| Cranmore Farms | | 125 | | 125 |
| Eastside Mutual Water Company | 215 | | | 215 |
| Goose Club Farms and Teichert Aggregates | | 125 | | 125 |
| Pelger Mutual Water Company | 173 | | | 173 |
| Pleasant Grove-Verona Mutual Water Company | 129 | 118 | | 124 |
| Reclamation District 1004 | 191 | 76 | | 145 |
| Reclamation District 108 | | 200 | | 200 |
| Reclamation District 2068 | | 75 | | 75 |
| Sacramento County Water Agency | | 116 | | 116 |
| Sycamore Mutual Water Company | | 117 | | 117 |
| Te Velde Revocable Family Trust | | 110 | | 110 |
| Tule Basin Farms | | 125 | 190 | 147 |
| **Grand Total** | **162** | **110** | **190** | **117** |

**Table J-27. Summary of Maximum Engine Horsepower by Fuel Type**

| Max of HP | Fuel Type | | | |
|---|---|---|---|---|
| **Agency** | **Diesel** | **Electric** | **Natural Gas** | **Grand Total** |
| Anderson-Cottonwood Irrigation District | | 200 | | 200 |
| Butte Water District | | 350 | | 350 |
| City of Sacramento | | 150 | | 150 |
| Conaway Preservation Group | 227 | 250 | | 250 |
| Cordua Irrigation District | | 125 | | 125 |
| Cranmore Farms | | 125 | | 125 |
| Eastside Mutual Water Company | 215 | | | 215 |
| Goose Club Farms and Teichert Aggregates | | 125 | | 125 |
| Pelger Mutual Water Company | 173 | | | 173 |
| Pleasant Grove-Verona Mutual Water Company | 250 | 250 | | 250 |
| Reclamation District 1004 | 225 | 125 | | 225 |
| Reclamation District 108 | | 250 | | 250 |
| Reclamation District 2068 | | 75 | | 75 |
| Sacramento County Water Agency | | 200 | | 200 |
| Sycamore Mutual Water Company | | 125 | | 125 |
| Te Velde Revocable Family Trust | | 143 | | 143 |
| Tule Basin Farms | | 125 | 190 | 190 |
| **Grand Total** | **250** | **350** | **190** | **350** |

**Table J-28. Summary of Minimum Engine Horsepower by Fuel Type**

| Min of HP | Fuel Type | | | |
|---|---|---|---|---|
| **Agency** | **Diesel** | **Electric** | **Natural Gas** | **Grand Total** |
| Anderson-Cottonwood Irrigation District | | 50 | | 50 |
| Butte Water District | | 300 | | 300 |
| City of Sacramento | | 30 | | 30 |
| Conaway Preservation Group | 227 | 75 | | 75 |
| Cordua Irrigation District | | 50 | | 50 |
| Cranmore Farms | | 125 | | 125 |
| Eastside Mutual Water Company | 215 | | | 215 |
| Goose Club Farms and Teichert Aggregates | | 125 | | 125 |
| Pelger Mutual Water Company | 173 | | | 173 |
| Pleasant Grove-Verona Mutual Water Company | 62 | 30 | | 30 |
| Reclamation District 1004 | 150 | 40 | | 40 |
| Reclamation District 108 | | 100 | | 100 |
| Reclamation District 2068 | | 75 | | 75 |
| Sacramento County Water Agency | | 50 | | 50 |
| Sycamore Mutual Water Company | | 75 | | 75 |
| Te Velde Revocable Family Trust | | 52 | | 52 |
| Tule Basin Farms | | 125 | 190 | 125 |
| **Grand Total** | **62** | **30** | **190** | **30** |

## GHG Emission Factors

**Table J-29. GHG Emission Factors for Electric Pumps**

| County | Utility Company | Emission Factors | | |
|---|---|---|---|---|
| | | CO2 (lbs/MWh) | CH4 (lbs/GWh) | N2O (lbs/GWh) |
| Colusa | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Glenn | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Merced | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Placer | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Sacramento | Sacramento Municipal Utility District | 521.73 | 28.49 | 6.03 |
| San Joaquin | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Shasta | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Solano | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Sutter | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Yolo | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |
| Yuba | Pacific Gas & Electric | 444.62 | 28.49 | 6.03 |

**Table J-30. Utility-Specific CO2 Emission Factors**

| 2009 Emission Rates | | |
|---|---|---|
| Utility | Factor Type | Emission Factor (lbs $CO_2$/MWh) |
| Modesto Irrigation District | Retail Power | 1,036.17 |
| | Special Power | 0 |
| | Wholesale Power | 2,048.09 |
| Pacific Gas & Electric | System Average | 575.38 |
| Bonneville Power Authority | System Average | 93.17 |
| **2010 Emission Rates** | | |
| Utility | Factor Type | Emission Factor (lbs $CO_2$/MWh) |
| Sacramento Municipal Utility District | Retail Power | 526.47 |
| | Special Power | 0.00 |
| | Wholesale Power | 828.58 |
| Newmont Nevada Energy Investment | Wholesale Power | 2,055.79 |
| Pacific Gas & Electric | System Average | 444.64 |
| City of Vernon, Light and Power | System Average | 775.83 |
| Modesto Irrigation District | Retail Power | 942.99 |
| | Special Power | 0.00 |
| | Wholesale Power | 2,026.12 |
| Northern States Power Company (Xcel Energy) | System Average | 1,047.20 |
| Public Service Company of Colorado (Xcel Energy) | System Average | 1,675.51 |
| Southwestern Public Service Company (Xcel Energy) | System Average | 1,552.05 |
| Seattle City Light | Retail Power | 45.57 |
| | Special Power | 0.00 |
| | Wholesale Power | 537.64 |
| Bonneville Power Authority | System Average | 134.70 |

| 2011 Emission Rates | | |
|---|---|---|
| **Utility** | **Factor Type** | **Emission Factor (lbs $CO_2$/MWh)** |
| Pacific Gas & Electric | System Average | 392.87 |
| Bonneville Power Authority | System Average | 47.86 |
| Seattle City Light | Retail Power | 13.77 |
| | Special Power | 0.00 |
| | Wholesale Power | 218.75 |
| Sacramento Municipal Utility District | Retail Power | 429.29 |
| | Special Power | 0.00 |
| | Wholesale Power | 795.14 |
| City of Vernon, Light and Power | System Average | 731.49 |
| Northern States Power Company (Xcel Energy) | System Average | 1,071.45 |
| Public Service Company of Colorado (Xcel Energy) | System Average | 1,618.19 |
| Southwestern Public Service Company (Xcel Energy) | System Average | 1,472.69 |
| **2012 Emission Rates** | | |
| **Utility** | **Factor Type** | **Emission Factor (lbs $CO_2$/MWh)** |
| City of Vernon, Light and Power | System Average | 765.97 |
| Pacific Gas & Electric | System Average | 444.62 |
| Sacramento Municipal Utility District | Retail Power | 521.73 |
| | Special Power | 0.00 |
| | Wholesale Power | 799.77 |
| Seattle City Light | Retail Power | 25.62 |
| | Special Power | 0.00 |
| | Wholesale Power | 362.85 |
| Metropolitan Water District of Southern California | Wholesale Power | 658.73 |
| | Self-consumed Power | 157.87 |
| | | |

*Source:*

*The Climate Registry. 2014. Utility-Specific Emission Factors. Accessed on: May 12, 2014. Available at: http://www.theclimateregistry.org/resources/protocols/general-reporting-protocol/.*

**Table J-31. eGRID GHG Emission Factors**

| eGRID Subregion | eGRID Subregion Name | 2010 Emission Rates | | |
|---|---|---|---|---|
| | | (lbs CO2/MWh) | (lbs CH4/GWh) | (lbs N2O/GWh) |
| AKGD | ASCC Alaska Grid | 1,256.87 | 26.08 | 7.18 |
| AKMS | ASCC Miscellaneous | 448.57 | 18.74 | 3.68 |
| AZNM | WECC Southwest | 1,177.61 | 19.21 | 15.72 |
| CAMX | WECC California | 610.82 | 28.49 | 6.03 |
| ERCT | ERCOT All | 1,218.17 | 16.85 | 14.07 |
| FRCC | FRCC All | 1,196.71 | 38.91 | 13.75 |
| HIMS | HICC Miscellaneous | 1,330.16 | 73.98 | 13.88 |
| HIOA | HICC Oahu | 1,621.86 | 99.3 | 22.41 |
| MROE | MRO East | 1,610.80 | 24.29 | 27.52 |
| MROW | MRO West | 1,536.36 | 28.53 | 26.29 |
| NEWE | NPCC New England | 722.07 | 71.76 | 12.98 |
| NWPP | WECC Northwest | 842.58 | 16.05 | 13.07 |
| NYCW | NPCC NYC/Westchester | 622.42 | 23.81 | 2.8 |
| NYLI | NPCC Long Island | 1,336.11 | 81.49 | 10.28 |
| NYUP | NPCC Upstate NY | 545.79 | 16.3 | 7.24 |
| RFCE | RFC East | 1,001.72 | 27.07 | 15.33 |
| RFCM | RFC Michigan | 1,629.38 | 30.46 | 26.84 |
| RFCW | RFC West | 1,503.47 | 18.2 | 24.75 |
| RMPA | WECC Rockies | 1,896.74 | 22.66 | 29.21 |
| SPNO | SPP North | 1,799.45 | 20.81 | 28.62 |
| SPSO | SPP South | 1,580.60 | 23.2 | 20.85 |
| SRMV | SERC Mississippi Valley | 1,029.82 | 20.66 | 10.76 |
| SRMW | SERC Midwest | 1,810.83 | 20.48 | 29.57 |
| SRSO | SERC South | 1,354.09 | 22.82 | 20.89 |
| SRTV | SERC Tennessee Valley | *1,389.20* | 17.7 | 22.41 |
| SRVC | SERC Virginia/Carolina | 1,073.65 | 21.69 | 17.64 |

*Source: U.S. Environmental Protection Agency. 2014. eGRID 9th edition Version 1.0 Year 2010 GHG Annual Output Emission Rates. Accessed on: May 12, 2014. Available at: http://www.epa.gov/cleanenergy/documents/egridzips/eGRID_9th_edition_V1-0_year_2010_GHG_Rates.pdf.*

**Table J-32. Diesel Emission Factors**

| Pollutant | Emission Factor | Unit | Emission Factor Description |
|---|---|---|---|
| CO2 | 10.21 | kg/gallon | Table 12.1, Distillate Fuel Oil No. 2 |
| CH4 | 0.003 | kg/MMBtu | Table 12.9, Petroleum Products, Industrial |
| N2O | 0.0006 | kg/MMBtu | Table 12.9, Petroleum Products, Industrial |
| Heat Content | 0.138 | MMBtu/gallon | Table 12.1, Distillate Fuel Oil No. 2 |

*Source: The Climate Registry. 2014. 2014 Climate Registry Default Emission Factors with U.S. EPA 11/29/2013 Update (Released: March 14, 2014). Accessed on: May 12, 2014. Available at: http://www.theclimateregistry.org/downloads/2014/03/2014-TCR-Default-EFs-with-EPA-11.29.2013-update.pdf*

**Table J-33. Natural Gas Emission Factors**

| Pollutant | Emission Factor | Unit | Emission Factor Description |
|---|---|---|---|
| CO2 | 53.06 | kg/MMBtu | Table 12.1, US Weighted Average |
| CH4 | 0.001 | kg/MMBtu | Table 12.9, Natural Gas, Industrial |
| N2O | 0.0001 | kg/MMBtu | Table 12.9, Natural Gas, Industrial |
| Heat Content | 1,026 | Btu/scf | Table 12.1, US Weighted Average |

*Source: The Climate Registry. 2014. 2014 Climate Registry Default Emission Factors with U.S. EPA 11/29/2013 Update (Released: March 14, 2014). Accessed on: May 12, 2014. Available at: http://www.theclimateregistry.org/downloads/2014/03/2014-TCR-Default-EFs-with-EPA-11.29.2013-update.pdf*

**Table J-34. Reduced Exhaust Emissions from Cropland Idling**

| Water Agency | Groundwater Substitution | Cropland Idling/ Crop | GW Pumping Equivalent | Annual Emissions (MT/year) | | | Annual Emissions (MTCO2e/year) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | (acre-feet/year) | (acre-feet/year) | (acre-feet/year) | CO2 | CH4 | N2O | CO2 | CH4 | N2O | Total |
| Anderson-Cottonwood Irrigation District | 5,226 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Browns Valley Irrigation District | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Butte Water District | 5,500 | 11,500 | 2,706 | 205 | 0.009 | 0.002 | 205 | 0.24 | 0.58 | 205 |
| City of Sacramento | 5,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Conaway Preservation Group | 35,000 | 21,349 | 5,023 | 380 | 0.018 | 0.004 | 380 | 0.44 | 1.07 | 381 |
| Cordua Irrigation District | 12,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Cranmore Farms | 8,000 | 2,500 | 588 | 44 | 0.002 | 0.000 | 44 | 0.05 | 0.13 | 45 |
| Eastside Mutual Water Company | 2,230 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Garden Highway Mutual Water Company | 14,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Gilsizer Slough Ranch | 3,900 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Glenn-Colusa Irrigation District | 25,000 | 66,000 | 15,529 | 1,174 | 0.055 | 0.011 | 1,174 | 1.36 | 3.31 | 1,178 |
| Goose Club Farms and Teichert Aggregates | 10,000 | 10,000 | 2,353 | 178 | 0.008 | 0.002 | 178 | 0.21 | 0.50 | 179 |
| Merced Irrigation District | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Natomas Central Mutual Water Company | 30,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Pelger Mutual Water Company | 3,750 | 2,538 | 597 | 45 | 0.002 | 0.000 | 45 | 0.05 | 0.13 | 45 |
| Placer County Water Agency | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Pleasant Grove-Verona Mutual Water Company | 18,000 | 9,000 | 2,118 | 160 | 0.007 | 0.002 | 160 | 0.19 | 0.45 | 161 |
| Pope Ranch | 2,800 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Reclamation District 1004 | 7,175 | 10,000 | 2,353 | 178 | 0.008 | 0.002 | 178 | 0.21 | 0.50 | 179 |
| Reclamation District 108 | 15,000 | 20,000 | 4,706 | 356 | 0.017 | 0.003 | 356 | 0.41 | 1.00 | 357 |
| Reclamation District 2068 | 4,500 | 7,500 | 1,765 | 133 | 0.006 | 0.001 | 133 | 0.15 | 0.38 | 134 |
| River Garden Farms | 9,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Sacramento County Water Agency | 15,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Sacramento Suburban Water District | 30,000 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| South Sutter Water District | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| Sycamore Mutual Water Company | 15,000 | 10,000 | 2,353 | 178 | 0.008 | 0.002 | 178 | 0.21 | 0.50 | 179 |
| Te Velde Revocable Family Trust | 7,094 | 6,975 | 1,641 | 124 | 0.006 | 0.001 | 124 | 0.14 | 0.35 | 125 |
| Tule Basin Farms | 7,320 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| **Total** | **290,495** | **177,362** | **41,732** | **3,154** | **0.146** | **0.030** | **3,154** | **3.66** | **8.91** | **3,167** |

Notes:

Pelger Mutual Water Company used to estimate emissions for other water agencies.

Engine power rating equal to 250 hp for Pelger Mutual Water Company engines.

The Byron Buck memo is based on diesel-fueled engines with sizes ranging from 121 to 225 hp; all engines are noncertified (Tier 0).

Pelger Mutual Water Company engines are therefore determined to be a sufficient proxy to estimate the difference in emissions between groundwater substitution and cropland idling.

1 acre-foot of groundwater pumped = 4.25 acre-feet produced by fallowing

*Source: Byron Buck & Associates. 2009. "Comparison of Summertime Emission Credits from Land Fallowing Versus Groundwater Pumping."*

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# Appendix K

# Climate Change Technical Appendix

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# Appendix K Climate Change Technical Appendix

## K.1 Introduction and Overview

This modeling appendix provides a description of assumptions, methods and modeling of the effects of future uncertainties in climate conditions on the Central Valley Project (CVP), State Water Project (SWP), and on water transfers. In keeping with the U.S. Department of the Interior, Bureau of Reclamation's (Reclamation) policy to use the best available science to inform decision making, quantitative methods and modeling tools were used whenever possible. Reclamation has actively pursued analysis and understanding of the potential effects of uncertainties related to climate change and socioeconomic conditions through several recent studies. Studies include the Sacramento and San Joaquin Basins Climate Impact Assessment (Reclamation, 2014a), Central Valley Project Integrated Resource Plan (Reclamation, 2014b), and the Sacramento and San Joaquin Rivers Basin Study (Reclamation, 2016a). This modeling appendix relies upon information and technical analyses developed under those studies, including modeling results that quantify the effects of future uncertainties in socioeconomic and climate change conditions. Modeling performed as part of the Sacramento and San Joaquin Rivers Basin Study (Basins Study) was analyzed in the development of this modeling appendix. Model results from the Basins Study are summarized to illustrate the potential effects of climate change on the CVP and SWP. Model results also were used to quantify the potential effects of future uncertainties related to climate change on the long-term water transfers.

This appendix is organized as follows:

- Section 2 of this appendix presents information on a summary of global climate projections and relevant research on climate change implications for California water resources, particularly those for the Central Valley of California.
- Section 3 provides an overview of the scenarios analyzed in the Basins Study that are relied upon for this analysis.
- Section 4 is a summary of changes in water transfer supply and demand under a range of future climate projections analyzed in the Basins Study.
- Section 5 lists the references used in preparation of this appendix.

# K.2 Climate Change Research and Anticipated Effects on Central Valley of California

This section provides a summary of global climate projections and relevant research on climate change implications for California water resources, including a summary of key findings on the sensitivity of California water resources to climate changes, particularly those for the Central Valley of California.

## K.2.1 Historical Climate

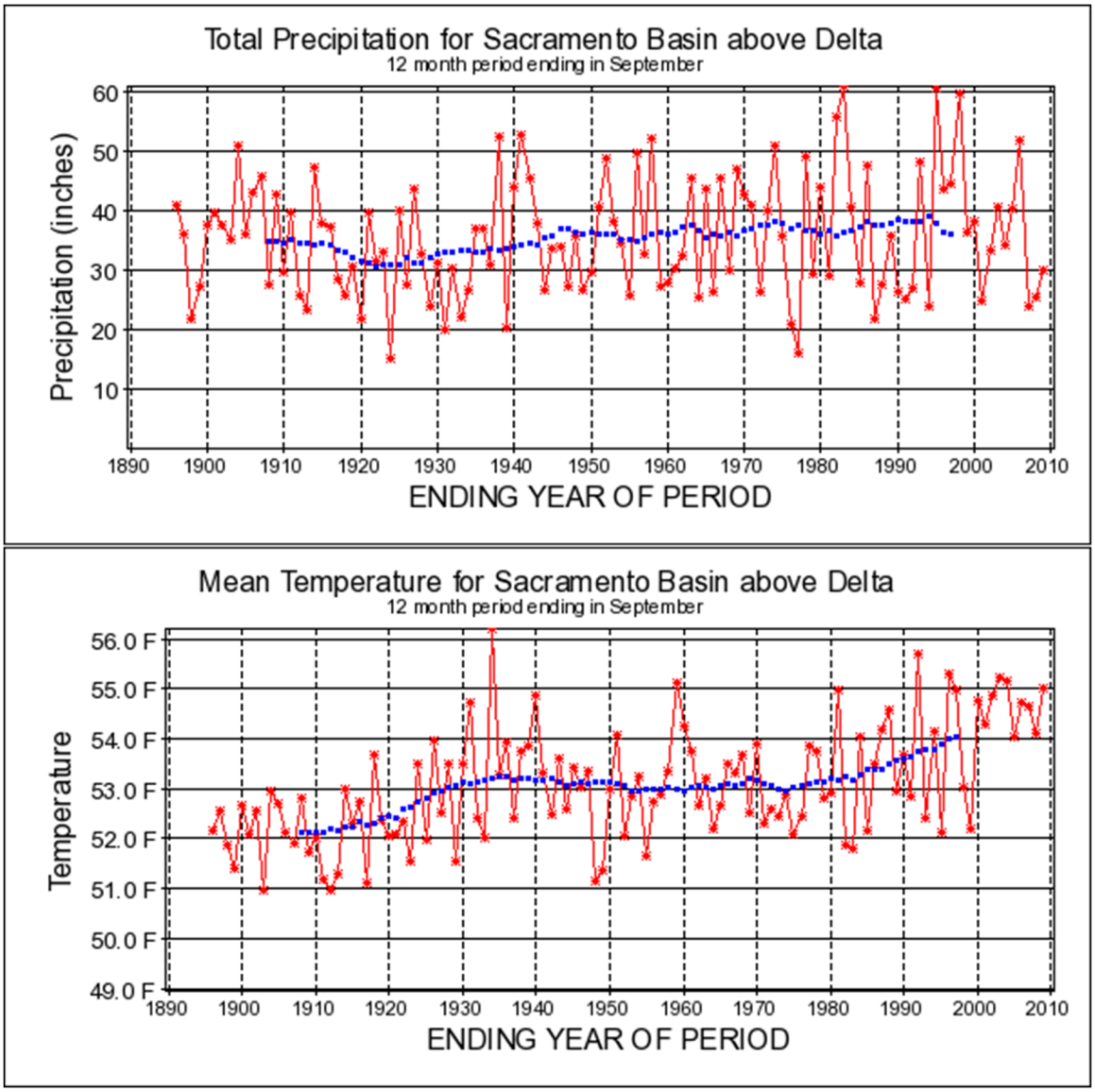
The historical climate of the Central Valley is characterized by hot and dry summers and cool and damp winters. Over the course of the 20th century, warming has been prevalent over the Sacramento and San Joaquin River basins. Basin average mean-annual temperature has increased by approximately 2°F during the course of the 20th century for just the Sacramento River basin north of the Delta (Figure K-1) or the San Joaquin River basin south of the Delta (Figure K-2).

Warming has not occurred steadily throughout the 20th century. Increases in air temperatures occurred primarily during the early part of the 20th century between 1910 and 1935. Subsequently, renewed warming began again in the mid-1970s and appears to be continuing at present, as shown for the Sacramento River basin in Figure K-1. Similar results are apparent for the San Joaquin River basin (Figure K-2) and have been reported in other studies.

In the Sacramento basin, the warming trend also has been accompanied by a gradual trend starting in the 1930s toward increasing precipitation (Figure K-1, top panel). However, a similar precipitation trend is not evident in the San Joaquin basin (Figure K-2, bottom panel). Other studies have shown similar results. Regonda et al. (2005) reported increased winter precipitation trends from 1950 to 1999 at many Western United States locations, including several in California's Sierra Nevada; but a consistent region-wide trend was not apparent. The variability of annual precipitation appears to have increased in the latter part of the 20th century, as can be seen by comparing the range of differences in high and low values of the solid red line in Figure K-1 and Figure K-2. These extremes in wet and dry years have been especially frequent since the mid-1970s in both the Sacramento and San Joaquin basins.

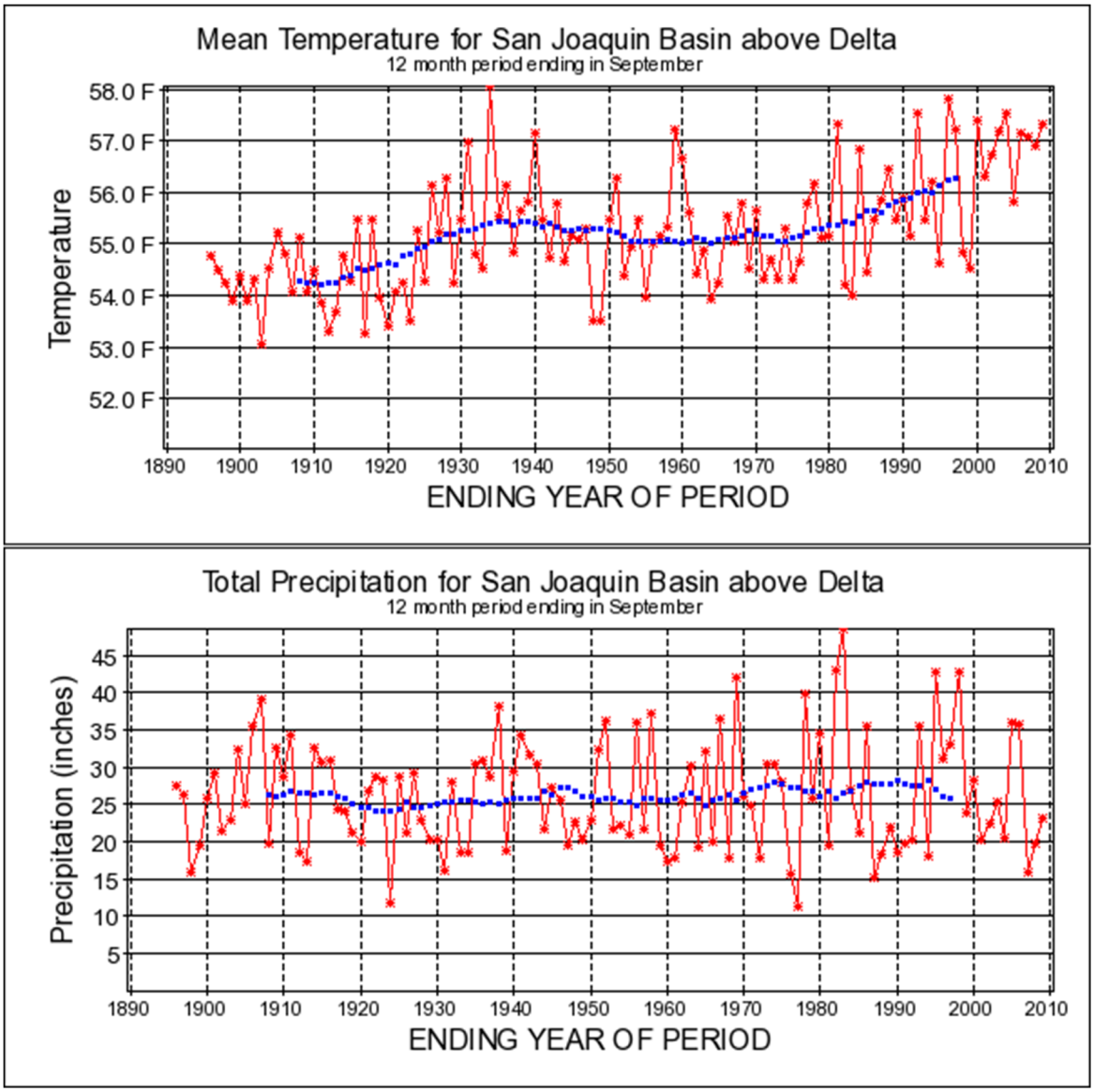
## K.2.2 Historical Hydrology

Streamflow in the Sacramento River and San Joaquin River basins has historically varied considerably from year to year. Runoff can also vary geographically; during any particular year, some portions of the basin may experience relatively greater runoff than other areas. On a monthly to seasonal basis, runoff is generally greater during the winter to early summer months, with winter runoff generally originating from rainfall-runoff events and spring to early summer runoff generally supported by snowmelt from the Cascade Mountains and Sierra Nevada.




*Source: Western Climate Mapping Initiative (WestMap) available at: http://www.cefa.dri.edu/ Westmap/. Red line indicates annual time series for the given geographic region. Blue line indicates 25-year moving annual mean values, where each value is plotted on the center year of its respective 25-year period. WestMap data are derived from the PRISM climate mapping system (Daly et al. 1994; Gibson et al. 2002).*

**Figure K-1.**
**Observed Annual (red) and Moving-Mean Annual (blue) Temperature and Precipitation, Averaged over the Sacramento River Basin**




*Source: Western Climate Mapping Initiative (WestMap) available at: http://www.cefa.dri.edu/ Westmap/. Red line indicates annual time series for the given geographic region. Blue line indicates 25-year moving annual mean values, where each value is plotted on the center year of its respective 25-year period. WestMap data are derived from the PRISM climate mapping system (Daly et al. 1994; Gibson et al. 2002).*

**Figure K-2.**
**Observed Annual (red) and Moving-Mean Annual (blue) Temperature and Precipitation, Averaged Over the San Joaquin River Basin**

Historical changes in climate have resulted in several important effects on Sacramento and San Joaquin basin hydrology. Although annual precipitation may have slightly increased or remained relatively unchanged, corresponding increases in mean annual runoff in the Sacramento and San Joaquin rivers did not occur (Dettinger and Cayan 1995). However, a shift in the seasonal timing of runoff has been observed. In the Sacramento River Basin, a decrease of about 10 percent in the fraction of total runoff occurring from April through July has been observed over the course of the 20th century

(Roos 1991). Similar results were obtained from analyses of the combined basin runoffs for both the Sacramento and San Joaquin basins by Dettinger and Cayan (1995).

Increases in winter runoff have been observed. Analysis of data for 18 Sierra Nevada river basins found earlier runoff trends (Peterson et al. 2008). Of the potential climatic factors that could produce such changes, analyses indicated increasing spring temperatures rather than increased winter precipitation was the primary cause of the observed trends (Cayan 2001). Studies by these researchers and others showed the magnitude of the decreases in April through July runoff was correlated with the altitude of the basin watershed. High altitude basins like the San Joaquin exhibited less decrease in spring runoff than lower elevation watersheds such as the Sacramento. However, it is noted that the appearance of runoff trends in the basins depends on location and period of record being assessed. For example, runoff trends were evaluated for the Basins Study during the last half of the 20th century; and although similar trends were found, they were found to be statistically weak.[1]

Other studies of the magnitude of spring snowpack changes during the 20th century found that snowpack as measured by April 1 Snow Water Equivalent (SWE) showed a decreasing trend in the latter half of the 20th century (Mote 2005). Coincident with these trends, reduced snowpack and snowfall ratios were indicated by analyses of SWE measurements made from 1948 through 2001 at 173 Western United States stations (Knowles et al. 2007). Regonda et al. (2005) reported decreasing spring SWE trends in 50 percent of Western United States locations evaluated.

Changes discussed in the previous paragraphs over regional drainages such as the Sacramento and San Joaquin River basins are sensitive to the uncertainties of station measurements, the periods of analyses, and analyzed locations. For the entire Western United States, observed trends of temperature, precipitation, snowpack, and streamflow might be partially explained by anthropogenic influences on climate (e.g., Barnett et al. 2008; Pierce et al. 2008; Bonfils et al. 2008; Hidalgo et al. 2009; and Das et al. 2009). However, it remains difficult to attribute observed changes in hydroclimate to historical human influences or anthropogenic forcings. This is particularly the case for trends in precipitation (Hoerling et al. 2010) and for trends in basin-scale conditions rather than at the larger Western United States scale (Hidalgo et al. 2009).

Sea level change is also an important factor in assessing the effect of climate on California's water resources because of its effect on water quality in the Sacramento-San Joaquin Delta. Higher mean sea levels (msl) are associated with increasing salinity in the Delta, which influences the suitability of its water for agricultural, urban, and environmental uses. The global rate of msl change was estimated by IPCC (2007) to be 1.8 +/- 0.5 millimeters (mm)/year (0.07 +/- 0.02 inches per year (in/year)) from 1961–

[1] Trend significance was assessed using statistical testing during the period from 1951 through 1999 applied to historical simulated runoff results under observed historical weather conditions (Reclamation 2011). Trends were computed and assessed for four Missouri basin locations, focusing on annual and April–July runoff. In all cases, computed trends were judged to not be statistically significant with 95 percent confidence.

2003 and 3.1 +/- 0.7 mm/year (0.12+/0.03 in/year) during 1993–2003. During the 20th century, msl at Golden Gate Bridge in San Francisco Bay has risen by an average of 2 mm/year (0.08 in/year) (Anderson et al. 2008). These rates of sea level rise appear to be accelerating based on tidal gauges and remote sensing measurements (Church and White 2006; Beckley et al. 2007).

# K.3 Technical Approach and Modeling

The modeling approach and analysis tools for the Basins Study were developed as part of the CVP Integrated Resource Plan (Reclamation 2014a) and the Sacramento and San Joaquin Basin's Climate Risk Assessment Report (Reclamation 2014b) and further improved for the Basins Study. During these studies, Reclamation evaluated future uncertainties related to climate and socioeconomic changes. Uncertainties in future climates primarily surround changes in temperature and precipitation. Changes in both temperature and precipitation then drive changes in runoff, snowpack, and sea level rise assumptions that can affect water supplies and the operations of the CVP/SWP system. Additionally, changes in temperature and precipitation can also affect water needs for agriculture, urban, and the environment.

The following provides a brief overview of the significant body of work performed in support of the CVP Integrated Resource Plan and the Basins Study. Detailed information is available in those plans and technical appendices to those plans. The purpose of this overview is to provide a high-level background on the assumptions included in the Basins Study modeling that was relied upon for the long-term water transfer analysis.

## K.3.1 Description of Ensemble Climate Scenarios

A total of five representative climate futures were developed for use in the Basins Study using results from recent global climate model (GCM) simulations (IPCC 2013) that had been further refined for use in climate studies such as the Basins Study. These are usually referred to as "ensemble" scenarios as they are assembled from an ensemble group of climate projections. By using only five representative future climates, it was possible to efficiently assess the impacts of a range of potential climate futures without having to perform an excessive number of simulations.

The representative climate futures were created by combining together multiple individual GCM projections that occur within defined representative climate categories. Future projections of temperature show a consistent trend of warming, but the magnitude of the warming can vary. Future projections of precipitation are less consistent with some GCMs showing future increases in precipitation while others show a decrease in precipitation. The combination of these two variables and the range of future projections create a range of future conditions that are grouped into five different climate categories. A representative scenario is then selected from each category. The representative climate scenarios are shown conceptually in Figure K-3.

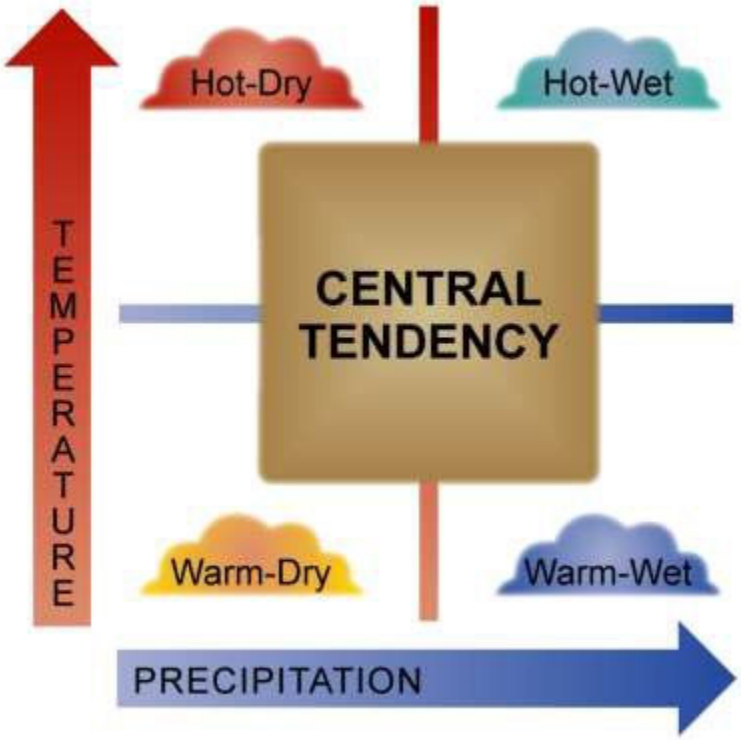



**Figure K-3.**
**Conceptual Representation of Ensemble Climate Scenarios to Relate the Concept of Developing a Wide Range of Ensemble Projections (Reclamation 2016a)**

Representative scenarios illustrated in Figure K-3 are described as:

- Central Tendency (CEN) scenario is in the middle of the range of all the projected temperatures and precipitations. It consists of a large number of projections and can be viewed as a better, though not certain, estimate of what the future climate may be.

- Warm-Dry (WD) scenario consists of a small number of projections that are not as warm as the central tendency but are significantly drier.

- Warm-Wet (WW) scenario consists of a small number of projections that are not as warm as the central tendency but are significantly wetter

- Hot-Dry (HD) scenario consists of a small number of projections that are significantly warmer and drier than the central tendency.

- Hot-Wet (HW) scenario consists of a small number of projections that are significantly hotter and wetter than the central tendency projection.

Both the Basins Study and this analysis for water transfers focus effort on evaluation of three of the five scenarios. The Central Tendency, Warm-Wet, and Hot-Dry scenarios are used to evaluate a relatively wide range of potential future climate conditions, particularly future conditions related to water supply and the operations of the CVP and SWP.

### K.3.2 Socioeconomic Scenarios and Future Demands for Water

As population increases, municipal, commercial, and industrial water demands tend to increase. These demands are dynamic and depend on a variety of factors, such as urban development and land use density. Agricultural demand is also influenced by socioeconomic trends but to a lesser degree. The Basins Study evaluated three different socioeconomic scenarios to describe how water demands might evolve with changing populations and land use. These scenarios vary based on the expected future population growth and urban density and include Expansive Growth, Current Trends, and Slow Growth scenarios. This analysis focuses only on the Current Trends scenario, in part because this analysis is primarily addressing uncertainty related to future climate conditions.

Future water demands depend upon changes in population and land use as well as climate changes. As urban population increases, adjacent agricultural land is often incorporated into urban areas, thus reducing the agricultural land area to varying degrees. Consequently, with fewer acres of future irrigated lands, projected agricultural water demands tend to decline over time. Correspondingly, future urban demands may be anticipated to increase with increasing populations. The agricultural and urban demands and growth vary by regions.

Additionally, modeling performed for the Basins Study includes changes in demand through time, as opposed to a fixed level of demand analyzed over a range of hydrologic conditions. Demands in the first decades of the analysis are similar to current levels of demand, while demands closer to the end of analysis period in 2099 are different due to both socioeconomic and climate driven changes expected by the end of the century.

Agricultural water demands are affected by climate, population, and land use as well as other factors such as the types of crops and agricultural water management practices. The crop types, acreages, and changes in irrigated land area are based on the scenarios developed from the DWR analysis in the California Water Plan (DWR 2014). Under assumptions used in the Current Trends socioeconomic scenario for population growth and land changes, agricultural land in the Central Valley is projected to gradually decline from 6.5 million acres in 2012 to 5.8 million acres in 2040 and 5.4 million acres by 2099. Even though irrigated acreages were simulated as declining, the amount of contracted water supply available to the CVP/SWP contractors was not reduced. Details regarding the crop types, irrigated acreages, growing seasons, and other parameters used in the agricultural demands assessment are provided in technical reports to the Basins Study.

If there were no climate change, then the projected average annual agricultural demands for water in the Central Valley would decline from estimates of current demands of approximately 21.7 million acre-feet to 19.1 million acre-feet by 2070 – 2099 (see No

Climate Change [No CC] in Table K-1). This decline reflects a decrease in irrigated crop acreage. Changes in climate—especially increased carbon dioxide levels and temperature increases that exceed crop water stress thresholds, create additional changes in agricultural demand. This result occurs because the hotter climate scenarios have higher temperatures as well as higher levels of carbon dioxide. These changes do not become significant until the latter part of the 21st century and are therefore less significant for the analysis of water transfers over the next several years. Table K-1 shows the average annual agricultural water demands for the Central Valley for the Current Trends socioeconomic scenario.

Urban demands are an important portion of Reclamation's water deliveries. Urban demands now account for about one-twelfth of the water use in the Central Valley. Urban demands are driven largely by population and therefore tend to change steadily over time based on the assumed level of population, municipal, commercial, and industrial growth associated with each of the socioeconomic scenarios. Table K-1 shows the average annual urban water demands for the Central Valley for the Current Trends socioeconomic scenario.

**Table K-1.**
**Average Annual Water Demands under the No CC Scenario Compared with Ensemble Climate Scenarios in the Current Trends Socioeconomic Scenario in Thousand Acre-Feet/Year**

| Demand | Period | No CC | Hot-Dry | Warm-Wet | Central Tend. |
|---|---|---|---|---|---|
| Agricultural | 2015-2039 | 21,722 | 22,456 | 21,416 | 21,946 |
| | 2040-2069 | 20,135 | 20,211 | 19,373 | 19,990 |
| | 2070-2099 | 19,081 | 15,864 | 17,905 | 17,695 |
| | **2015-2099** | **20,230** | **19,337** | **19,456** | **19,756** |
| Urban | 2015-2039 | 2,152 | 2,211 | 2,153 | 2,178 |
| | 2040-2069 | 2,920 | 3,036 | 2,933 | 2,986 |
| | 2070-2099 | 3,701 | 3,851 | 3,705 | 3,769 |
| | **2015-2099** | **2,970** | **3,081** | **2,976** | **3,025** |

### K.3.3 Future Sea Level Rise

Transient sea level changes were also included in the analysis of climate change scenarios. The amount of sea level rise was based on National Research Council (NRC) median projection for sea level rise, The NRC report suggested that by 2100, sea levels could rise by about 90 centimeters (cm), with a projected range between 42 cm through 166 (NRC 2012).

### K.3.4 No Climate Change Scenario

In order to understand the uncertainties related to future climate and socioeconomic changes it is necessary to compare results that include future projections with historical climate conditions. Therefore, a No Climate Change (No CC) scenario was developed that "projected" historical climate conditions into the future climate period. In the No CC

scenario, total Central Valley demands change temporally in responses to changes in population and land use.

### K.3.5 Modeling Tools

Several different modeling tools were used in the Basins Study to analyze uncertainties in future climate and socioeconomic trends. The Water Evaluation and Planning model of the Central Valley (WEAP-CV) hydrology model was used to simulate water supply and demands for multiple scenarios to address critical uncertainties related to climate and socioeconomic changes. Results from WEAP-CV were used as inputs to the CalLite-CV model to simulate how the CVP, SWP, and other water management systems operate to meet urban, agriculture, and environmental needs. Results from the CalLite-CV model were used to understand and quantify the potential changes in CVP and SWP operations as a result of climate change and assess how those changes may affect long-term water transfers. The following sections provide additional details on WEAP-CV and CalLite-CV. Additional details on these tools is available in technical appendices to the Basins Study.

WEAP-CV is a planning model of the Central Valley, developed on the WEAP modeling platform. Water supply is primarily driven by climatic variables such as precipitation and temperature. Precipitation directly affects water supplies whereas temperature influences water supply through water evaporation and crop evapotranspiration. Demands are influenced by socioeconomic conditions such as population, commercial and industrial growth, and land-use changes. WEAP-CV is capable of simulating both water supply and demand changes under the different climate change scenarios and socioeconomic conditions.

WEAP-CV includes rainfall-runoff modules used to develop climate-based watershed runoff for the main watersheds of the Bay-Delta, the Sacramento River, San Joaquin River, and Tulare Lake hydrologic regions. One of the key components of the model is the dynamic calculation of crop water requirements under various climate change scenarios. Each climate change scenario is analyzed using a transient approach in which the climate and socioeconomic factors gradually change as the simulation progresses through time.

Results from WEAP-CV model are input to the CalLite-CV model. CalLite-CV simulates CVP and SWP operations, delivery allocation decisions, Delta salinity, river flows, and reservoir levels based on hydrologic inputs from WEAP-CV. CalLite-CV is developed on the GoldSim modeling platform and has the ability to rapidly simulate system operations and to incorporate changes with relative ease, making it suitable for analysis of multiple climatic and socioeconomic scenarios. Results from the CalLite-CV model were used in the Basins Study to understand water supply and demand, and as inputs to other tools for evaluating impacts on water temperature, hydropower, greenhouse gas emissions, and economics.

# K.4 Effects of Climate Change on CVP/SWP Operations

This analysis focuses on three climate change scenarios: 1) Central Tendency 2) Warm-Wet, and 3) Hot-Dry. These climate change scenarios are based on the Current Trends scenario of socio-economic development. These three climate change scenarios were selected out of the five scenarios as they represent a relatively wide range of potential future climate conditions, particularly future conditions related to water supply and the operations of the CVP and SWP.

While the remainder of the analysis focuses on only three climate change scenarios, Figure K-4 and Figure K-5 illustrate the range of runoff for all five ensemble climate scenarios to illustrate how the Central Tendency, Warm-Wet, and Hot-Dry scenarios compare with the Warm-Dry and Hot-Wet scenarios.

Figure K-4 compares the average annual runoff in the Sacramento River basin under the different climate change scenarios with the No Climate Change scenario (No CC) for water year 2015 through 2099. Average annual runoff in the Sacramento River basin varies from nearly 18 million acre-feet under the Hot-Dry scenario to 27 million acre-feet under the Hot-Wet scenario. Average annual runoff in the Sacramento River system under both Warm-Dry and Hot-Dry scenarios is nearly the same, and shows a decrease of approximately 4 million acre-feet compared to the No CC scenario. Similarly, average annual runoff under both Hot-Wet and Warm-Wet scenarios is nearly the same, and shows an increase of approximately 5 million acre-feet from the No CC scenario. The average annual runoff in the Sacramento River system under the Central Tendency scenario is similar in volume to the No CC scenario, though there are changes in the monthly timing of runoff.

Figure K-5 presents average annual runoff in the San Joaquin River basin. Relative changes in runoff between scenarios in the San Joaquin basin are similar to those seen in the Sacramento basin. The Hot-Dry scenario has the lowest runoff at just less than 5 million acre-feet, a reduction of approximately 1.2 million acre-feet compared to the No CC scenario. The Warm-Wet scenario shows the highest runoff of over 8 million acre-feet, an increase of approximately 2 million acre-feet from the No CC scenario. Runoff under the Central Tendency scenario is again similar in volume to the No CC scenario with an average of approximately 6.2 million acre-feet annually.

Tables K-2, K-3, and K-4 summarize key results of CVP and SWP operations from the CalLite-CV model for the three climate change scenarios as compared against the No CC scenario. Each table provides the average monthly results for one of the three climate projections, the No CC scenario, and the change from the No CC scenario.

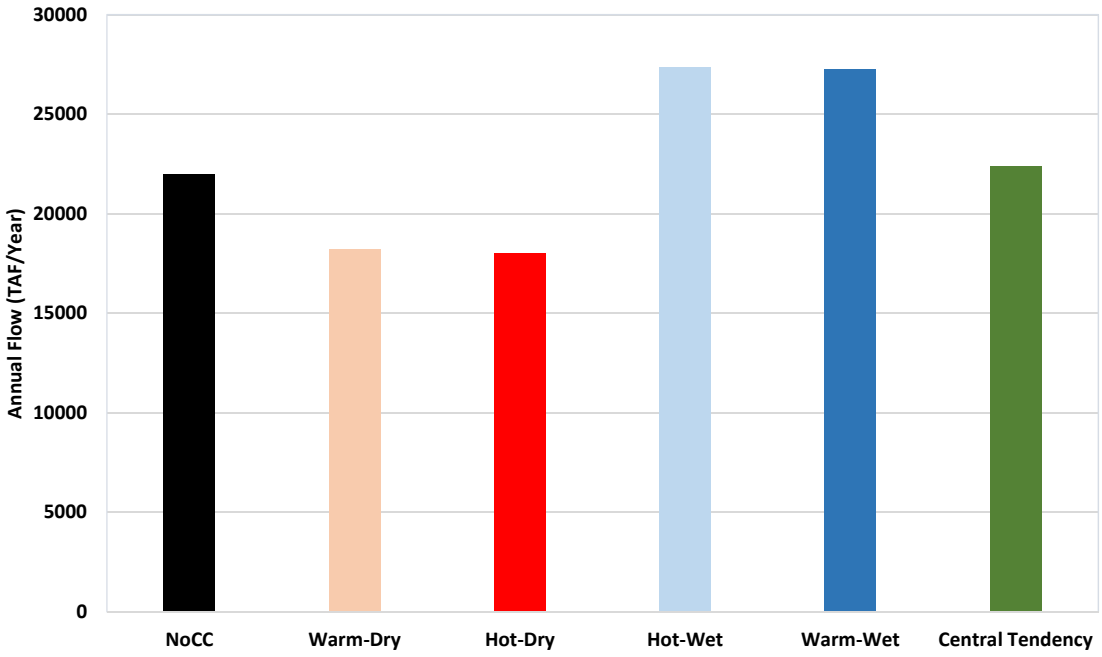



**Figure K-4.**
**Average Annual Runoff in the Sacramento River System under different climate change projections and Current Trend Scenario (Reclamation 2016b)**

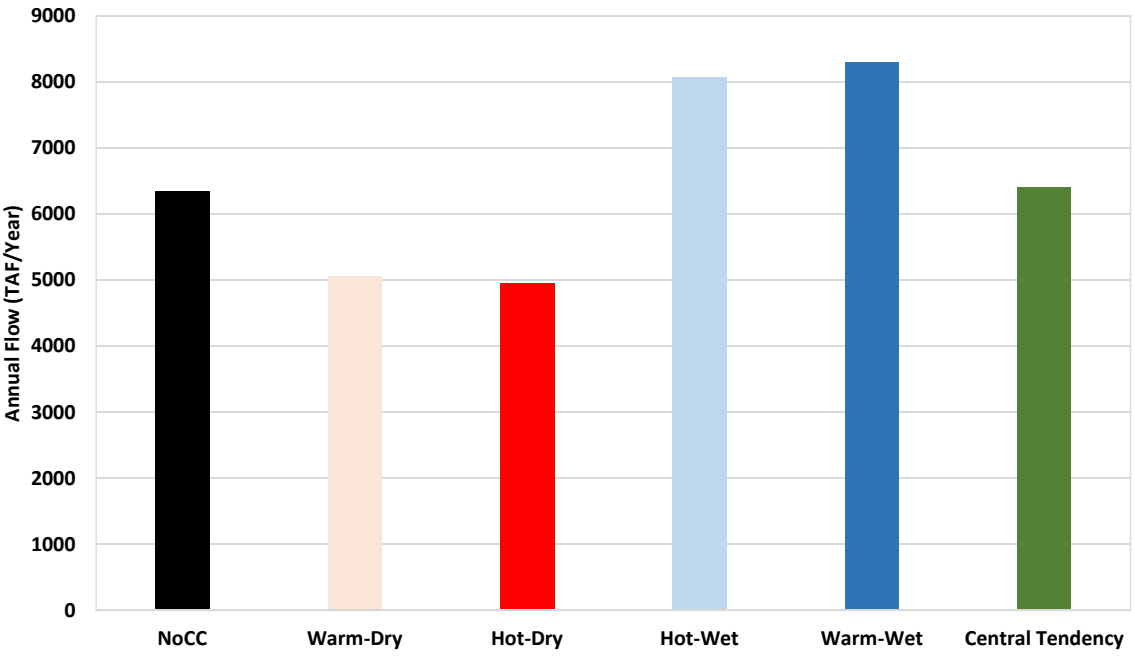



**Figure K-5.**
**Average Annual Runoff in the San Joaquin River System under different climate change projections and Current Trend Scenario (Reclamation 2016b)**

**Table K-2.**
**Comparison of Average Monthly Values of CVP/SWP Operations between Central Tendency and No CC Scenarios**

| No CC Scenario | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Delta Outflow (cfs) | 11282 | 23296 | 45282 | 50666 | 48877 | 37851 | 22265 | 11413 | 7197 | 4443 | 4473 | 5812 |
| Jones Pumping Plant (cfs) | 3582 | 3961 | 3170 | 3047 | 2804 | 1516 | 1241 | 3004 | 3789 | 3445 | 3862 | 2728 |
| Banks Pumping Plant (cfs) | 6064 | 4340 | 4169 | 4509 | 4884 | 1641 | 1232 | 3149 | 4857 | 3410 | 3566 | 6187 |
| Sac. River at Hood (cfs) | 15957 | 24143 | 34614 | 37660 | 40112 | 29534 | 18696 | 16073 | 16592 | 10873 | 9414 | 11191 |
| Sac. River at Keswick (cfs) | 4253 | 5719 | 8609 | 11307 | 12962 | 9225 | 7731 | 13585 | 12971 | 9580 | 5520 | 5422 |
| Sac. River at NCP (cfs) | 6488 | 11903 | 19266 | 22307 | 21325 | 13407 | 7030 | 6650 | 6668 | 4799 | 4648 | 5299 |
| Feather River blw. Thermalito (cfs) | 2656 | 3267 | 5680 | 6810 | 8474 | 6024 | 4341 | 4416 | 6943 | 3903 | 1477 | 2864 |
| American River at Nimbus (cfs) | 2765 | 3226 | 5518 | 5315 | 5378 | 4708 | 3525 | 3696 | 2462 | 1838 | 1485 | 1480 |
| American River at H.St (cfs) | 2494 | 2970 | 5272 | 5082 | 5151 | 4469 | 3252 | 3375 | 2101 | 1470 | 1135 | 1167 |
| SJ River at Vernalis (cfs) | 2557 | 2724 | 5231 | 6569 | 7482 | 8957 | 6822 | 4440 | 2930 | 2692 | 2553 | 2720 |
| Shasta Storage (TAF) | 2269 | 2368 | 2604 | 2956 | 3227 | 3369 | 3427 | 3442 | 2994 | 2567 | 2326 | 2313 |
| Folsom Storage (TAF) | 426 | 407 | 440 | 469 | 495 | 589 | 675 | 749 | 642 | 536 | 471 | 449 |
| Oroville Storage (TAF) | 1461 | 1531 | 1700 | 1949 | 2114 | 2267 | 2379 | 2401 | 2127 | 1716 | 1498 | 1504 |
| CVP San Luis Storage (TAF) | 273 | 395 | 570 | 689 | 769 | 821 | 768 | 630 | 491 | 346 | 247 | 274 |
| SWP San Luis Storage (TAF) | 439 | 619 | 701 | 813 | 863 | 908 | 789 | 587 | 449 | 388 | 270 | 255 |
| **Central Tendency** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 11702 | 27528 | 55280 | 58777 | 50419 | 36170 | 19017 | 9811 | 8461 | 4869 | 4416 | 6906 |
| Jones Pumping Plant (cfs) | 3301 | 3910 | 3355 | 3011 | 2720 | 1508 | 1116 | 2928 | 3514 | 3078 | 3633 | 2418 |
| Banks Pumping Plant (cfs) | 5987 | 4578 | 4441 | 4874 | 5062 | 1754 | 1095 | 3018 | 4809 | 2829 | 3543 | 5159 |
| Sac. River at Hood (cfs) | 15944 | 26374 | 37505 | 39268 | 40111 | 27651 | 16605 | 15093 | 18073 | 10431 | 9297 | 10952 |
| Sac. River at Keswick (cfs) | 4080 | 6031 | 9585 | 11924 | 12581 | 8790 | 8726 | 14235 | 13896 | 9187 | 5462 | 5146 |
| Sac. River at NCP (cfs) | 6279 | 13124 | 21639 | 23885 | 20672 | 12758 | 7843 | 7455 | 7865 | 4697 | 4538 | 4961 |
| Feather River blw. Thermalito (cfs) | 3004 | 3717 | 7341 | 8097 | 8913 | 5616 | 3731 | 4254 | 7199 | 3707 | 1671 | 2999 |
| American River at Nimbus (cfs) | 2685 | 4119 | 7450 | 6171 | 5307 | 3692 | 2392 | 2913 | 2718 | 1708 | 1394 | 1457 |
| American River at H.St (cfs) | 2411 | 3860 | 7201 | 5934 | 5076 | 3448 | 2113 | 2587 | 2352 | 1336 | 1041 | 1146 |
| SJ River at Vernalis (cfs) | 2585 | 2912 | 7143 | 8983 | 9013 | 9698 | 5839 | 3345 | 2321 | 2394 | 2370 | 2688 |
| Shasta Storage (TAF) | 2068 | 2173 | 2478 | 2878 | 3164 | 3301 | 3366 | 3300 | 2805 | 2322 | 2108 | 2096 |
| Folsom Storage (TAF) | 376 | 383 | 439 | 476 | 501 | 592 | 645 | 647 | 542 | 440 | 395 | 388 |
| Oroville Storage (TAF) | 1340 | 1407 | 1633 | 1945 | 2165 | 2300 | 2382 | 2346 | 2039 | 1585 | 1386 | 1384 |
| CVP San Luis Storage (TAF) | 273 | 381 | 558 | 694 | 779 | 831 | 785 | 652 | 527 | 382 | 267 | 285 |
| SWP San Luis Storage (TAF) | 363 | 548 | 653 | 785 | 850 | 905 | 795 | 591 | 445 | 385 | 239 | 226 |
| **Change from No CC Scenario** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 420 | 4231 | 9997 | 8111 | 1543 | -1681 | -3247 | -1601 | 1264 | 426 | -58 | 1093 |
| Jones Pumping Plant (cfs) | -281 | -50 | 185 | -36 | -84 | -8 | -125 | -76 | -276 | -367 | -229 | -311 |
| Banks Pumping Plant (cfs) | -77 | 238 | 272 | 365 | 178 | 113 | -136 | -131 | -48 | -580 | -23 | -1027 |
| Sac. River at Hood (cfs) | -13 | 2231 | 2891 | 1607 | -1 | -1883 | -2092 | -980 | 1481 | -442 | -117 | -239 |
| Sac. River at Keswick (cfs) | -173 | 312 | 976 | 617 | -381 | -435 | 995 | 650 | 925 | -393 | -57 | -276 |
| Sac. River at NCP (cfs) | -209 | 1221 | 2372 | 1578 | -653 | -649 | 814 | 805 | 1197 | -103 | -110 | -338 |
| Feather River blw. Thermalito (cfs) | 348 | 450 | 1661 | 1287 | 439 | -409 | -610 | -161 | 256 | -196 | 194 | 134 |
| American River at Nimbus (cfs) | -80 | 893 | 1932 | 856 | -71 | -1016 | -1133 | -784 | 256 | -130 | -92 | -24 |
| American River at H.St (cfs) | -82 | 890 | 1928 | 852 | -75 | -1021 | -1139 | -787 | 251 | -133 | -94 | -21 |
| SJ River at Vernalis (cfs) | 28 | 188 | 1912 | 2414 | 1531 | 741 | -983 | -1096 | -609 | -298 | -184 | -32 |
| Shasta Storage (TAF) | -200 | -195 | -126 | -78 | -63 | -69 | -61 | -141 | -189 | -245 | -218 | -217 |
| Folsom Storage (TAF) | -50 | -24 | 0 | 8 | 6 | 2 | -30 | -102 | -100 | -96 | -76 | -61 |
| Oroville Storage (TAF) | -121 | -124 | -68 | -4 | 52 | 33 | 3 | -54 | -88 | -131 | -112 | -120 |
| CVP San Luis Storage (TAF) | 0 | -14 | -13 | 5 | 10 | 10 | 18 | 22 | 37 | 36 | 20 | 11 |
| SWP San Luis Storage (TAF) | -76 | -71 | -48 | -29 | -13 | -3 | 6 | 4 | -4 | -2 | -31 | -28 |

## Table K-3.
## Comparison of Average Monthly Values of CVP/SWP Operations between Hot-Dry and No CC Scenarios

| No CC Scenario | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Delta Outflow (cfs) | 11282 | 23296 | 45282 | 50666 | 48877 | 37851 | 22265 | 11413 | 7197 | 4443 | 4473 | 5812 |
| Jones Pumping Plant (cfs) | 3582 | 3961 | 3170 | 3047 | 2804 | 1516 | 1241 | 3004 | 3789 | 3445 | 3862 | 2728 |
| Banks Pumping Plant (cfs) | 6064 | 4340 | 4169 | 4509 | 4884 | 1641 | 1232 | 3149 | 4857 | 3410 | 3566 | 6187 |
| Sac. River at Hood (cfs) | 15957 | 24143 | 34614 | 37660 | 40112 | 29534 | 18696 | 16073 | 16592 | 10873 | 9414 | 11191 |
| Sac. River at Keswick (cfs) | 4253 | 5719 | 8609 | 11307 | 12962 | 9225 | 7731 | 13585 | 12971 | 9580 | 5520 | 5422 |
| Sac. River at NCP (cfs) | 6488 | 11903 | 19266 | 22307 | 21325 | 13407 | 7030 | 6650 | 6668 | 4799 | 4648 | 5299 |
| Feather River blw. Thermalito (cfs) | 2656 | 3267 | 5680 | 6810 | 8474 | 6024 | 4341 | 4416 | 6943 | 3903 | 1477 | 2864 |
| American River at Nimbus (cfs) | 2765 | 3226 | 5518 | 5315 | 5378 | 4708 | 3525 | 3696 | 2462 | 1838 | 1485 | 1480 |
| American River at H.St (cfs) | 2494 | 2970 | 5272 | 5082 | 5151 | 4469 | 3252 | 3375 | 2101 | 1470 | 1135 | 1167 |
| SJ River at Vernalis (cfs) | 2557 | 2724 | 5231 | 6569 | 7482 | 8957 | 6822 | 4440 | 2930 | 2692 | 2553 | 2720 |
| Shasta Storage (TAF) | 2269 | 2368 | 2604 | 2956 | 3227 | 3369 | 3427 | 3442 | 2994 | 2567 | 2326 | 2313 |
| Folsom Storage (TAF) | 426 | 407 | 440 | 469 | 495 | 589 | 675 | 749 | 642 | 536 | 471 | 449 |
| Oroville Storage (TAF) | 1461 | 1531 | 1700 | 1949 | 2114 | 2267 | 2379 | 2401 | 2127 | 1716 | 1498 | 1504 |
| CVP San Luis Storage (TAF) | 273 | 395 | 570 | 689 | 769 | 821 | 768 | 630 | 491 | 346 | 247 | 274 |
| SWP San Luis Storage (TAF) | 439 | 619 | 701 | 813 | 863 | 908 | 789 | 587 | 449 | 388 | 270 | 255 |
| **Hot-Dry Scenario** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 8991 | 18400 | 36288 | 39622 | 36099 | 27594 | 16321 | 9536 | 9414 | 4759 | 5129 | 7605 |
| Jones Pumping Plant (cfs) | 2328 | 3245 | 2936 | 2646 | 2409 | 1448 | 1136 | 2326 | 2510 | 2002 | 2446 | 1669 |
| Banks Pumping Plant (cfs) | 4513 | 4160 | 3846 | 4153 | 4172 | 1682 | 1132 | 2358 | 3570 | 1764 | 2270 | 3470 |
| Sac. River at Hood (cfs) | 12207 | 20437 | 29857 | 32318 | 31449 | 22504 | 15441 | 14537 | 17042 | 8591 | 8206 | 9810 |
| Sac. River at Keswick (cfs) | 3994 | 3871 | 5690 | 7582 | 9044 | 7246 | 9308 | 14108 | 13666 | 8222 | 5092 | 5225 |
| Sac. River at NCP (cfs) | 5010 | 8605 | 14533 | 16494 | 15174 | 10108 | 7867 | 7377 | 7967 | 4233 | 3950 | 4506 |
| Feather River blw. Thermalito (cfs) | 2617 | 3037 | 4190 | 5593 | 6576 | 4576 | 3479 | 4024 | 6363 | 2930 | 1749 | 3120 |
| American River at Nimbus (cfs) | 1769 | 3089 | 5436 | 4855 | 4275 | 3113 | 2322 | 3279 | 2798 | 1277 | 1109 | 1132 |
| American River at H.St (cfs) | 1498 | 2830 | 5187 | 4617 | 4041 | 2865 | 2041 | 2947 | 2437 | 933 | 779 | 835 |
| SJ River at Vernalis (cfs) | 2042 | 2082 | 4179 | 5352 | 5763 | 7125 | 4617 | 2624 | 2090 | 1991 | 1996 | 2322 |
| Shasta Storage (TAF) | 1310 | 1372 | 1634 | 2083 | 2439 | 2658 | 2719 | 2556 | 2022 | 1529 | 1355 | 1351 |
| Folsom Storage (TAF) | 235 | 258 | 346 | 415 | 466 | 552 | 592 | 560 | 404 | 273 | 244 | 244 |
| Oroville Storage (TAF) | 1011 | 1053 | 1226 | 1552 | 1764 | 1938 | 2006 | 1925 | 1625 | 1223 | 1076 | 1075 |
| CVP San Luis Storage (TAF) | 270 | 334 | 484 | 617 | 705 | 758 | 736 | 645 | 553 | 433 | 316 | 299 |
| SWP San Luis Storage (TAF) | 243 | 380 | 499 | 673 | 790 | 863 | 785 | 617 | 454 | 353 | 193 | 159 |
| **Change from No CC Scenario** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | -2291 | -4897 | -8994 | -11044 | -12778 | -10258 | -5944 | -1877 | 2216 | 316 | 656 | 1792 |
| Jones Pumping Plant (cfs) | -1254 | -715 | -234 | -402 | -395 | -68 | -105 | -678 | -1279 | -1442 | -1416 | -1060 |
| Banks Pumping Plant (cfs) | -1552 | -180 | -323 | -356 | -713 | 41 | -99 | -792 | -1287 | -1646 | -1296 | -2716 |
| Sac. River at Hood (cfs) | -3749 | -3706 | -4758 | -5342 | -8662 | -7029 | -3255 | -1536 | 449 | -2282 | -1208 | -1382 |
| Sac. River at Keswick (cfs) | -259 | -1848 | -2919 | -3725 | -3918 | -1980 | 1578 | 523 | 695 | -1358 | -428 | -197 |
| Sac. River at NCP (cfs) | -1478 | -3298 | -4734 | -5813 | -6151 | -3299 | 837 | 727 | 1299 | -566 | -698 | -793 |
| Feather River blw. Thermalito (cfs) | -40 | -230 | -1490 | -1217 | -1898 | -1448 | -862 | -391 | -580 | -974 | 272 | 256 |
| American River at Nimbus (cfs) | -996 | -137 | -81 | -461 | -1103 | -1595 | -1203 | -418 | 336 | -561 | -376 | -348 |
| American River at H.St (cfs) | -996 | -140 | -86 | -466 | -1110 | -1604 | -1211 | -428 | 336 | -537 | -356 | -332 |
| SJ River at Vernalis (cfs) | -515 | -642 | -1052 | -1217 | -1718 | -1832 | -2205 | -1816 | -840 | -701 | -557 | -398 |
| Shasta Storage (TAF) | -959 | -996 | -970 | -874 | -788 | -711 | -709 | -886 | -972 | -1038 | -971 | -962 |
| Folsom Storage (TAF) | -191 | -149 | -94 | -53 | -29 | -37 | -82 | -189 | -238 | -263 | -227 | -204 |
| Oroville Storage (TAF) | -450 | -478 | -474 | -397 | -349 | -329 | -373 | -476 | -502 | -493 | -422 | -429 |
| CVP San Luis Storage (TAF) | -3 | -60 | -86 | -72 | -64 | -63 | -32 | 15 | 62 | 87 | 69 | 24 |
| SWP San Luis Storage (TAF) | -196 | -239 | -202 | -140 | -73 | -45 | -3 | 30 | 5 | -35 | -78 | -95 |

**Table K-4.**
**Comparison of Average Monthly Values of CVP/SWP Operations between Warm-Wet and No CC Scenarios**

| No CC Scenario | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Delta Outflow (cfs) | 11282 | 23296 | 45282 | 50666 | 48877 | 37851 | 22265 | 11413 | 7197 | 4443 | 4473 | 5812 |
| Jones Pumping Plant (cfs) | 3582 | 3961 | 3170 | 3047 | 2804 | 1516 | 1241 | 3004 | 3789 | 3445 | 3862 | 2728 |
| Banks Pumping Plant (cfs) | 6064 | 4340 | 4169 | 4509 | 4884 | 1641 | 1232 | 3149 | 4857 | 3410 | 3566 | 6187 |
| Sac. River at Hood (cfs) | 15957 | 24143 | 34614 | 37660 | 40112 | 29534 | 18696 | 16073 | 16592 | 10873 | 9414 | 11191 |
| Sac. River at Keswick (cfs) | 4253 | 5719 | 8609 | 11307 | 12962 | 9225 | 7731 | 13585 | 12971 | 9580 | 5520 | 5422 |
| Sac. River at NCP (cfs) | 6488 | 11903 | 19266 | 22307 | 21325 | 13407 | 7030 | 6650 | 6668 | 4799 | 4648 | 5299 |
| Feather River blw. Thermalito (cfs) | 2656 | 3267 | 5680 | 6810 | 8474 | 6024 | 4341 | 4416 | 6943 | 3903 | 1477 | 2864 |
| American River at Nimbus (cfs) | 2765 | 3226 | 5518 | 5315 | 5378 | 4708 | 3525 | 3696 | 2462 | 1838 | 1485 | 1480 |
| American River at H.St (cfs) | 2494 | 2970 | 5272 | 5082 | 5151 | 4469 | 3252 | 3375 | 2101 | 1470 | 1135 | 1167 |
| SJ River at Vernalis (cfs) | 2557 | 2724 | 5231 | 6569 | 7482 | 8957 | 6822 | 4440 | 2930 | 2692 | 2553 | 2720 |
| Shasta Storage (TAF) | 2269 | 2368 | 2604 | 2956 | 3227 | 3369 | 3427 | 3442 | 2994 | 2567 | 2326 | 2313 |
| Folsom Storage (TAF) | 426 | 407 | 440 | 469 | 495 | 589 | 675 | 749 | 642 | 536 | 471 | 449 |
| Oroville Storage (TAF) | 1461 | 1531 | 1700 | 1949 | 2114 | 2267 | 2379 | 2401 | 2127 | 1716 | 1498 | 1504 |
| CVP San Luis Storage (TAF) | 273 | 395 | 570 | 689 | 769 | 821 | 768 | 630 | 491 | 346 | 247 | 274 |
| SWP San Luis Storage (TAF) | 439 | 619 | 701 | 813 | 863 | 908 | 789 | 587 | 449 | 388 | 270 | 255 |
| **Warm-Wet Scenario** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 17037 | 41762 | 81242 | 80532 | 70668 | 48340 | 25308 | 11774 | 8008 | 4474 | 5137 | 8256 |
| Jones Pumping Plant (cfs) | 4055 | 4205 | 3494 | 3557 | 3098 | 1699 | 1229 | 3348 | 4237 | 4014 | 4230 | 3443 |
| Banks Pumping Plant (cfs) | 6314 | 5045 | 4809 | 5701 | 6012 | 1908 | 1209 | 3492 | 5593 | 4306 | 4235 | 5850 |
| Sac. River at Hood (cfs) | 20761 | 34033 | 45503 | 45936 | 48517 | 34446 | 20009 | 16263 | 17953 | 11479 | 10526 | 13275 |
| Sac. River at Keswick (cfs) | 5544 | 9237 | 13852 | 15143 | 15381 | 10669 | 8139 | 13895 | 13516 | 9342 | 6005 | 5800 |
| Sac. River at NCP (cfs) | 8757 | 18115 | 29202 | 29751 | 26652 | 16313 | 8429 | 7521 | 7605 | 5055 | 5472 | 6269 |
| Feather River blw. Thermalito (cfs) | 3338 | 5289 | 11860 | 11671 | 11345 | 6924 | 4382 | 4273 | 6936 | 3873 | 1487 | 3315 |
| American River at Nimbus (cfs) | 3877 | 6419 | 9478 | 7589 | 6578 | 4671 | 3022 | 3146 | 2638 | 1955 | 1602 | 1823 |
| American River at H.St (cfs) | 3596 | 6154 | 9224 | 7348 | 6345 | 4426 | 2738 | 2812 | 2264 | 1573 | 1243 | 1501 |
| SJ River at Vernalis (cfs) | 3136 | 4787 | 11700 | 14652 | 14218 | 13212 | 8097 | 4782 | 3131 | 3026 | 2872 | 3169 |
| Shasta Storage (TAF) | 2636 | 2733 | 2952 | 3248 | 3479 | 3650 | 3735 | 3802 | 3373 | 2915 | 2694 | 2670 |
| Folsom Storage (TAF) | 492 | 465 | 490 | 509 | 519 | 612 | 691 | 729 | 646 | 574 | 526 | 514 |
| Oroville Storage (TAF) | 1741 | 1822 | 2037 | 2279 | 2423 | 2560 | 2680 | 2700 | 2430 | 2004 | 1797 | 1812 |
| CVP San Luis Storage (TAF) | 262 | 405 | 586 | 708 | 800 | 856 | 795 | 628 | 466 | 296 | 196 | 227 |
| SWP San Luis Storage (TAF) | 463 | 639 | 737 | 830 | 879 | 938 | 806 | 583 | 440 | 413 | 317 | 314 |
| **Change from No CC Scenario** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 5755 | 18465 | 35960 | 29866 | 21791 | 10488 | 3043 | 361 | 811 | 31 | 664 | 2444 |
| Jones Pumping Plant (cfs) | 473 | 244 | 324 | 510 | 294 | 183 | -12 | 344 | 447 | 569 | 368 | 715 |
| Banks Pumping Plant (cfs) | 250 | 705 | 640 | 1192 | 1128 | 267 | -23 | 342 | 736 | 897 | 669 | -336 |
| Sac. River at Hood (cfs) | 4804 | 9891 | 10889 | 8275 | 8406 | 4912 | 1313 | 190 | 1360 | 606 | 1112 | 2084 |
| Sac. River at Keswick (cfs) | 1290 | 3518 | 5243 | 3836 | 2419 | 1444 | 408 | 310 | 546 | -238 | 485 | 378 |
| Sac. River at NCP (cfs) | 2269 | 6212 | 9935 | 7444 | 5327 | 2907 | 1399 | 871 | 937 | 256 | 824 | 970 |
| Feather River blw. Thermalito (cfs) | 681 | 2023 | 6180 | 4860 | 2871 | 900 | 41 | -142 | -8 | -31 | 10 | 451 |
| American River at Nimbus (cfs) | 1113 | 3193 | 3960 | 2273 | 1200 | -37 | -503 | -550 | 177 | 117 | 117 | 343 |
| American River at H.St (cfs) | 1102 | 3184 | 3952 | 2266 | 1195 | -43 | -514 | -562 | 163 | 103 | 108 | 334 |
| SJ River at Vernalis (cfs) | 579 | 2062 | 6469 | 8083 | 6736 | 4255 | 1275 | 341 | 201 | 335 | 319 | 449 |
| Shasta Storage (TAF) | 367 | 365 | 348 | 292 | 252 | 280 | 307 | 361 | 379 | 347 | 368 | 357 |
| Folsom Storage (TAF) | 65 | 57 | 50 | 40 | 24 | 23 | 16 | -20 | 4 | 37 | 55 | 65 |
| Oroville Storage (TAF) | 280 | 291 | 337 | 330 | 309 | 293 | 300 | 299 | 304 | 288 | 299 | 308 |
| CVP San Luis Storage (TAF) | -11 | 10 | 15 | 19 | 31 | 35 | 27 | -2 | -25 | -49 | -50 | -48 |
| SWP San Luis Storage (TAF) | 24 | 20 | 36 | 17 | 15 | 30 | 17 | -3 | -9 | 26 | 47 | 59 |

Table K-2 compares average monthly results for the Central Tendency scenario as compared to the No CC scenario. Under the Central Tendency scenario, Delta outflow is higher by approximately 1.2 million acre-feet per year than under the No CC scenario. The majority of the increase in Delta outflow occurs from November through January, in part due to the shift in the timing of runoff in the Central Tendency scenario. During the months of March, April, May, and August, Delta outflow is reduced under the Central Tendency scenario. Total Delta exports decrease by nearly 150 thousand acre-feet under

the Central Tendency scenario as compared to the No CC scenario. In some months, the river flows are greater and in other months they are lower under Central Tendency as compared to the No CC scenario. River flows in the Sacramento basin show consistent average monthly increases from November through January. Average monthly flow of the San Joaquin River at Vernalis increases from November through March. Overall, on an average annual basis, Sacramento River flows and San Joaquin River flows increase by approximately 300 cfs under Central Tendency scenario as compared to the No CC scenario. Combined North-of-Delta (NOD) upstream reservoir carryover storage at the end-of-September under the Central Tendency scenario is lower by nearly 400 thousand acre-feet as compared to the No CC scenario.

Table K-3 summarizes similar results for the Hot-Dry scenario. This scenario is the driest scenario in terms of water supply with the greatest reduction in Delta exports and Delta outflows relative to the No CC scenario. Delta outflows decrease by nearly 3 million acre-feet per year and Delta exports decrease by 1.2 million acre-feet per year as compared to the No CC scenario. Decrease in exports could result in increased potential for transfers to SLDMWA under Hot-Dry scenario. Reductions in average monthly Delta outflows occur from October through May, with the highest reduction in February. Under the Hot-Dry scenario, river flows and reservoir storages are consistently lower when compared to the No CC scenario. On an average annual basis, Sacramento River flows at Hood decrease by nearly 3,500 cfs as compared to the No CC scenario. Average annual flow in the San Joaquin River at Vernalis is reduced by nearly 1,100 cfs under the Hot-Dry scenario. Combined carryover storage (end of September) in Shasta, Folsom, and Oroville is reduced by nearly 1.6 million acre-feet under the Hot-Dry scenario. San Luis reservoir carryover storage is reduced by approximately 70 thousand acre-feet under the Hot-Dry scenario as compared to the No CC scenario, though the reduction occurs only in the SWP portion of San Luis Reservoir while the CVP portion has higher average carryover storage.

Table K-4 presents results for the Warm-Wet scenario as compared against the No CC scenario. The Warm-Wet scenario is the wettest scenario with increased reservoir storage, river flows, and Delta exports. Delta outflow increases by an average of nearly 7.8 million acre-feet per year and exports increase by nearly 660 thousand acre-feet per year. It is noted that Delta exports under the Warm-Wet scenario increase by only a fraction of the increase in Delta outflow indicating increases in Delta inflow occur primarily during periods when only a small fraction can be diverted under existing regulatory requirements and with existing infrastructure. River flows are higher in most months in the Sacramento basin. On an average annual basis, Sacramento River flow at Hood is nearly 4,500 cfs higher under Warm-Wet scenario as compare to the No CC scenario. San Joaquin River flow at Vernalis is higher in all months, with average annual flows higher by nearly 2,600 cfs under the Warm-Wet scenario. San Luis Reservoir storage does not change significantly under the Warm-Wet scenario, in part due to the relatively modest increase in Delta exports.

## K.4.1 Transient Change

To help understand how climate change will vary temporally in the future, Figure K-6 is presented which shows the annual mean temperature and precipitation changes for California and Nevada derived from the central quadrant (Central Tendency climate scenario). Projected changes for the future periods 2011-2040 (2025 centering), 2041-2070 (2055 centering), and 2070-2099 (2084 centering) are compared to the historical climatological period of 1981-2010. Changes in climate are less dramatic in the first 30 years with substantial warming expected to occur by 2050 and more severe effects by the end of the 21st century.

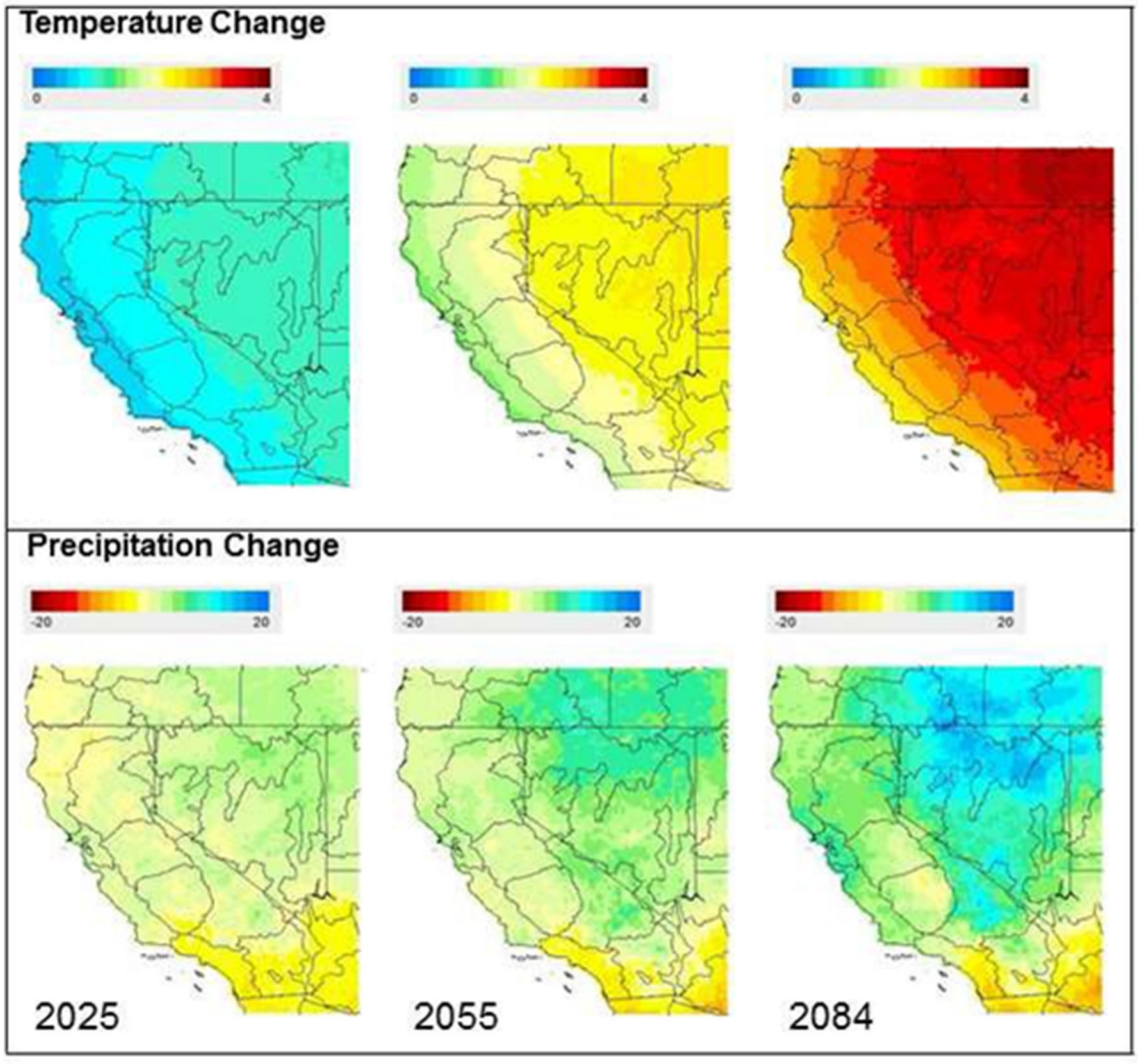



**Figure K-6.**
**Projected changes in annual mean temperature and precipitation for 2011-2040 (2025), 2041-2070 (2055) and 2070-2099 (2084).**

To illustrate how the transient change in climate and may affect CVP/SWP operations, reservoir carryover storage and Delta exports were analyzed over the three different future periods. Figures K-7 through K-9 show changes in north of Delta CVP/SWP reservoir carryover storage from the CalLite-CV model under the three future periods of 2025, 2055 and 2084. These figures generally show an increased range of potential carryover storage (greater differences between Warm-Wet and Hot-Dry scenario results) at the end of the 21st century (Figure K-9) as compared to the first 30 years (Figure K-7).

Figures K-10 through K-12 show similar effects of this transient change of climate on Delta exports based on results from CalLite-CV models. The range or the difference in Delta exports between the extreme climate change scenarios are greater with time and are more pronounced at the end of the 21st century than the beginning.

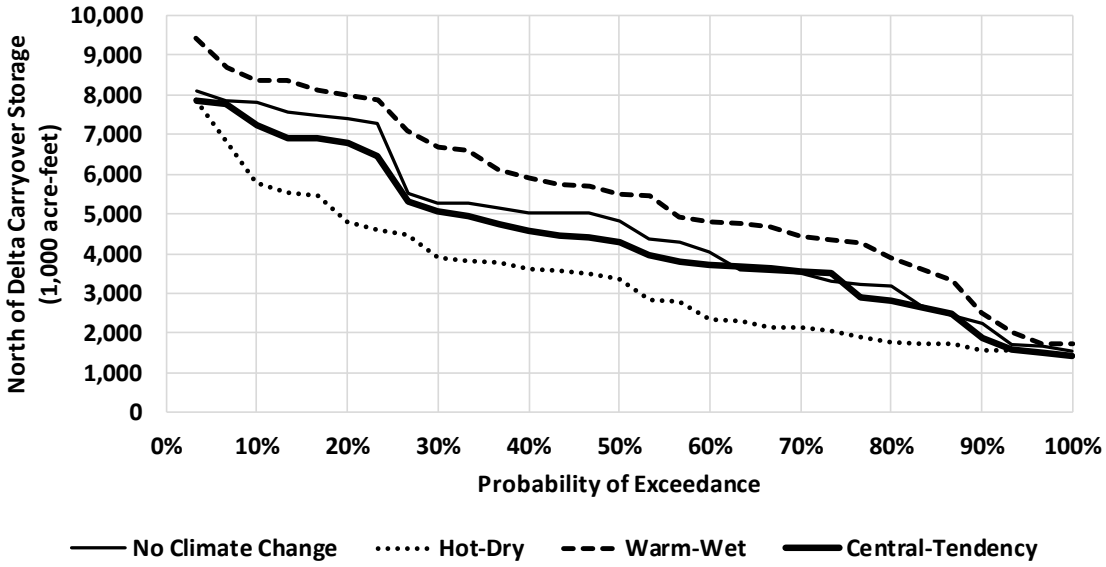



**Figure K-7.**
**North of Delta Carryover Storage (Trinity, Folsom, Shasta and Oroville) (2015-2044)**

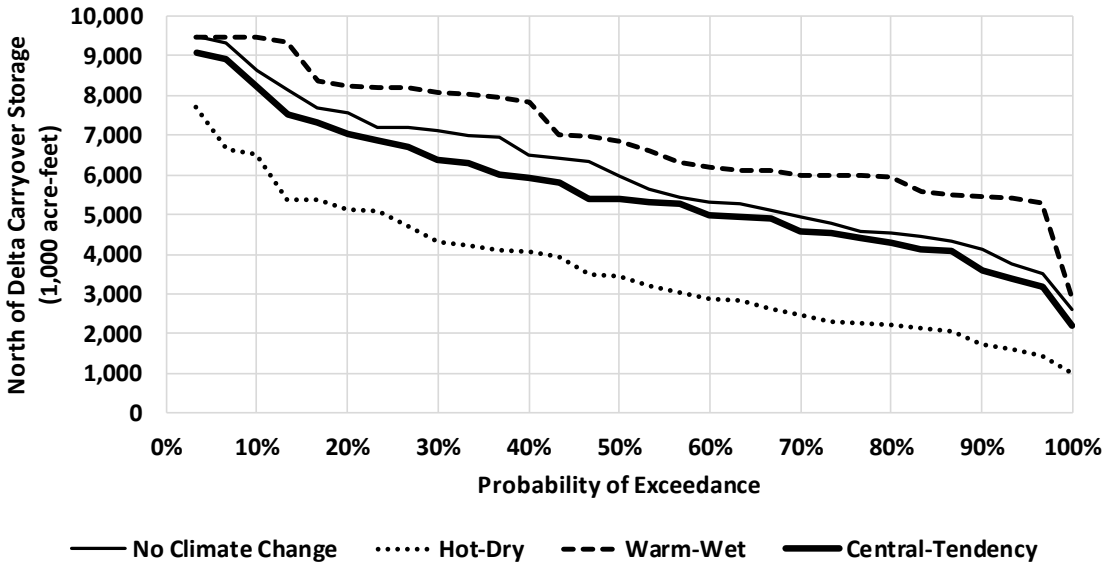



**Figure K-8.**
**North of Delta Carryover Storage (Trinity, Folsom, Shasta and Oroville)**
**(2045-2074)**

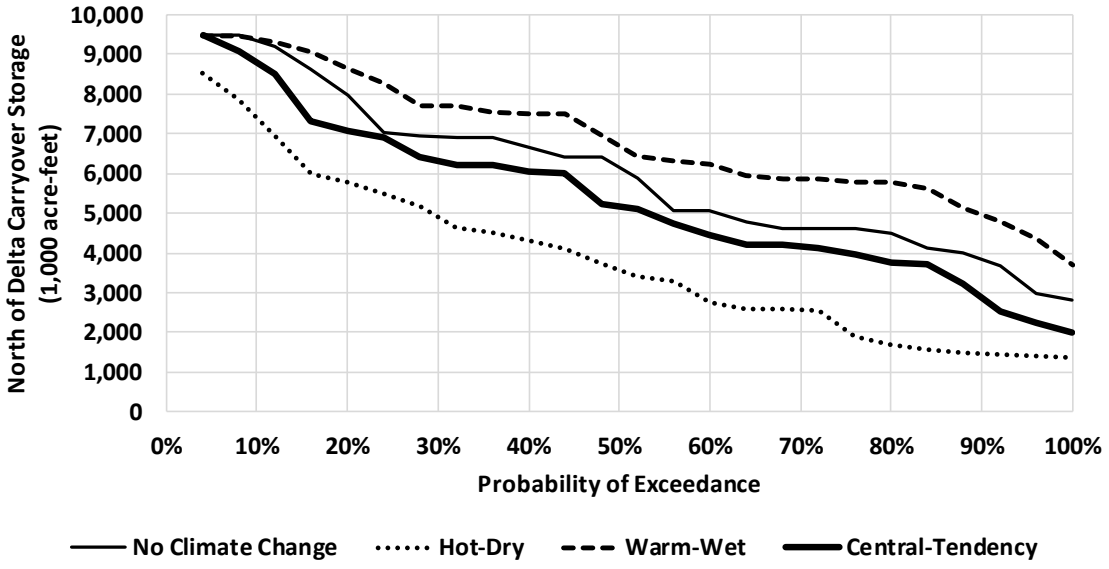



**Figure K-9.**
**North of Delta Carryover Storage (Trinity, Folsom, Shasta and Oroville)**
**(2075-2099)**

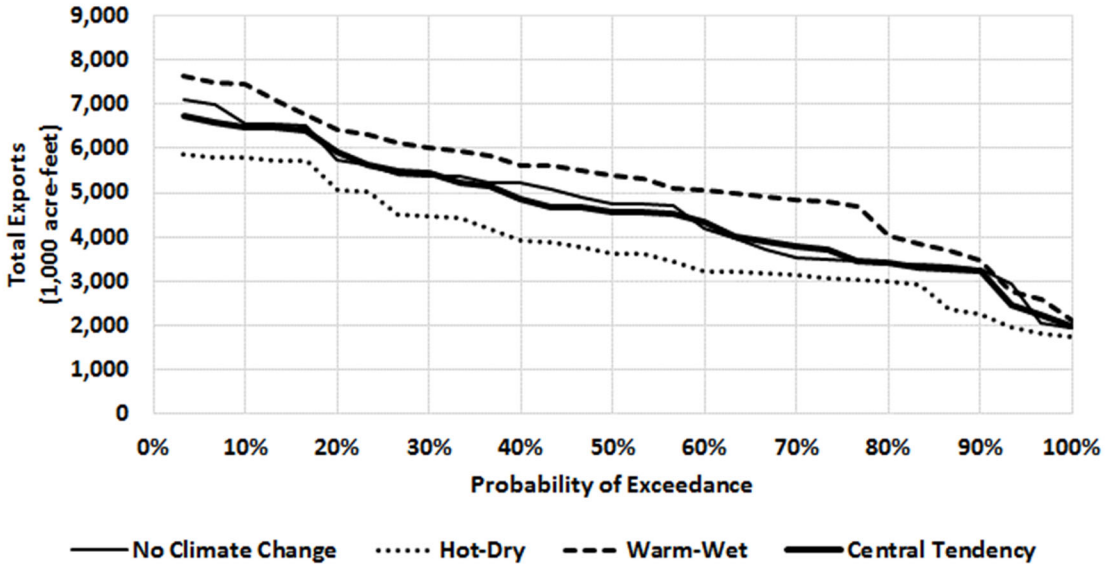



**Figure K-10.**
**Annual Exports (Jones and Banks) (2011-2044)**

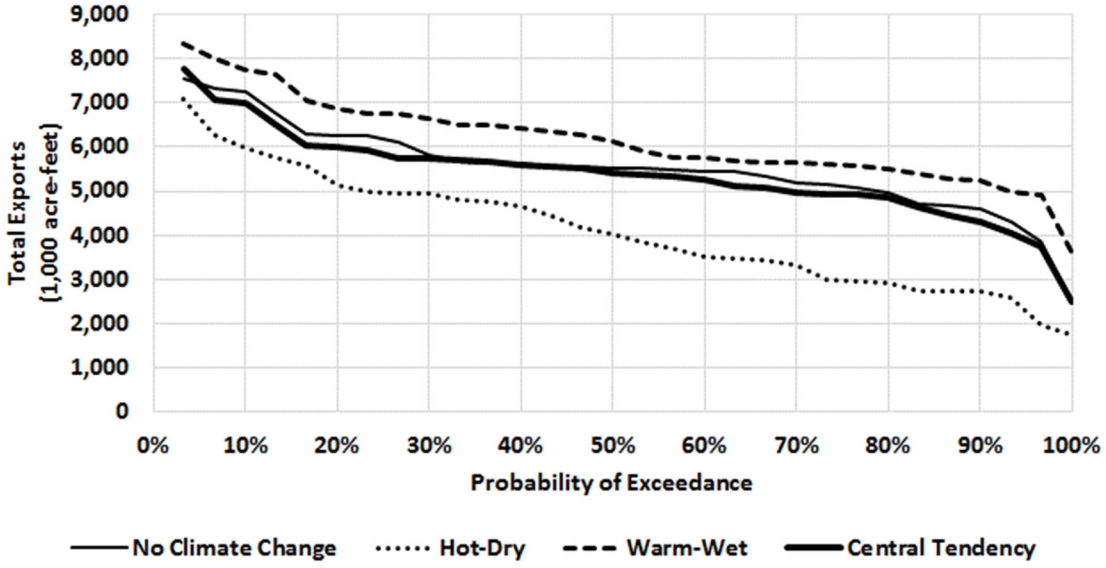



**Figure K-11.**
**Annual Exports (Jones and Banks) (2045-2074)**

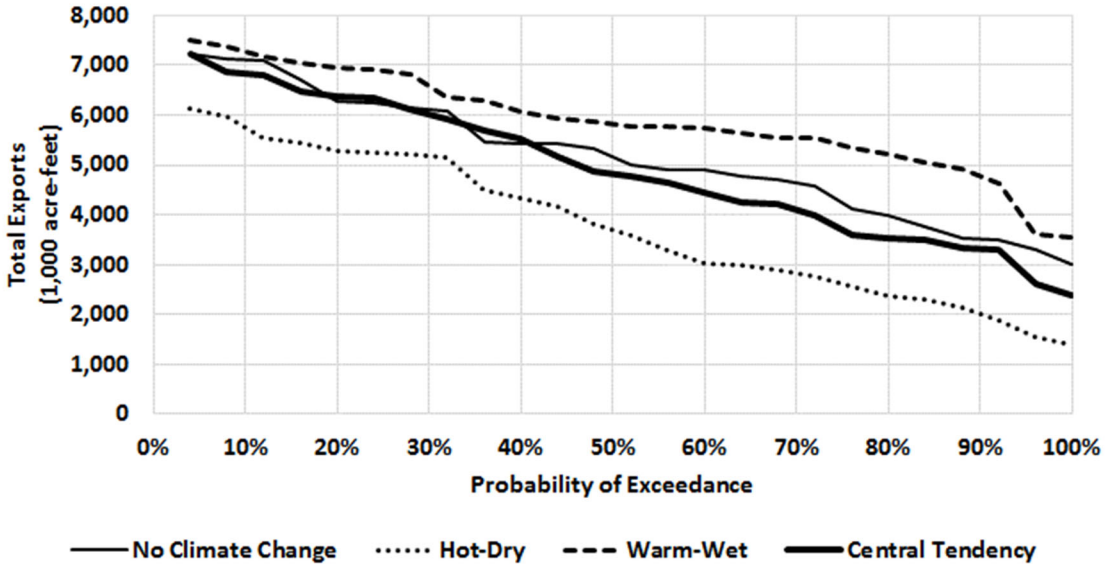



**Figure K-12.**
**Annual Exports (Jones and Banks) (2075-2099)**

# K.5 Effects on Long-Term Water Transfers

## K.5.1 Methods and Assumptions

This section summarizes the methods used in the assessment of climate change effects on long-term water transfers. This climate change analysis relies upon information and technical analyses developed as part of the Basins Study. CalLite-CV model results from the Basins Study were used to quantify the potential effects of future uncertainties related to climate change on water transfers. In addition to the effects of climate change on transfers, an additional assumption was made to limit the annual volume of demand for transfer water to 250,000 acre-feet. This assumption reduces the total volume of transfers that would occur from the volumes analyzed for the 2014 Draft EIS/EIR.

As stated earlier, this climate change analysis focuses on three of the five scenarios, the Central Tendency, Warm-Wet, and Hot-Dry scenarios to evaluate the effects on long-term water transfer supply and demand. The following section presents a detailed description of the methods applied in developing the transfer demands and supply under the climate change scenarios using model results from the Basins Study.

## K.5.2 Transfer Demand

San Luis & Delta-Mendota Water Authority (SLDMWA) demand for transfer water was assumed to be equal to estimated available Delta export capacity and was calculated by post-processing Basins Study CalLite-CV results. This is the same assumption and approached used in the 2014 Draft EIS/EIR when available Delta export capacity was calculated by post-processing CalSim II results. Demand for transfer water from East Bay Municipal Utility District (EBMUD) and Contra Costa Water District (CCWD) were assumed to be the same as analyzed in the 2014 Draft EIS/EIR. For the 2014 Draft

EIS/EIR, EBMUD and CCWD performed independent modeling to assess their transfer demand under the current conditions without climate change. EBMUD and CCWD did not perform additional modeling of their respective systems with climate change.

### K.5.3 Transfer Supply

Water is made available for transfer by one of four different methods: reservoir release of stored water, water conservation, groundwater substitution, and crop idling. The following sections describe methods used to estimate the available transfer supply for the climate change assessment for each transfer supplier.

### K.5.4 Reservoir Release

Several different sellers that proposed to make water available through reservoir release were analyzed in the EIS/EIR. The following sections describe assumptions for the climate change analysis for each seller.

Estimates of stored water available from Merced Irrigation District (MID) were based on end-of-October Lake McClure storage results from CalLite-CV models. It was assumed MID would make water available when simulated end-of-October storage exceeded 300 thousand acre-feet, and may make water available at lower carryover storage levels depending on prior year transfers.

Stored water releases from Browns Valley Irrigation District (BVID), South Sutter Water District (SSWD), and Nevada Irrigation District (NID) were based on simulated inflow into New Bullards Bar Reservoir on the Yuba River from CalLite-CV models. Each of these districts receives water supply from the Yuba River and adjacent watersheds such as Dry Creek (BVID) and the Bear River (NID and SSWD). Yuba River flow was used as a surrogate for the available transfer supply from these three districts.

Available transfer supply from Placer County Water Agency (PCWA) was estimated using monthly inputs of inflows into Folsom Lake from the CalLite-CV models. It was assumed PCWA would make more water available for transfers when there is less water available in the American River Basin, similar to analysis in the EIS/EIR and their agreement under the Water Forum. Simulated inflow to Folsom was assumed to be a surrogate for unimpaired March through November runoff at Folsom.

### K.5.5 Conserved Water

Conserved water from BVID is available in all years under current conditions and with climate change.

### K.5.6 Groundwater Substitution

Groundwater substitution supply was dependent on available surface water supply to some sellers participating in groundwater substitution transfers. These sellers identified that during years when they experience a reduced surface water supply, it would subsequently limit groundwater substitution transfers.

Water shortage years varied for different sellers. Sacramento River Settlement Contractors have shortages in CVP supplies during Shasta Critical years. In this climate change assessment, Shasta Critical years under the different climate change scenarios were determined based on CalLite-CV model inputs of hydrologic indices. Similar logic was used in the computation of years when Feather River Settlement Contractors' Feather River supplies would be curtailed based on CalLite-CV model hydrologic indices.

Groundwater substitution supplies from Yuba River contractors were based on simulated end-of-September storage in New Bullards Bar reservoir as a surrogate for when Yuba River surface water supplies may be limited.

CalLite-CV model inputs of Folsom Lake inflow were used to determine transfer water supply from Sacramento Suburban Water District under the different climate change scenarios. It was assumed that Sacramento Suburban Water District would only make groundwater substitution transfers in years when they have available surface water supplies. These years are generally when the March through November inflow to Folsom Lake exceeds 1.6 million acre-feet.

### K.5.7 Crop Idling Supply

Assumptions for available crop idling transfer supply were based on similar triggers as groundwater substitution transfers to determine the volume of transfer supply. Crop idling sellers include some Sacramento and Feather river settlement contractors whose identified volumes of crop idling transfers based on their contract criteria. Other sellers propose to make the same volume of water available in all years and were analyzed with this assumption for the climate change assessment.

## K.6 Results

This section presents results from climate change analysis along with EIS/EIR modeling results adjusted to reflect the 250 thousand acre-feet annual limit on total water transfer demands.

### K.6.1 EIS/EIR

Figures K-13 and K-14 show the water transfer demand and supply based on EIS/EIR modeling results. Based on the modeling performed for EIS/EIR, water transfer occurs during 13 years out of 34 years (38 percent) with an annual average transfer demand of 75 thousand acre-feet and an annual average transfer supply of 88 thousand acre-feet. Nearly 80 percent of the transfer demand comes from SLDMWA. Nearly 70 percent of the total water transfer demands are met by groundwater substitution followed by stored water release, which provides nearly 16 percent of the total demand for transfer.

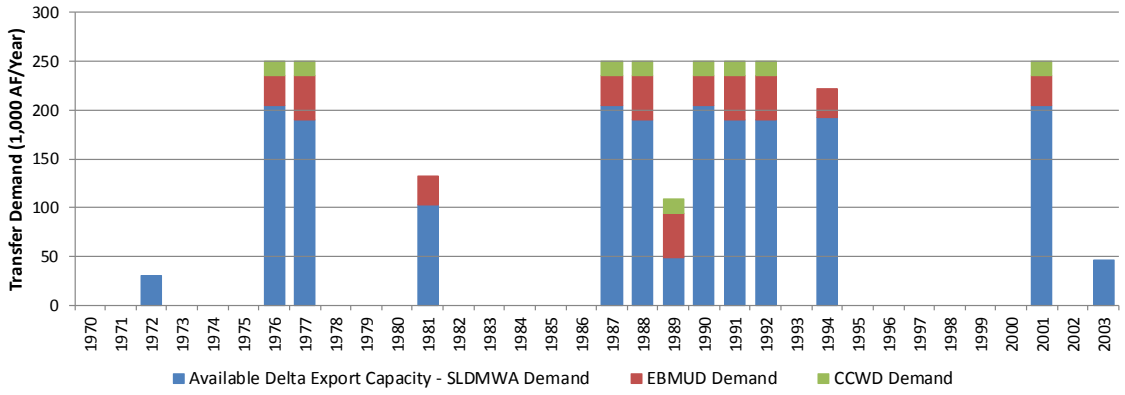



**Figure K-13.**
**Annual Demand for Transfer Water by CVP Buyers (EIS/EIR)**

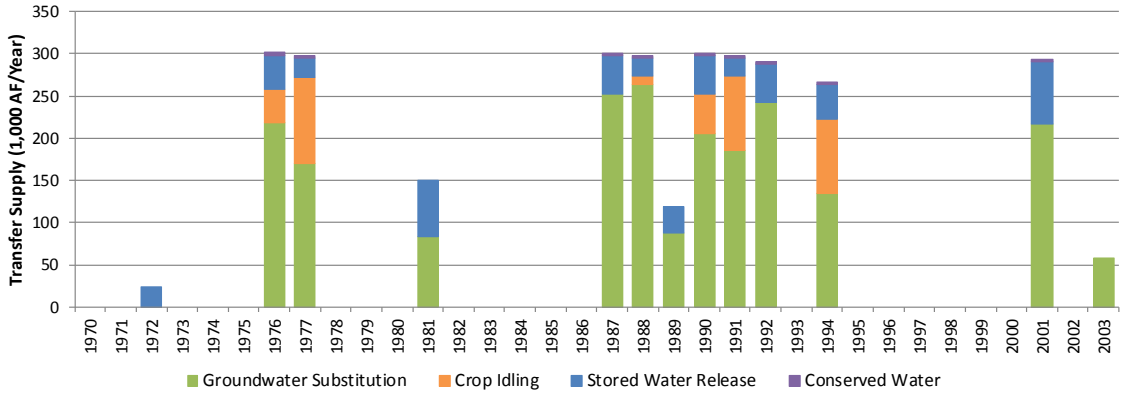



**Figure K-14.**
**Annual Available Water Transfer Supply (EIS/EIR)**

## K.6.2 Basins Study with No Climate Change Scenario

Figures K-15 and K-16 show the water transfer demand and supply based on CalLite-CV modeling results from the No Climate Change scenario from the Basins Study. Water transfers under the No Climate Change scenario occurs for 15 years out of 34 years (44 percent) with an average transfer demand of 61 thousand acre-feet/year and an average transfer supply of 71 thousand acre-feet/year. Even though this scenario does not include any climate change assumptions and contains assumptions like the EIS/EIR, the results are different between the two scenarios. EIS/EIR results are based on CalSim II whereas this scenario uses CalLite-CV. The No Climate Change scenario results show a slightly greater frequency of water transfers as compared to the EIS/EIR which may be due to differences in CVP/SWP operations between CalLite-CV and CalSim II and other foundational differences in these models.

The climate change results from CalLite-CV models present a high-level summary of climate change effects and the results must be understood in light of the different

assumptions built in the post-processing method. This climate change assessment using CalLite-CV model results is similar to the EIS/EIR, which was based on CalSim II modeling, but not exactly the same. Therefore, results of the climate change analyses based on CalLite-CV, and results in the EIS/EIR based on CalSim II, should not be compared. Results from the CalLite-CV model are not directly comparable with CalSim II results due to differences in the models. CalSim II is a more detailed model than CalLite-CV and includes fewer simplifying assumptions. CalSim II results were more thoroughly reviewed and validated as compared to CalLite-CV modeling which was performed at a higher level to understand more generalized potential effects of climate change on CVP/SWP operations.

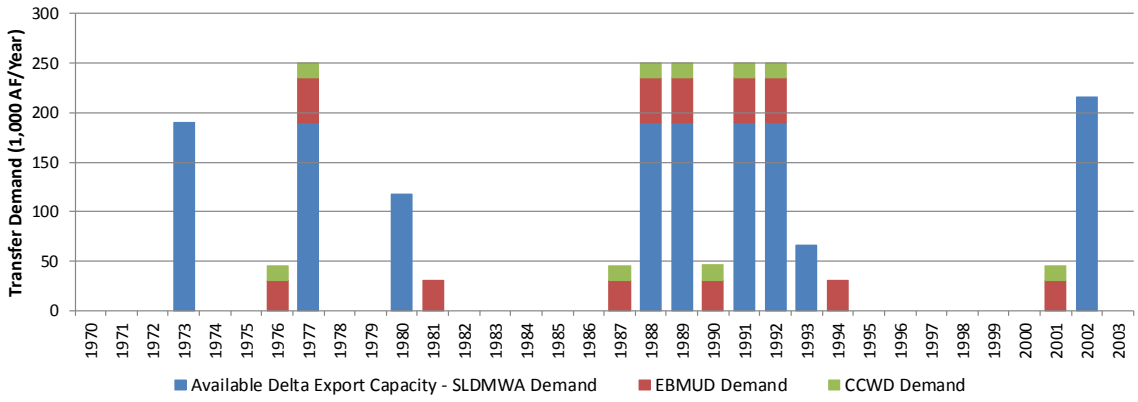



**Figure K-15.**
**Annual Demand for Transfer Water by CVP Buyers (No Climate Change)**

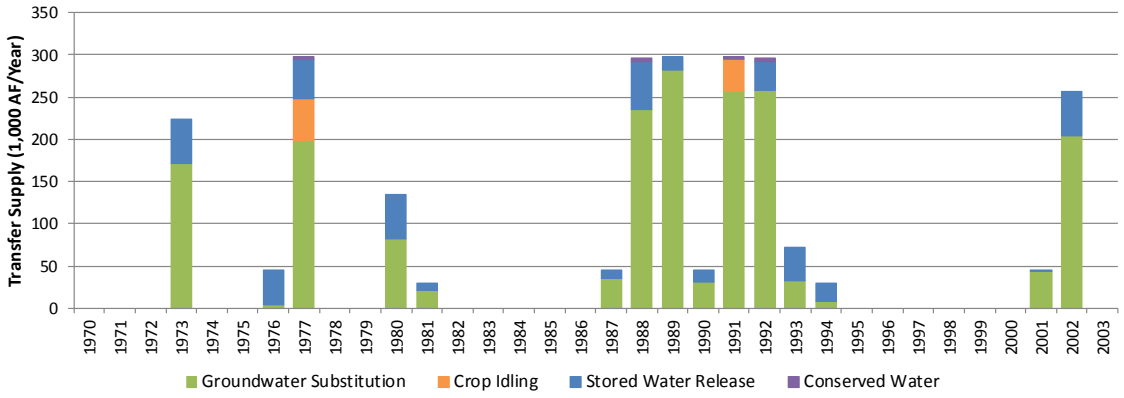



**Figure K-16.**
**Annual Available Water Transfer Supply (No Climate Change)**

### K.6.3 Hot-Dry Scenario

The Hot-Dry scenario has the lowest total water supply among the scenarios (see Figures K-4 and K-5) and thus the lowest CVP and SWP water supply allocations to water users. Lower allocations to South of Delta water users means higher availability of export capacity in the Delta to transfer water which is demonstrated in Figure K-17. Figure K-

17 shows 22 years when water transfers could occur under this climate change scenario with average water transfer demand of 121 thousand acre-feet/year and average water transfer supply of 144 thousand acre-feet/year, the highest among the climate change scenarios.

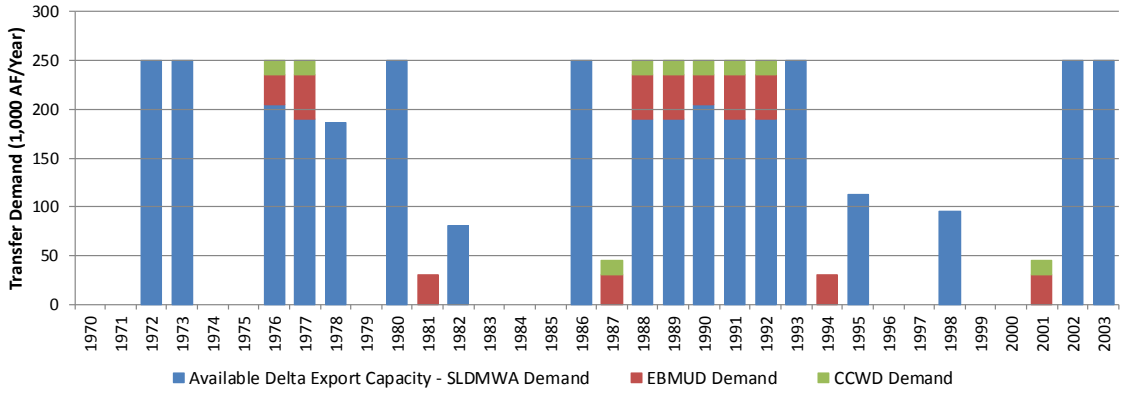



**Figure K-17.**
**Annual Demand for Transfer Water by CVP Buyers (Hot-Dry)**

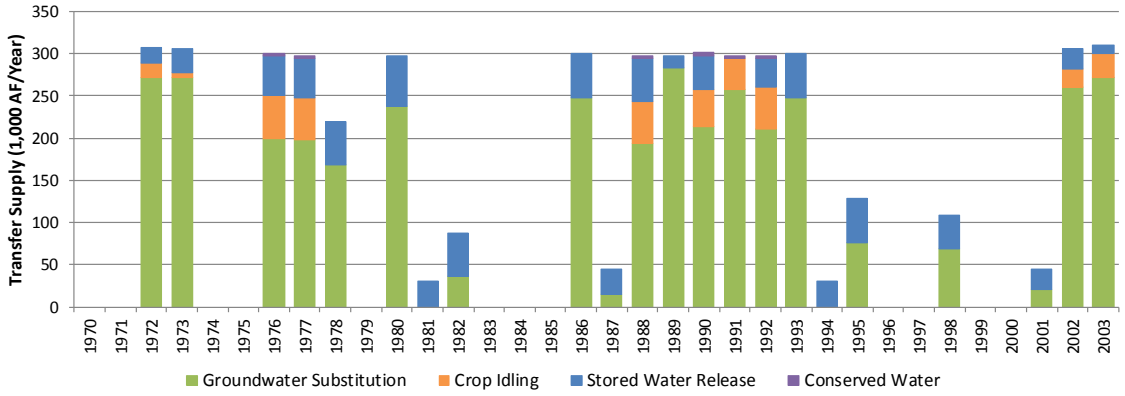



**Figure K-18.**
**Annual Available Water Transfer Supply (Hot-Dry)**

## K.6.4 Warm-Wet Scenario

The Warm-Wet scenario is the wettest scenario evaluated with the largest water supply, CVP/SWP allocations, and highest Delta exports of CVP/SWP supplies. Figure K-19 and K-20 show how the transfer demand and supply are lowest in this scenario, primarily driven by unavailability of export capacity in the Delta. Figure K-19 shows 12 years when transfers could occur under this climate change scenario with average water transfer demand of 24 thousand acre-feet/year and average water transfer supply at 26 thousand acre-feet/year, the lowest among the scenarios.

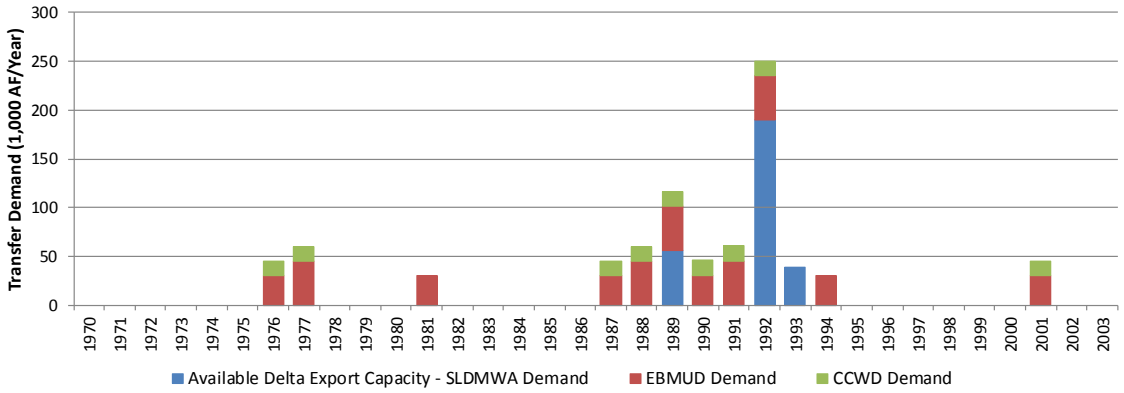



**Figure K-19.**
**Annual Demand for Transfer Water by CVP Buyers (Warm-Wet)**

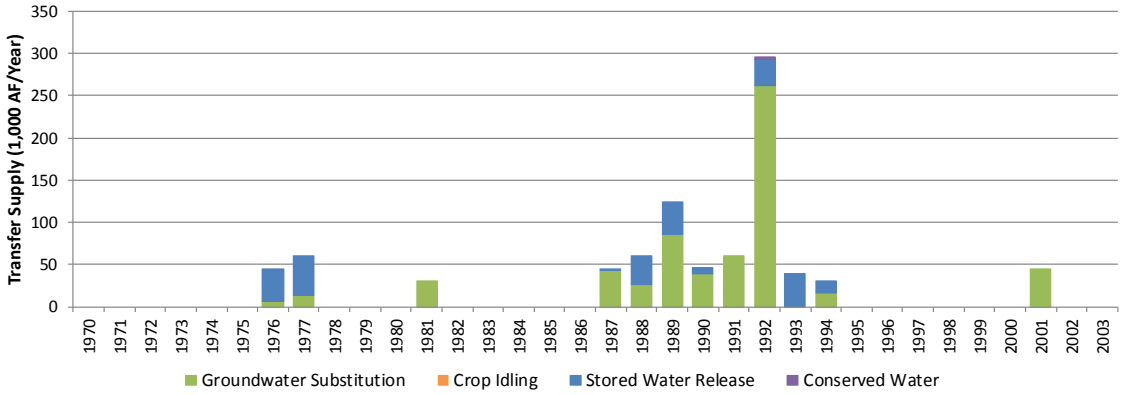



**Figure K-20.**
**Annual Available Water Transfer Supply (Warm-Wet)**

## K.6.5 Central Tendency Scenario

Figures K-21 and K-22 present water transfer demand and supply under the Central Tendency climate change scenario. Results indicate the average annual demand and supply are nearly identical to EIS/EIR results, but the frequency of transfers are greater compared to the EIS/EIR.

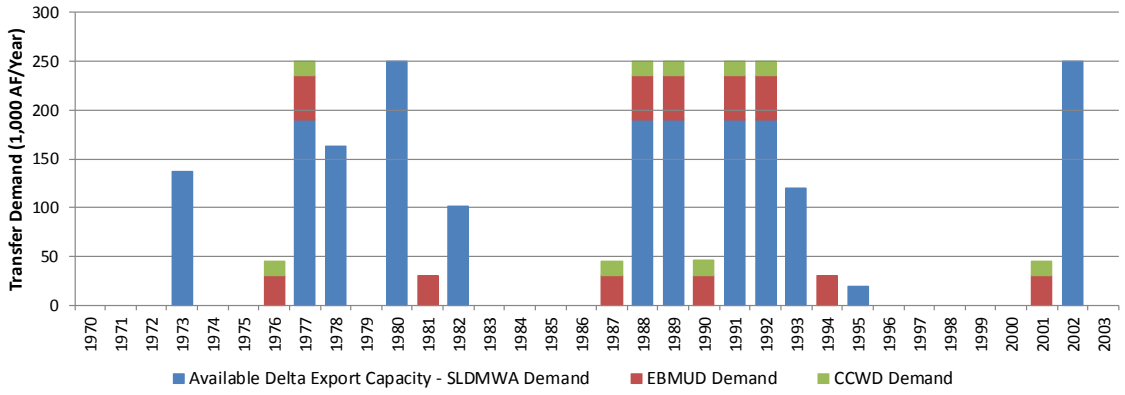



**Figure K-21.**
**Annual Demand for Transfer Water by CVP Buyers (Central Tendency)**

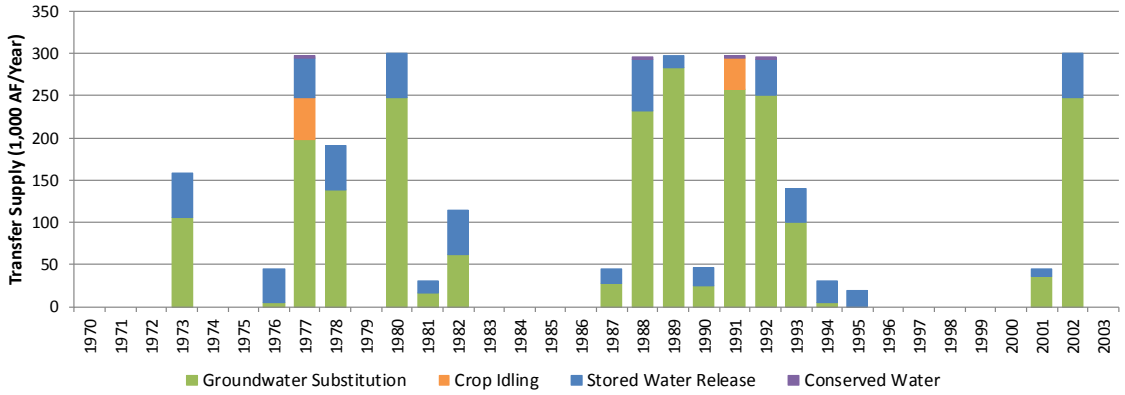



**Figure K-22.**
**Annual Available Water Transfer Supply (Central Tendency)**

Table K-5 provides a summary of the annual average transfer demand, supply, and the number of years when transfers may occur within the 34-year period of analysis. Results summarized in Table K-5 show climate change may create considerable variability in the annual average volume of transfers that may occur. The Hot-Dry climate changed condition results in the highest demand and frequency for transfers, while the Warm-Wet condition has the lowest demand and frequency.

**Table K-5.**
**Summary of Transfer Demand, Supply, and Frequency for Assumptions on Maximum Annual Demand and Climate Change**

| | Annual Average Demand(1,000 acre-feet) | Annual Average Transfer Supply (1,000 acre-feet) | Years with Potential Transfers |
|---|---|---|---|
| EIS/EIR[1] | 75 | 88 | 13 |
| No Climate Change | 61 | 71 | 15 |
| Hot-Dry | 121 | 144 | 22 |
| Warm-Wet | 24 | 26 | 12 |
| Central Tendency | 75 | 87 | 18 |

[1] Water transfer demands limited to 250 thousand acre-feet/year and thus different from results presented in EIR/EIS

Climate change assessment results show there are adequate transfer supplies available from the four different methods analyzed for making water available for transfer (groundwater substitution, crop idling, stored water release, and conserved water). Annual average transfer supply exceeds demand in all scenarios to account for the additional water needed to convey transfers across the Delta, for those transfers exported from the Delta.

### K.6.6 Results Interpretation

The following points should be considered in the interpretation of the reported results of climate change effects on water transfers.

- Modeling completed for the Basins Study included predicted climate change over the course of the next century, including increased effects of climate change through time, i.e. the effects of climate change are more pronounced at the end of the century than at the beginning.

- Modeling performed for the Basins Study estimated the effects of climate change by perturbing the historical hydrology. Historical hydrology covered the period from water year (WY) 1926 through 2010 with 1926 historical hydrology representing the first year of simulation, 2015.

- Analysis conducted for the EIS/EIR was based on the historical hydrology for the period of WY 1970 through 2003. This period was selected because it represented the period of overlapping simulation for the SACFEM2013 and CalSim II models and covered a period of the historical hydrology that included the range of hydrology that might be expected over the period of the project.

- For this analysis, a consistent 34-year period of the historical hydrology (WY 1970 through 2003) was selected to be consistent with the EIS/EIR, and climate changed hydrology for the same historical period. This results in an analysis of mid to late-century climate change effects being imposed on the historical, WY 1970 through 2003 period as this period translates to WY 2059 through 2092 in modeling performed for the Basins Study. Therefore, the effects of climate change illustrated in these results is more than what the Basins Study would

indicate should be expected over the next decade. In this way the effects of climate change on transfers is likely overstated.

- Annual average demand for transfer water was estimated based on post-processing of Basins Study CalLite-CV results to estimate available Delta export capacity as a surrogate for SLDMWA demand for transfer water.

- Demand for transfer water from EBMUD and CCWD with climate change were assumed to be the same as analyzed in the EIS/EIR. These demands for transfer water were based on independent modeling conducted by EBMUD and CCWD.

- The estimates of available export capacity from CalLite-CV modeling results are coarse as compared to CalSim II and thus require interpretation of results. The available export capacity and the transfer demands vary under the climate change scenarios depending on CVP and SWP allocations and several other discretionary operating criteria used to operate the CVP and the SWP. Allocations and discretionary operating criteria in Basins Study CalLite-CV models also are coarse.

- Basins Study models are not exact predictions of how Reclamation and DWR may operate the CVP/SWP in the future, particularly a future where the effects of climate change may result in significant differences in the available water supply. Basins Study models have not been refined to include operational and regulatory adaptation that may occur because of changes in demands, water supply, and the timing of runoff within different basins.

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# Appendix L

# Regulatory Setting

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# Appendix L
# Regulatory Settings

Applicable groundwater related regulatory settings are described below in Section L.1, Groundwater. All water transfers will have to comply with applicable regulations: State regulations; Central Valley Project (CVP) and State Water Project (SWP) contractual requirements; and local regulations, as described below. Section L.2, Biological Resources, describes laws, rules, regulations and policies that apply to the natural communities, common plants and wildlife, fisheries, and special-status species that occur within the area of analysis. Climate change is governed by several federal and state laws and policies described in Section L.3.

## L.1 Groundwater

### L.1.1 Federal Regulation

***Central Valley Project Improvement Act (Section 3405)***

Reclamation approves water transfers consistent with provisions of the Central Valley Project Improvement Act (CVPIA) and State law that protect against injury to other legal users of water. According to the CVPIA Section 3405, the following principles must be satisfied for any transfer:

- Transfer may not violate the provisions of Federal or state law;
- Transfer may not cause significant adverse effects on Reclamation's ability to deliver CVP water to its contractors or other legal user;
- Transfer will be limited to water that would be consumptively used or irretrievably lost to beneficial use;
- Transfers cannot exceed the average annual quantity of water under contract actually delivered; and
- Transfer will not adversely affect water supplies for fish and wildlife purposes.

Reclamation will not approve a water transfer if these basic principles are not satisfied and will issue its decision regarding potential CVP transfers in coordination with the U.S. Fish and Wildlife Service (USFWS), contingent upon the evaluation of impacts on fish and wildlife.

### L.1.2 State Regulation

Groundwater use is subject to limited statewide regulation; however, all water use in California is subject to constitutional provisions that prohibit waste and unreasonable use of water (State Water Resources Control Board [SWRCB] 1999). In general, groundwater and groundwater-

related transfers are subject to a number of provisions in the California Water Code (Water Code). Some of these provisions are listed below.

***Water Code (Section 1745.10)***

Section 1745.10 of the Water Code requires that for water transfers pursuant to Sections 1725[1] and 1735[2], the transferred water may not be replaced with groundwater unless the following criteria are met (SWRCB 1999):

- The transfer is consistent with applicable Groundwater Management Plans (GMPs); or
- The transferring water supplier approves the transfer and, in the absence of a GMP, determines that the transfer will not create, or contribute to, conditions of long-term overdraft in the groundwater basin.

***Water Code (Section 1220)***

Section 1220 of the Water Code regulates the direct export of groundwater from the combined Sacramento and Delta-Central Sierra Basins. It states that groundwater cannot be exported from these basins unless pumping complies with a GMP, adopted by the county board of supervisors in collaboration with affected water districts, and approved by a vote from the counties that lie within the basin. This excludes water seepage into groundwater from water supply project or export facilities, which may be returned to the facilities. In certain cases, the county board of supervisors may select a county water agency to represent the board.

In addition to these requirements, state well standards and local ordinances govern well placement, and the Water Code requires submission of well completion reports. Any groundwater substitution transfers would be subject to these regulations, as well as other applicable local regulations and ordinances. Reclamation requires sellers to submit well completion reports (if they are available) or video logs to evaluate proposed groundwater substitution transfers. Groundwater substitution transfers are not contingent on the submission of well completion reports.

***Water Code (Section 1810) "no injury" provisions***

Several provisions of the Water Code (including Sections 1702, 1706, 1725, 1735, and 1810, among others) provide that transfers cannot cause "injury to any legal user of the water involved." Both surface and groundwater users are protected by these provisions as long as they are legal users of water.

***Water Code (Section 10750) or Assembly Bill (AB) 3030***

AB 3030, commonly referred to as the Groundwater Management Act, permits local agencies to develop GMPs that cover certain aspects of management. Subsequent legislation has amended

[1] Section 1725 of the Water Code pertains to short-term/temporary transfers of water under post 1914 water rights that involve the amount of water that would have been consumptively used or stored by the transferee in the absence of the change or transfer. Such changes or transfers are exempt from CEQA, but require findings of "no injury to other legal users" and "no unreasonable effects on fish and wildlife."

[2] Section 1735 of the Water Code pertains to long-term transfers of water or water rights involving a change of point of diversion, place of use, or purpose of use. A transfer is considered long-term if it exceeds a period of one year.

this chapter to make the adoption of a management program mandatory if an agency is to receive public funding for groundwater projects, creating an incentive for the development and implementation of plans.

***Water Code (Section 10753.7) or Senate Bill (SB) 1938***

SB 1938, requires local agencies seeking State funds for groundwater construction or groundwater quality projects to have the following: (1) a developed and implemented GMP that includes basin management objectives[3] (BMOs) and addresses the monitoring and management of groundwater levels, groundwater quality degradation, inelastic land subsidence, and surface water/ groundwater interaction; (2) a plan addressing cooperation and working relationships with other public entities; (3) a map showing the groundwater subbasin the project is in, neighboring local agencies, and the area subject to the GMP; (4) protocols for the monitoring of groundwater levels, groundwater quality, inelastic land subsidence, and groundwater/surface water interaction; and (5) GMPs with the components listed above for local agencies outside the groundwater subbasins delineated by the Department of Water Resources' (DWR) California's Groundwater Bulletin 118 (Bulletin 118), published in 2003 (DWR 2003).

***Water Code (Section 10920-10936 and 12924) or SB X7 6***

SB X7 6, established a voluntary statewide groundwater monitoring program and requires that groundwater data collected be made readily available to the public. The bill requires DWR to: (1) develop a statewide groundwater level monitoring program to track seasonal and long-term trends in groundwater elevation; (2) conduct an investigation of the state's groundwater basins delineated by Bulletin 118 and report its findings to the Governor and Legislature no later than January 1, 2012 and thereafter in years ending in five or zero; and (3) work cooperatively with local Monitoring Entities to regularly and systematically monitor groundwater elevations to demonstrate seasonal and long-term trends. AB 1152, Amendment to Water Code Sections 10927, 10932 and 10933, allows local Monitoring Entities to propose alternate monitoring techniques for basins meeting certain conditions and requires submittal of a monitoring plan to DWR for evaluation.

***Water Code (Section 10927, 10933, 12924, 10750.1 and 10720) or SB 1168***

SB 1168 requires the establishment of Groundwater Sustainability Agencies (GSA) and adoption of Groundwater Sustainability Plans (GSP). GSAs must be formed by June 30, 2017. GSAs are new entities that consist of local agency(ies) and include new authority to: 1) investigate and determine the sustainable yield of a groundwater basin; 2) regulate groundwater extractions; 3) impose fees for groundwater management; 4) require registration of groundwater extraction facilities; 5) require groundwater extraction facilities to use flow measurement devices; and 6) enforce the terms of a GSP.

Additionally, this bill requires groundwater basins to be prioritized as high-, medium-, low- or very low- with respect to groundwater conditions, adverse impacts on local habitat and adverse impacts on local stream flow no later than January 31, 2015. DWR has determined that the initial basin prioritization developed in June 2014 will be the initial prioritization adopted under this

[3] BMOs are management tools that define the acceptable range of groundwater levels, groundwater quality, and inelastic land subsidence that can occur in a local area without causing significant adverse impacts.

legislation. DWR has not identified basins with critical overdraft conditions as of January 31, 2015.

GSPs for groundwater basins designated by DWR as high- and medium-priority with critical overdraft conditions (per SB X7 6) are required to be developed by January 31, 2020. GSPs for the remaining high- and medium-priority groundwater basins are to be developed by January 31, 2022. GSPs are encouraged to be developed for groundwater basins prioritized as low- or very low-priority (Pavley 2014a). All high- and medium-priority basins must achieve sustainability within 20 years of adopting a GSP.

***Water Code (Section 10729, 10730, 10732, 10733 and 10735) or AB 1739***

AB 1739 establishes the following: (1) provides the specific authorities to a GSA (as defined by SB 1168); (2) requires DWR to publish best management practices for the sustainable management of groundwater by January 1, 2017; and (3) requires DWR to estimate and report the amount of water available for groundwater replenishment by December 31, 2016. The bill authorizes DWR to approve and periodically review all GSPs (Dickinson 2014).

The bill authorizes SWRCB to: (1) conduct inspections and obtain an inspection warrant; (2) designate a groundwater basin as a probationary groundwater basin; (3) develop interim plans for probationary groundwater basins in consultation with DWR if the local agency fails to remedy a deficiency resulting in the designation of probationary; and (4) issue cease and desist orders or violations of restrictions, limitations, orders, or regulations issued under AB 1739 (Dickinson 2014).

***Water Code (Section 10735.2 and 10735.8) or SB 1319***

SB 1319 would authorize the SWRCB to designate high- and medium-priority basins (defined by SB 1168) as a probationary basin after January 31, 2025. This bill allows the SWRCB to develop interim management plans that may override a local agency. However, if the appointed GSA can demonstrate compliance with sustainability goals for the basin, then the SWRCB has to exclude the groundwater basin or a portion of the groundwater basin from probationary status (Pavley 2014b).

***Other Groundwater Regulations***

Groundwater quality issues are monitored through a number of different legislative acts and are the responsibility of several different State agencies including:

- SWRCB and nine Regional Water Quality Control Boards (RWQCB) - responsible for protecting water quality for present and future beneficial use;
- California Department of Toxic Substances Control - responsible for protecting public health from improper handling, storage, transport, and disposal of hazardous materials;
- California Department of Pesticide Regulation - responsible for preventing pesticide pollution of groundwater;
- California Department of Public Health (CDPH) - responsible for drinking water supplies and standards;

- California Integrated Waste Management Board - oversees non-hazardous solid waste disposal, and

- California Department of Conservation - responsible for preventing groundwater contamination due to oil, gas, and geothermal drilling and related activities.

## L.1.3 Local Regulation

Local GMPs and county ordinances vary by authority/agency and region, but typically involve provisions to limit or prevent groundwater overdraft, regulate transfers, prevent subsidence and protect groundwater quality.

### *Sustainable Groundwater Management Act*

SB 1168 requires the establishment of GSA and adoption of GSPs. GSPs for groundwater basins designated by DWR as high- and medium-priority with critical overdraft conditions (per SB X7 6) are required to be developed by January 31, 2020. GSPs for the remaining high- and medium-priority groundwater basins are to be developed by January 31, 2022. All high- and medium-priority basins must achieve sustainability within 20 years of adopting a GSP. Table L-1 describes actions and agencies related to the Sustainable Groundwater Management Act.

**Table L-1.**
**Actions and Agencies related to the Sustainable Groundwater Management Act**

| Groundwater Basin/Subbasin | CASGEM Priority | Groundwater Sustainability Agencies (GSA) | Groundwater Sustainability Plan (GSP) | Notes |
|---|---|---|---|---|
| Redding Area Groundwater Basin- Anderson subbasin | High-priority basin due to participation in Type A groundwater transfers | Enterprise-Anderson GSA | GSP will be developed by January 31, 2022 | The Enterprise-Anderson GSA began the GSP development process in September 2018.<br><br>Website:<br>- www.cityofredding.org/departments/public-works/eagsa |
| Sacramento Valley Groundwater Basin- Colusa subbasin | High-priority basin due to declining groundwater levels, localized groundwater quality issues, and increased housing development | Glenn Groundwater Authority and Colusa Groundwater Authority | GSP will be developed by January 31, 2022 | Glenn Groundwater Authority and Colusa Groundwater Authority released a Notice of Intent to develop the GSP for the Colusa Subbasin in May 2018.<br><br>Websites:<br>- www.countyofglenn.net/dept/agriculture/water-resources/glenn-groundwater-authority<br>- colusagroundwater.org |

| Groundwater Basin/Subbasin | CASGEM Priority | Groundwater Sustainability Agencies (GSA) | Groundwater Sustainability Plan (GSP) | Notes |
|---|---|---|---|---|
| Sacramento Valley Groundwater Basin- West Butte subbasin | High-priority basin due to declining groundwater levels and localized groundwater quality issues | Glenn County, Reclamation District No. 1004, Butte County, Durham Irrigation District, Reclamation District 2106, and Western Canal Water District | GSP will be developed by January 31, 2022 | The GSA managers are holding facilitated discussions and will begin holding public workshops on governance and GSP development in the spring of 2018.<br><br>Website:<br>- www.buttecounty.net/ waterresourceconservation/ SustainableGroundwater ManagementAct.aspx |
| Sacramento Valley Groundwater Basin- Sutter subbasin | High-priority basin due to participation in Type A groundwater transfers | Sutter Community Service District, Reclamation District No. 1500, City of Yuba City, Reclamation District No. 70, Reclamation District No. 1660, and Sutter Extension Water District | Not Applicable (Alternative analysis submitted) | The GSAs submitted the *Sutter County Alternative Submittal to a Groundwater Sustainability Plan for Sutter Subbasin* to DWR in December 2016 demonstrating that the basin has operated within its sustainable yield over a period of at least 10 years.<br><br>Website:<br>- https://sgma.water.ca.gov/ portal/alternative/print/17 |
| Sacramento Valley Groundwater Basin- Yolo subbasin | High-priority basin due to localized groundwater quality issues and subsidence | Yolo Subbasin Groundwater Agency and Reclamation District No. 999 | GSP will be developed by January 31, 2022 | In March 2018 the Yolo Subbasin Groundwater Agency Board adopted Resolution 2018-1 formalizing the initiation of developing the Yolo Subbasin GSP.<br><br>Website:<br>- yologroundwater.org/ index.php/yolo-subbasin-groundwater-sustainability-plan/ |
| Sacramento Valley Groundwater Basin- Solano subbasin | High-priority basin due to declining groundwater levels and salt intrusion | Solano Irrigation District, City of Vacaville GSA, Solano Subbasin GSA, and Northern Delta GSA | GSP will be developed by January 31, 2022 | Solano GSA accepted funding under the Proposition 1 Sustainable Groundwater Planning Grant Program in May 2018 to prepare the GSP.<br><br>Website:<br>http://www.scwa2.com/ resources-management/ground-water/solano-gsa-bod |

| Groundwater Basin/Subbasin | CASGEM Priority | Groundwater Sustainability Agencies (GSA) | Groundwater Sustainability Plan (GSP) | Notes |
|---|---|---|---|---|
| Sacramento Valley Groundwater Basin- North American subbasin | High-priority basin due to localized groundwater contamination and declining groundwater levels | Sacramento Groundwater Authority, West Placer GSA, South Sutter Water District, Sutter County, and Reclamation District 1001 | GSP will be developed by January 31, 2022 | The GSAs have agreed to work together and prepare one GSP for the entire North American subbasin.<br><br>Websites:<br>https://www.sgah2o.org/<br>https://westplacergroundwater.com/<br>http://www.southsutterwd.com/ |
| Sacramento Valley Groundwater Basin- South American subbasin | High-priority basin due to localized groundwater contamination and declining groundwater levels | Sloughhouse Resource Conservation District, Sacramento Central Groundwater Authority, Omochumne-Hartnell Water District, Northern Delta GSA, and County of Sacramento | Not Applicable (Alternative analysis submitted) | Sacramento Central Groundwater Authority submitted the *South American Subbasin Alternative Submittal* to DWR in December 2016 demonstrating that the basin has operated within its sustainable yield over a period of at least 10 years.<br><br>Website:<br>https://sgma.water.ca.gov/portal/alternative/print/15 |

*Source: DWR 2018*

### *Groundwater Management Plans*

AB 3030, the Groundwater Management Act, encourages local water agencies to establish local GMPs. The Groundwater Management Act lists 12 elements that should be included within the GMPs to ensure efficient groundwater use, good groundwater quality, and safe production of water.

While GMPs aid in establishing best practices, not all of the GMPs set quantitative groundwater elevation triggers for their BMOs. Table L-2 lists the counties in the Sacramento Valley with existing GMPs. The table also provides a description of the BMOs, as described in each GMP. This list is provided for the entire Sacramento Valley; however, in addition to listing counties that contain potential groundwater substitution pumping sellers, the list also contains counties that do not (e.g., Butte County).

**Table L-2.**
**Groundwater Management Plans and BMOs in the Sacramento Valley**

| County | Basin Management Plan | Groundwater Basin Management Objective |
|---|---|---|
| Shasta (Anderson Cottonwood Irrigation District Groundwater Management Plan) | http://www.andersoncottonwoodirrigationdistrict.org/uploads/2/7/2/8/2728665/acid_gwmp.pdf | Pg. 3-2: No set elevation thresholds. |
| Shasta County (Shasta County Water Agency) | http://www.co.shasta.ca.us/index/pw_index/engineering/water_agency.aspx | No elevation thresholds. |
| Tehama County (Tehama County Flood Control and Water Conservation District) | http://www.tehamacountypublicworks.ca.gov/Flood/<br><br>Groundwater trigger levels for each sub-basin located here: http://www.tehamacountypublicworks.ca.gov/Flood/groundwater.htm | Trigger levels vary based on groundwater measurements in each monitoring well. Trigger levels generally follow a pattern of:<br>• Historical low of spring measurements plus 20% of the range of spring measurements: notify and inform public.<br>• Second consecutive year of groundwater levels at or below spring trigger level 1: monitor and investigate cause.<br>• Historical low of spring measurements: consider management options.<br>• Historical low of late groundwater measurements: notify public and begin investigations. |
| Glenn County | http://www.glenncountywater.org/documents/GlennCoBMOdocument_000.pdf | There are 17 basin management sub-areas in the basin. BMOs for groundwater levels are established separately for each sub-area.<br><br>There are no clear BMOs established yet. Objectives for the sub-areas are qualitative and relate to maintaining groundwater surface elevations at a level that will assure an adequate and affordable irrigation water supply; sustainable agricultural water supply; adequate groundwater supply for all domestic users. Additionally, some BMOs state that the objective is to develop an understanding of groundwater levels in the sub-area.<br><br>Elevation thresholds vary depending on sub-area and monitoring well within each sub-area. |
| Butte County | http://www.buttecounty.net/Portals/26/GWMP/Section_3__1-7-05_2.pdf | Pg. 3-4: Groundwater level declines in many areas of the county have been observed. These range from 0.8 to 2.0 feet per year. Declining groundwater levels are used as a trigger for close observation of groundwater level trends. |

| County | Basin Management Plan | Groundwater Basin Management Objective |
|---|---|---|
| Colusa County | http://colusagroundwater.ucdavis.edu/Technical%20Materials%20for%20Posting/ColusaCo_GMP_Volume-1_9-10-08.pdf | Pg. 34: From a review of the groundwater level hydrographs on Figure II.5, it can be seen that the extent to which the groundwater basin is utilized throughout the County varies significantly. Accordingly, the assessment of changes in groundwater levels in the respective areas must be performed with full consideration of the historic levels. It is premature to attempt to set groundwater level targets or thresholds in Colusa County. It is, however, very important to evaluate the groundwater level data in relation to historic data and report the results of that evaluation together with an assessment of overall hydrologic conditions, known changes in land use, etc. |
| Sutter County | http://www.co.sutter.ca.us/pdf/pw/wr/gmp/Sutter_County_Final_GMP_20120319.pdf | There are three BMOs for groundwater levels. One is related to low groundwater levels: Avoid ongoing declines in groundwater levels during water year types identified by DWR to be "above normal" or "wet" for the Sacramento Valley.<br><br>The BMO also states "groundwater levels are to be managed to ensure adequate water supplies while avoiding adverse impacts and mitigating them if and when they do occur. Adverse impacts related to groundwater levels can occur from excessively high or low groundwater levels. What constitutes an excessively high or low groundwater level may change over time, and will also vary by land use and hydrologic and climatic conditions. |
| Yuba County Water Agency | http://www.ycwa.com/documents/943 | Pg. 3-12: No specific threshold. Qualitative objectives:<br>• Avoid potential unreasonable impacts that may occur from changes in groundwater surface elevations because of external transfers.<br>• Monitor any lowering of groundwater surface elevations that may occur as a result of groundwater extraction to meet local demands in drier years. |
| Nevada County (Martis Valley Groundwater Management Plan) | http://www.pcwa.net/files/docs/enviro/MartisValleyGMPFinal07.22.2013.pdf | Very general BMO about protecting groundwater quantity. Plan includes details on the establishment of a groundwater elevation monitoring program. |
| Placer County Water Agency (Western Placer County Groundwater Management Plan) | http://www.pcwa.net/general-information/environmental-and-planning-documents.html and http://www.pcwa.net/files/docs/enviro/WPCGMP_Groundwater_Managerment_Plan_07.pdf | Pg. 3-8: discusses the need to create a uniform groundwater elevation monitoring program. No thresholds are set because historically, data have not been collected consistently. |

| County | Basin Management Plan | Groundwater Basin Management Objective |
|---|---|---|
| Sacramento Groundwater Authority | http://www.sgah2o.org/sga/files/2008-SGA-GMP-FINAL-20090206-print_ready.pdf | Pg. 29: "SGA members intend that overall groundwater elevations in the basin be improved over time, and that the groundwater basin be managed such that the impacts during drier years will be minimized when surface water supplies are curtailed and are replaced by increased groundwater supplies.<br><br>This is accomplished, similar to what is done in the Central Sacramento Basin, by measuring groundwater levels in more than 30 wells throughout the SGA. A similar 5 square mile grid pattern is used to monitor groundwater levels over time throughout the basin. SGA monitors groundwater elevations twice a year. |
| Central Sacramento County | http://www.amwater.com/files/CSCGMP_final.pdf | Pg. 3-3: An operating range for groundwater elevations in the basin define the upper and lower groundwater elevation thresholds. Upper and lower elevation limits are defined for 5 square mile polygons throughout the basin. Each polygon represents its own management unit with lower and upper elevation attributes. Groundwater elevation contour maps are on pages 3-4 and 3-5 of the plan. Lower groundwater thresholds range from -90 feet msl in the southwestern part of the basin to 150 feet msl in the northeastern part of the basin. Upper groundwater thresholds range from -70 feet msl in the southwestern part of the basin to 200 feet msl in the northeastern part of the basin. |
| South Area Water Council | http://www.water.ca.gov/groundwater/docs/GWMP/SJ-20_SouthBasin_GWMP_2011.pdf | Similar to the Sacramento Groundwater Authority and Central Sacramento County, the South Area Water Council's groundwater management plan uses several wells throughout the basin to gather groundwater elevation data and high/low thresholds would be based on individual wells. The BMO, on p. 2-2, states generally: Maintain or enhance groundwater elevations to meet the long-term needs of groundwater users within the Groundwater Management Area. |
| Yolo County | http://www.water.ca.gov/groundwater/docs/GWMP/SR-35_YoloCountyFCWCD_GWMP_2006.pdf | p. 12: "when ¾ of monitoring wells reach within 25% of the lowest water level recorded for that well. Spring and fall measurements will be analyzed separately." |

### *County Regulations and Ordinances*

The following are descriptions of local regulations/ordinances which may need to be considered during a water transfer:

### Shasta County Ordinance SCC 98-1

This ordinance requires a permit for extraction and export of groundwater, either directly or indirectly, for use outside the county. Groundwater substitution transfers as defined in Chapter 2 of this document will be subject to this ordinance. Applications for a transfer permit should be submitted to Shasta County Water Agency. Permits may only be granted if the proposed groundwater extraction (1) will not cause or increase an overdraft of the groundwater underlying

the county; (2) will not adversely affect the long term ability for storage or transmission of groundwater; (3) will not exceed the annual yield of the groundwater underlying the county; (4) will not result in an injury to water replenishment, storage, or restoration project; (5) is in compliance with Water Code 1220; and (6) will not be detrimental to the health, safety and welfare of property owners overlying or in the vicinity of the proposed extraction site(s).

**Glenn County Ordinance No. 1115**

This ordinance does not prohibit the export of water nor does it prohibit groundwater management practices that may involve the export of water. The ordinance clearly states that groundwater management practices including water exports shall not cause harm to adjacent areas. The ordinance cites modification, reduction, or termination of wells involved with water exports as a first priority in a sequence of management actions to be taken in the event groundwater levels become critical.

**Colusa County Ordinance No. 615**

This ordinance prohibits direct or indirect extraction of groundwater for transfer outside county boundaries without permit approval, except in certain circumstances. The permit approval process includes public and environmental reviews. Permits may only be approved after the environmental review determines that the Proposed Action would not result in the following: (1) overdraft or increased overdraft, (2) damage to aquifer storage or transmissivity, (3) exceedance of the annual yield or foreseeable injury to beneficial overlying groundwater users and property users, (4) injury to water replenishment, storage, or restoration projects, or (5) noncompliance with Water Code Section 1220. If Colusa County grants a three-year permit under Ordinance 615, the permit may also be subject to additional conditions to avoid adverse effects. Violators of this permitting process may be subject to a fine (Colusa County 1999). The ordinance does have an exemption process that would allow transfers to occur without obtaining a permit.

**Sacramento County Ordinance (Title 3 Section 3.40.090)**

This ordinance requires a permit to be issued for groundwater or surface water export of any manner from Sacramento County. The Director of the Sacramento County Department of Water Resources (or his designated representative) is required to (1) issue a permit for each source of transfer (i.e. pumping location); (2) conduct necessary investigations to determine if the transfers in in conformance with county water planning policies; (3) investigate if transfers could cause adverse impacts on the source, the area of use or the environment; and (4) determine if transfers is consistent with the general plan of the County of Sacramento, or the water plan of the Sacramento County Water Agency, or a specific plan of the county or water agency that may be affected by the work or activity.

**Yolo County Export Ordinance No. 1617**

Yolo County Export Ordinance No. 1617 is similar to the Colusa County ordinance described above. Indirect or direct export of groundwater outside Yolo County requires a permit. In addition to review by the county, the Director of Community Development may review the permit application with other affected county departments, DWR, RWQCB, and any other interested local water agency neighboring the area of the proposed transfer. Following a California Environmental Quality Act (CEQA) environmental review and a public review, the Yolo County Board of Supervisors may grant the permit if the evidence suggests that the extraction would not cause (1) adverse effects to long-term storage and transmissivity of the

aquifer, (2) exceedance of safe yield unless it is in compliance with an established conjunctive use program, (3) noncompliance with Water Code section 1220, or (4) injury to water replenishment, storage, or restoration projects. The Yolo County Board of Supervisors may impose additional conditions to the permit to ensure compliance with the aforementioned criteria. This ordinance subjects violators to fines (Yolo County 1996).

**Water Forum Agreement (WFA)**

The WFA consists of seven major elements designed to meet the following overall objective to: "Provide a reliable and safe water supply for the region's economic health and planned development to the year 2030; and preserve the fishery, wildlife, recreational, and aesthetic values of the Lower American River." The WFA's Groundwater Element encourages the management of the limited groundwater resources in three hydrogeologic areas within Sacramento County (Water Forum 2000). The WFA areas that could be affected by the proposed action include the areas termed as the North Area and Central Area. The major outcomes of this agreement included (Water Forum 2000):

- Formation of the Sacramento Groundwater Authority (SGA) and the American River Basin Cooperating Agencies (ARBCA); and

- A recommended sustainable yield of 131,000 acre-feet (AF) per year for the North Area and 273,000 AF per year for the Central Area.

Groundwater management negotiations in the Central area and the South area will continue.

SGA's primary mission is to protect the basin's safe yield, defined in the WFA, and water quality. Additional goals and objectives of the SGA include: (1) develop/facilitate a regional conjunctive use program consistent with the WFA; (2) mitigate conditions of regional groundwater overdraft; (3) replenish groundwater extraction; (4) mitigate groundwater contaminant migration; (5) monitor groundwater elevations and quality; and (6) develop relationships with State and Federal Agencies. The basin has approximately 600,000 AF of evacuated storage that could be exercised in such a program. The ultimate potential wet year in-lieu banking potential is about 100,000 AF per year, with a potential dry year surface water exchange potential of over 50,000 AF per year.

**American River Basin Regional Conjunctive Use Program (ARBCUP)**

A partnership between the SGA and the ARBCA resulted in the ARBCUP.

An outcome of the WFA, the ARBCUP intends to assist in meeting the WFA objectives, discussed above, by using the over drafted basin in the North Area for groundwater banking. Groundwater recharge as part of the ARBCUP consists of either (1) direct recharge using surface water from the American River and/or Sacramento River or (2) in lieu of recharge in which surface water is substituted for groundwater. The ARBCUP includes a combination of the use of groundwater and surface water to maximize "banking" of both groundwater below ground and surface water in reservoirs. ARBCUP assists in maintaining the WFA American River environmental flow standards. When the ARBCUP was completed in 2008, the program increased water supplies by 20,000 AF per year (Regional Water Authority [RWA] 2012).

# L.2 Biological Resources

## L.2.1 Federal Regulation

### *Endangered Species Act (ESA)*

The Federal ESA defines "endangered" species as those in danger of extinction throughout all or a significant portion of their range. A "threatened" species is any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. Additional special-status species include "candidate" species and "species of concern." Candidate species are those for which the USFWS, or National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) if applicable, has enough information on file to propose listing as endangered or threatened. A species that has been "delisted" is one whose population has met its recovery goal target and is no longer found to be in jeopardy of extinction. These agencies also may designate Critical Habitat for listed species.

Section 4 of the Federal ESA prohibits "take" of federally listed species without a permit that specifically authorizes that take. Take may be authorized through either a Section 10a1(a) permit for directed take of the species for scientific research, or through an incidental take permit, which allows an action to take of the species (under specifically prescribed conditions) where such take is incidental to the implementation of an otherwise lawful activity. Incidental take of a federally listed species may be addressed for a proposed project in one of two ways depending on whether the or not the project has a federal nexus. A federal nexus occurs when a project is authorized or funded by a federal agency. Projects without a federal nexus may address potential adverse impacts to species protected under Federal ESA Section 10, or (2) a federal lead agency regulates a proposed project in accordance with Federal ESA Section 7. As this project has a federal nexus, the Section 7 process will be followed. Section 7 defines a process for the federal lead agency to consult with the responsible federal resource agency (the USFWS or NOAA Fisheries), to determine whether proposed long-term water transfers are likely to adversely affect species that are listed or proposed for listing. The Section 7 process typically requires the preparation of a biological assessment (BA) by the federal lead agency followed by the preparation of biological opinion (BO) by the responsible federal resource agency.

### *Fish and Wildlife Coordination Act (FWCA)*

The FWCA (16 U.S. Code [USC] 661 et seq.) requires Federal agencies to consult with USFWS, or, in some instances, with NOAA Fisheries and with State fish and wildlife resource agencies before undertaking or approving water projects that control or modify surface water. The purpose of this consultation is to ensure that wildlife concerns receive equal consideration water resource development projects and are coordinated with the features of these projects. The consultation is intended to promote the conservation of fish and wildlife resources by preventing their loss or damage and to provide for the development and improvement of fish and wildlife resources in connection with water projects. Federal agencies undertaking water projects are required to fully consider recommendations made by USFWS, NOAA Fisheries, and State fish and wildlife resource agencies in project reports and to include measures to reduce impacts on fish and wildlife in project plans.

The 1988 amendment to the FWCA mandates USFWS to identify species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are

likely to become candidates for listing under the ESA of 1973. In 2008, USFWS issued the most recent version of the National list of *Bird Species of Conservation Concern.*

#### *Magnuson-Stevens Fisheries Act of 2006*

The Amended Magnuson-Stevens Fishery Conservation and Management Act, also known as the Sustainable Fisheries Act (Public Law 104-297) is the primary law governing the marine fisheries of the United States. The law establishes requirements to provide for the sustainable management of these fisheries and to promote the protection of essential fish habitat. This Act requires all Federal agencies to consult with the Secretary of Commerce on activities, or proposed activities, authorized, funded, or undertaken by that agency that may adversely affect Essential Fish Habitat. The Essential Fish Habitat provisions of the Sustainable Fisheries Act are designed to protect fisheries habitat from being lost due to disturbance and degradation.

#### *Migratory Bird Treaty Act (MBTA)*

The MBTA domestically implements a series of international treaties that provide for migratory bird protection. The MBTA authorizes the Secretary of the Interior to regulate the taking of migratory birds. The act further provides that it is unlawful, except as permitted by regulations, "to pursue, take, or kill any migratory bird, or any part, nest or egg of any such bird…" (16 USC 703). This prohibition includes both direct and indirect acts, although harassment and habitat modification are not included unless they result in direct loss of birds, nests, or eggs. The current list of species protected by the MBTA can be found in the March 1, 2010 Federal Register (75 FR 9281). This list comprises several hundred species, including essentially all native birds. Permits for take of nongame migratory birds can be issued only for specific activities, such as scientific collecting, rehabilitation, propagation, education, taxidermy, and protection of human health and safety and of personal property. USFWS publishes a list of birds of conservation concern (BCC) to identify migratory nongame birds that are likely to become candidates for listing under ESA without additional conservation actions. The BCC list is intended to stimulate coordinated and collaborative conservation efforts among federal, state, tribal, and private parties.

#### *Executive Order 11990 (Protection of Wetlands)*

Executive Order 11990 (Protection of Wetlands) requires Federal agencies to take actions to minimize the destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands when undertaking Federal activities and programs. Any agency considering a proposal that might affect wetlands must evaluate factors affecting wetland quality and survival. These factors should include the proposal's effects on the public health, safety, and welfare due to modifications in water supply and water quality; maintenance of natural ecosystems and conservation of flora and fauna; and other recreational, scientific, and cultural uses.

### L.2.2 State Regulation

#### *California Endangered Species Act (CESA)*

CESA (California Fish and Game Code Sections 2050–2116) was implemented in 1984 to prohibit the take of species that are listed as endangered and or threatened. CESA defines "endangered" species as those whose continued existence in California is jeopardized. State-listed "threatened" species are those not presently threatened with extinction, but which may

become endangered if their environments change or deteriorate. Section 86 of the California Department of Fish and Game Code defines take as to "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill." California Department of Fish and Wildlife (CDFW) administers CESA and authorizes incidental take through either California Fish and Game Code Section 2080.1 (consistency determination) or Section 2081 (Incidental Take Permit).

***Fully Protected Species***

Sections 3511, 3513, 4700, and 5050 of the California Fish and Game Code pertain to fully protected wildlife species (birds in Sections 3511 and 3513, mammals in Section 4700, and reptiles and amphibians in Section 5050) and strictly prohibit the take of these species. CDFW cannot issue a take permit for fully protected species, except under narrow conditions for scientific research or the protection of livestock, or if a Natural Community Conservation Plan (NCCP) has been adopted. Specifically, Section 3513 prohibits any take or possession of birds designated by the MBTA as migratory nongame birds except as allowed by federal rules and regulations pursuant to the MBTA.

***Protection of Birds and Raptors***

Section 3503 of the Fish and Game Code prohibits the killing of birds and/or the destruction of bird nests. Section 3503.5 prohibits the killing of raptor species and/or the destruction of raptor nests. Typical violations include destruction of active bird and raptor nests as a result of tree removal, and failure of nesting attempts (loss of eggs and/or young) as a result of disturbance of nesting pairs caused by nearby human activity.

***California Native Plant Protection Act (CNPPA)***

The CNPPA of 1977 prohibits importation of rare and endangered plants into California, take of rare and endangered plants, or sale of rare and endangered plants. CESA defers to the CNPPA, which ensures that state-listed plant species are protected when state agencies are involved in projects subject to CEQA.

***Natural Community Conservation Planning Act (NCCPA)***

The NCCPA, California Fish and Game Code, Section 2800, et seq., was enacted to form a basis for broad-based planning to provide for effective protection and conservation of the State's wildlife heritage, while continuing to allow appropriate development and growth. The purpose of natural community conservation planning is to sustain and restore those species and their habitat identified by CDFW that are necessary to maintain the continued viability of biological communities impacted by human changes to the landscape. A NCCP identifies and provides for those measures necessary to conserve and manage natural biological diversity within the plan area while allowing compatible use of the land. CDFW may authorize the take of any identified species, including listed and non-listed species, pursuant to Section 2835 of the NCCPA, if the conservation and management of such species is provided for in an NCCP approved by CDFW. NCCPs in the planning area are described in greater detail in Section 3.6.1.2.5 Regional/Local Requirements. The proposed water transfers occurring in NCCP planning areas will not require separate incidental take permits pursuant to CESA for covered species if the project adheres to the requirements of the relevant plans.

***Requirements of the 1995 Bay Delta Plan Water Quality Control Plan (1995 Delta WQCP) and Decision 1641***

The State Water Resources Control Board (SWRCB) adopted its WQCP for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary in May 1995 and incorporated several elements of U.S. Environmental Protection Agency (USEPA), NOAA Fisheries, and USFWS regulatory objectives for water salinity and endangered species protection. The WQCP identifies the beneficial uses of the Bay-Delta that are to be protected and includes flow and water quality objectives that are intended to protect the beneficial uses. The plan also includes an implementation program for achieving the water quality objectives. Under the Clean Water Act, the water quality standards comprise the uses and the quality objectives established to protect them.

Features of the current WQCP affect the proposed water transfers because they require certain Delta outflows and regulate actions that may be used to protect fish and benefit the environment.

## L.2.3 State and Federal Laws and Regulations Governing Water Transfers and Water Acquisitions

***The Water Code***

Both State and Federal laws contain provisions that authorize, acknowledge, or support water transfers. The Water Code protects legal users of water and fish and wildlife during water transfers through the "no injury rule," analyses of impacts to fish and wildlife, evaluation of third-party impacts, and the 1707 process.

Water Code Sections 1435, 1725, and 1736 require that the SWRCB make a finding that certain proposed transfers not result in unreasonable effects on fish and wildlife or other instream beneficial uses. These Code Sections apply to specific types of water transfers (urgent, temporary, and long-term transfers) related to post-1914 water rights. Pre-1914 water rights are not subject to the permit system, although a change in use for instream flow may be permitted under Section 1707 on petition to the SWRCB. The proposed water transfers were conceived in compliance with these codes.

In the context of the proposed water transfers "third parties" are any persons and resources other than the entities transferring or receiving water. Although the Water Code does not define "third party impacts," they traditionally include impacts related to downstream water rights; adjacent groundwater users; fish and wildlife; and recreation, economic, and social impacts. Most third-party impacts are evaluated under Water Code Sections that protect prior rights and fish and wildlife as discussed above. However, Water Code Sections 386 and 1810 require evaluation of other third-party impacts for some specific transfers and prohibit such transfers from affecting the overall economy of the area or county from which the water is being transferred. Water Code Section 1810 states that transferors can utilize public water conveyance facilities as long as "this use of a water conveyance facility is to be made without injuring any legal user of water and without unreasonably affecting fish, wildlife, or other instream beneficial uses and without unreasonably affecting the overall economy or the environment of the county from which the water is being transferred."

Section 1707 of the Water Code allows water rights holders, including riparian rights holders, to dedicate their rights to instream uses "for the purpose of preserving or enhancing wetlands, fish and wildlife resources, or recreation in, or on, the water." These transfers, from a consumptive use to a non-consumptive use with an identified need, may be temporary or permanent. The transfer must meet the following requirements for the SWRCB to consider approving the change in use:

- Will not increase the amount of water the person is entitled to use;
- Will not unreasonably affect any legal user of water; and
- Otherwise meets the requirements of Division 2 of the Water Code.

The petitioner can request that the water subject to transfer approval be in addition to water required for "Federal, State, or local regulatory requirements governing water quantity, water quality, instream flows, fish and wildlife, wetlands, recreation and other instream beneficial uses." If the petitioner does not submit this request to the SWRCB, then the water shall be used to meet any of the above requirements.

### L.2.4 Other Pertinent Programs, Documents, Laws, and Agreements

Potential biological effects of water transfers in the project area have been previously addressed in documents.

#### *CVPIA*

The CVPIA is a Federal statute passed in 1992 with the following purposes:

> *"To protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California; To address impacts of the Central Valley Project on fish, wildlife and associated habitats; To improve the operational flexibility of the Central Valley Project; To increase water-related benefits provided by the Central Valley Project to the State of California through expanded use of voluntary water transfers and improved water conservation; To contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; To achieve a reasonable balance among competing demands for use of Central Valley Project water, including the requirements of fish and wildlife, agricultural, municipal and industrial and power contractors."*

The CVPIA changed the relative priorities of the various project purposes of the CVP by making fish and wildlife protection, as a project purpose, equal to water supply for agricultural and urban uses.

CVPIA Section 3406(b)(2) (CVPIA[b][2]) authorized and directed the Secretary to dedicate and manage 800,000 AF of CVP yield annually for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized in CVPIA, to assist the State of California in its efforts to protect the waters of the Bay-Delta Estuary, and to help meet obligations legally imposed on the CVP under State or Federal law following the date of enactment of the CVPIA. This dedicated 800,000 AF of water, known as (b)(2) water, was included as a component of the CALFED Programmatic Environmental Impact

Statement/Environmental Impact Report (PEIS/EIR) existing regulatory baseline for fishery protection conditions for environmental and fisheries protection measures.

The operation of CVP and the SWP facilities is subject to BOs issued by USFWS and the NOAA Fisheries. These BOs are subject to ongoing litigation and are currently under review by the two services:

- Biological Opinion on Implementation of the CVPIA and Continued Operation and Maintenance of the Central Valley Project (NOAA Fisheries 2000),
- Biological Opinion on the Effects of the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (NOAA Fisheries 2004),
- Consultation on Long-Term Renewal of Water Service Contracts in the Delta-Mendota Canal Unit (NOAA Fisheries 2005),
- Reinitiation of Formal and Early Section 7 Endangered Species Consultation on the Coordinated Operations of the Central Valley Project and State Water Project and the Operational Criteria and Plan to Address Potential Critical Habitat Issues (USFWS 2005a),
- Conclusion of Consultation on Long-Term Renewal of Water Service Contracts in the Delta-Mendota Canal Unit (USFWS 2005b),
- Formal Endangered Species Consultation on the Operations and Maintenance Program Occurring on Bureau of Reclamation Lands within the South-Central California Area Office: Biological Opinion (USFWS 2005c),
- Biological opinions for CVP Water contracts,
- Biological Opinion on the Coordinated Operations of the CVP and SWP in California. (USFWS 2008), and
- Biological Opinion on California's Central Valley Water Project (NOAA Fisheries 2009).

### L.2.5 Local Regulation

Both the ESA and the NCCPA include provisions for the development of conservation plans to protect vegetation and wildlife resources.

A Habitat Conservation Plan (HCP) is a planning document that is required for issuance of an incidental take permit under section 10 of the ESA. The HCP process provides opportunities to conserve listed species, while streamlining permitting for participants' development projects within the planning area. HCP documents typically includes the following information: the anticipated take of the proposed project; measures to avoid, minimize or mitigate impacts to the maximum extent practicable, and a funding mechanism for acquiring and managing lands containing the habitats on which the covered species depend. Covered species may include both listed and non-listed species. This may provide an extra level of certainty for permittees, given

that no amendments to the plan would be required if a covered species becomes listed under the ESA before the completion of project activities.

A NCCP is a similar process provided under state law, with some key differences. While the federal and state ESAs focus on protection and recovery of species that have already declined, NCCPs take a broader approach, seeking to anticipate and avoid future conflicts between preservation and development, as well as compliance with the CESA. NCCPs focus on regional-scale protection of ecosystems along with compatible development. A local agency oversees cooperative development of an NCCP by landowners, environmental groups, and other stakeholders, with support provided by CDFW and USFWS.

Project actions within the HCP/NCCP areas will comply with applicable requirements for covered activities within plan areas for existing HCPs/NCCPs. A separate Section 7 Consultation will also be undertaken for the long-term water transfers.

There are 11 HCPs or NCCPs that are either adopted or under development for areas that overlap with, or occur in the vicinity of, the long-term water transfers area of analysis (CDFW 2014a):

- Butte Regional Conservation Plan (BRCP) – The BRCP is a cooperative planning effort between the Cities of Biggs, Chico, Gridley, Oroville, County of Butte, and Butte County Association of Governments. The plan will provide streamlined ESA permitting for transportation projects, land development and covered activities such as construction and maintenance of facilities and infrastructure, residential construction, and recreational activity-related construction. The BRCP also aims to provide comprehensive conservation of species, wetlands and ecosystems, specifically contributing to the protection of 41 plant, fish, and wildlife species within the 564,270 acre plan area (CDFW 2014b). The BRCP covers nine of the focal species for the long-term water transfers including Red Bluff dwarf rush, Sacramento River winter-run Chinook salmon, and green sturgeon. This plan is under development.

- Bay-Delta Conservation Plan (BDCP) – The BDCP is a comprehensive conservation strategy for the Sacramento–San Joaquin River Delta (Delta) to protect ecosystem health, water quality, water supply, and California's economy, while permitting the operation of the CVP and SWP. The BDCP covers 56 species, including 11 of the focal species for the long-term water transfers including Central Valley Spring-run Chinook salmon, longfin smelt, and greater sandhill crane. This plan is under development. The draft BDCP and its corresponding draft EIS/EIR were published for public review and comment in December 2013 (Reclamation et al. 2013).

- East Contra Costa County HCP/NCCP – The East Contra Costa County HCP/NCCP was developed partially to address indirect and cumulative effects on terrestrial species from development supported by increases in water supply provided by Contra Costa Water District. Activities covered under the plan include public infrastructure projects, construction of residential and business development, and public infrastructure projects. The plan has been adopted by Contra Costa County, the Cities of Brentwood, Clayton, Pittsburg, and Oakley. The HCP/NCCP provides regional conservation and development guidelines to protect natural resources while improving the permit process for endangered

species and wetland regulations. The plan will encompass a preserve system covering 30,300 acres of land that will be managed for the benefit of 28 species and the natural communities they depend upon (East Contra Costa County HCP Association 2006). The East Contra Costa County HCP covers 4 of the focal species for the long-term water transfers including giant garter snake, San Joaquin kit fox, and Western pond turtle.

- Natomas Basin HCP (NBHCP) - The NBHCP establishes a multi-species conservation program to mitigate the expected loss of habitat and incidental take and/or loss of covered species that would result from planned urban development. The plan covers 53,537 acres within the levees surrounding the Natomas Basin and 22 plant and wildlife species (The Natomas Basin Conservancy 2003). Covered activities under the plan include urban development, public and drainage improvements, water agency projects, and approved activities of the Natomas Basin Conservancy. Plan participants include the City of Sacramento, Sutter County, Sacramento County, and the acting regulatory agencies. The NBHCP covers four of the focal species for the long-term water transfers including giant garter snake, Western pond turtle, and white-faced ibis.

- Placer County Conservation Plan (PCCP) HCP/NCCP – The PCCP HCP/NCCP is intended to address the impacts associated primarily with unincorporated growth in western Placer County in addition to growth associated with the build-out of Lincoln's updated General Plan. The PCCP is intended to protect 31 special status species and federally regulated wetlands, as well as indirectly protect the habitat of hundreds of plant and wildlife species across approximately 201,000 acres of Western Placer County (Placer County Planning Services Division 2011). Covered activities include: urban development, in-stream projects, capital projects, operation and maintenance, rural development, conservation strategy implementation, and other Placer County conservation programs. Participants include the City of Lincoln, Placer County, Placer County Water Agency and South Placer Regional Transportation Authority. PCCP covers five of the focal species for the long-term water transfers including Ahart's dwarf rush, Red bluff dwarf rush, and Central Valley Steelhead. This plan is under development.

- San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (SJMSCP) – The SJMSCP was developed to provide guidelines for converting open space to other land uses, preserving agriculture, and protecting plant and wildlife species. Activities covered under the plan include urban development, mining, non-agricultural activities occurring outside of urban boundaries, transportation projects, non-federal flood control projects, maintenance activities, and similar public agency projects. San Joaquin County, the Cities of Stockton, Lodi, Manteca, Tracy, Ripon, Escalon, and Lathrop are the plan participants. The plan addresses 97 special-status plant, fish and wildlife species in over 900,000 acres of the San Joaquin County (San Joaquin County 2000). The SJMSCP covers 12 of the focal species for the long-term water transfers including Sandford's arrowhead, Red Bluff dwarf rush, and Delta smelt.

- Santa Clara Valley (SCV) HCP/NCCP – The SCV HCP/NCCP is a regional partnership between the County of Santa Clara, Santa Clara Valley Transportation Authority, Santa Clara Valley Water District, and the Cities of San Jose, Gilroy and Morgan Hill, and regulatory agencies. The plan encompasses approximately 440,318 acres and will address

impacts primarily associated with the future uses of land identified in the plan area (CDFW 2014c). Land preservation would mitigate for the environmental impacts of planned urban and rural development, instream activities, public infrastructure operations and maintenance activities (e.g. water, transportation, etc.) and would enhance the long term viability of 21 threatened or endangered plant and wildlife species (CDFW 2014c). SCV HCP/NCCP covers three of the focal species for the long-term water transfers including San Joaquin kit fox, Western pond turtle, and tricolored blackbird.

- Solano Multispecies HCP (SMSHCP) – The SMSHCP plan area covers 585,000 acres (Solano County Water Agency 2012). It was developed to address species conservation in conjunction with urban development, flood control/infrastructure improvement activities, and to support the issuance of an incidental take permit under the Federal ESA for the Bureau of Reclamation's Solano Project Contract Renewal. Activities covered under the plan include preservation, restoration, invasive species control, and water quality improvement. Covered species include federally and state-listed fish species and other wildlife species of concern. Plan participants include Solano County, a small portion of Yolo County, Solano County Water Agency's contract service area, including the Cities of Fairfield, Vacaville, Vallejo, Suisun City, Solano Irrigation District, and the Main Prairie Water District. The SMSHCP covers eight of the focal species for the long-term water transfers including winter-run Chinook salmon, Central Valley steelhead, and longfin smelt. This plan is still under development.

- South Sacramento HCP (SSHCP) – The proposed SSHCP would address issues related to species conservation, agricultural protection, and urban development in 341,000 acres of south Sacramento County. Activities covered under the plan include construction of residential, commercial, and industrial buildings, and associated infrastructure. The plan is being prepared by Sacramento County, the Cities of Sacramento, Elk Grove, and Galt, and Rancho Powers Authority. The plan would cover 40 plant and wildlife species, including ten species that are listed by the state or federal governments. The SSHCP covers five of the focal species for the long-term water transfers including Ahart's dwarf rush, Greater sandhill crane, and giant garter snake. This plan is still under development.

- Yolo Natural Heritage Program (YNHP) – This plan is still under development and the program released a draft plan on June 28, 2013 (Yolo Natural Heritage Program 2013). This 653,818-acre county-wide HCP/NCCP will provide for the conservation of 32 sensitive species in five habitat types: wetland, riparian, oak woodland, grassland, and agriculture (Yolo Natural Heritage Program 2013). No aquatic species will be addressed in the YNHP. The plan describes measures that local agencies will implement to conserve biological resources, obtain permits for urban growth and public infrastructure projects, maintain the agricultural heritage of the county, and acquire permanent conservation easements for sensitive plant and wildlife species in the plan area. Plan participants include Yolo County, the Cities of Davis, Woodland, West Sacramento, and Winters. The YNHP covers four of the focal species for the long-term water transfers including giant garter snake, Western pond turtle, and purple martin.

- Yuba-Sutter NCCP/HCP – This plan is still under development. The Yuba-Sutter NCCP/HCP is a cooperative planning effort initiated by Yuba and Sutter Counties in

connection with improvements to Highways 99 and 70, as well as future development in the area surrounding those highways. The plan covers approximately 210,000 acres and provides for the regional protection and management of 31 listed and other special-status species and their habitats (CDFW 2014d). Plan participants include the Counties of Yuba and Sutter, Cities of Yuba, Live Oak, and Wheatland. The Yuba-Sutter HCP covers five of the focal species for the long-term water transfers including greater sandhill crane, Western pond turtle, and tricolored blackbird.

# L.3 Climate Change

## L.3.1 Federal Regulations

### *Department of the Interior (DOI) Secretarial Order No. 3289, Amendment No. 1*

In 2009, the DOI issued a Secretarial Order on climate change that expands DOI bureaus' responsibilities in addressing climate change (amended on February 22, 2010). The purpose of Secretarial Order No. 3289 is to provide guidance to bureaus and offices within the DOI on how to provide leadership by developing timely responses to emerging climate change issues. This Order replaces Secretarial Order No. 3226, signed on January 19, 2001, entitled "Evaluating Climate Change Impacts in Management Planning." It reaffirms efforts within DOI that are ongoing with respect to climate change. Among the requirements of the Order is one that requires each bureau and office of DOI to "consider and analyze potential climate change impacts when undertaking long-range planning exercises, setting priorities for scientific research and investigations, and/or when making major decisions affecting DOI resources" (DOI 2010).

### *Interior's Plan for a Coordinated, Science-Based Response to Climate Change Impacts on Our Land, Water, and Wildlife Resources*

DOI subsequently released *Interior's Plan for a Coordinated, Science-Based Response to Climate Change Impacts on Our Land, Water, and Wildlife Resources*. The plan provides a framework for DOI's conservation strategies related to climate change. DOI relies on three main resources – climate change impact science, data integration and dissemination, and enabling science-based adaptation strategies – to implement its vision. As part of its response to climate change, DOI established Climate Science Centers and Landscape Conservation Cooperatives to form the foundation of an integrated approach to climate change science and adaptation (DOI n.d.).

### *Reclamation National Environmental Policy Act (NEPA) Handbook*

The DOI, Reclamation's *NEPA Handbook* (Reclamation 2012) recommends that climate change be considered, as applicable, in every NEPA analysis. The *NEPA Handbook* acknowledges that there are two interpretations of climate change in regards to Reclamation actions: 1) Reclamation's action is a potentially significant contributor to climate change and 2) climate change could affect a Reclamation proposed action. The *NEPA Handbook* recommends considering different aspects of climate change (e.g., relevance of climate change to the proposed action, timeframe for analysis, and relevant regional/local projections of climate change) to determine the extent to which it should be discussed under NEPA.

***Principles and Requirements for Federal Investments in Water Resources***

Furthermore, Reclamation is subject to *Principles and Requirements for Federal Investments in Water Resources* (Council on Environmental Quality [CEQ] 2013). This document requires areas of risk and uncertainty to be identified, described, and considered when analyzing potential investments in water resources. It specifically requires climate change impacts to be accounted for and addressed.

## L.3.2 State Regulations

***Revised Climate Change Scoping Plan***

The initial Scoping Plan ( California Air Resources Board [CARB] 2008) provides a framework for the State's strategy to reduce greenhouse gas (GHG) emissions to 1990 levels by 2020. This reduction goal means reducing GHG emissions by approximately 30 percent from business-as-usual emission levels projected for 2020 or approximately 15 percent from 2005 levels. Key features of the State's plan for reducing emissions include six main recommendations:

- Expand and strengthen existing energy efficiency programs and building and appliance standards
- Achieve a statewide renewables energy mix of 33 percent
- Develop a cap-and-trade program that links other partner programs to create a regional market system
- Establish targets for transportation-related GHG emissions for regions throughout the State, and pursue policies and incentives to achieve those targets
- Adopt and implement measures, including California's clean car standards, goods movement measures, and the low carbon fuel standard
- Create targeted fees to fund the administrative costs of the State's long-term commitment to AB 32 implementation

The Scoping Plan recommends 39 measures that would achieve an emissions reduction of 174 million metric tons of carbon dioxide equivalent per year ($MMTCO_2e$/year) if fully implemented. The recommended measures cover nine sectors: 1) transportation, 2) electricity and natural gas, 3) green buildings, 4) water, 5) industry, 6) recycling and waste management, 7) forests, 8) high global warming potential (GWP) gases[4], and 9) agriculture. Additionally, nine discrete early actions were adopted to reduce GHG emissions.

The First Update to the Climate Change Scoping Plan (CARB 2014) builds on the 2008 Scoping Plan by identifying the next steps that are required to meet the State's emission reductions beyond 2020 (i.e., 80 percent below 1990 levels by 2050). The update adjusts the 2020 statewide limit to 431 $MMTCO_2e$ to reflect updated GWPs.

[4] GWP is a metric that measures how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to 1 ton of $CO_2$.

In November 2017, CARB finalized *California's 2017 Climate Change Scoping Plan* to describe potential policies that could be implemented to achieve the 2030 target established by EO B-30-15 (CARB 2017).

### *California Environmental Quality Act (CEQA) Guidelines*

On March 18, 2010, the California Natural Resources Agency (CNRA) adopted amendments to CEQA Guidelines to include provisions for evaluating the significance of GHG emissions. The amended guidelines give the lead agency leeway in determining whether GHG emissions should be evaluated quantitatively or qualitatively, but requires that the following factors be considered when assessing the significance of impacts from GHG emissions (14 California Code of Regulations 15064.4):

- The extent to which the project may increase or reduce GHG emissions as compared to the existing environmental setting.
- Whether the project emissions exceed a threshold of significance that the lead agency determines applies to the project.
- The extent to which the project complies with regulations or requirements adopted to implement a statewide, regional, or local plan for the reduction or mitigation of GHG emissions.

The amended guidelines also specify that lead agencies must analyze potentially significant impacts associated with placing projects in locations susceptible to hazardous conditions (e.g., floodplains, coastlines, and wildfire risk areas), including those that could be affected by climate change (Section 15126.2(a)).

Furthermore, the guidelines also suggest measures to mitigate GHG emissions, including implementing project features to reduce emissions, obtaining carbon offsets to reduce emissions, or sequestering GHG.

### *California EO S-13-08*

State of California EO S-13-08, signed in November 2008, tasked state agencies to develop California's first climate change adaptation strategy to identify and prepare for expected climate change impacts, including sea level rise, increased temperature, shifting precipitation, and extreme weather events. In response, the 2009 California Climate Adaptation Strategy (CAS) report (CNRA 2009) was released; the report summarized the best-known science on climate change impacts and outlined possible solutions to promote resiliency and reduce California's vulnerability to climate impacts.

The CAS included 12 recommendations that are largely geared toward state agencies but have implications for project-level analyses. For example, the CAS recommends that the potential impacts of climate change be considered for all significant state projects to the extent required by CEQA Guidelines Section 15126.2, which relates to the consideration and discussion of

significant environmental impacts[5]. This CEQA section requires Lead Agencies to identify and focus on the significant environmental effects of the Proposed Action; describe any significant impacts, including those that can be mitigated but not reduced to a level of insignificance; evaluate significant irreversible environmental changes that would be caused by the Proposed Action; and discuss growth-inducing impacts of the Proposed Action.

In 2010, the CNRA released the First Year Progress Report (CNRA 2010) that describes California's progress toward completing the tasks outlined in the CAS. *Safeguarding California: Reducing Climate Risk* was subsequently published in 2014 to provide further updates on the CAS (CNRA 2014). The 2014 plan highlights climate risks in key sectors, discusses progress to date, and makes sector-specific recommendations. In 2016, implementation plans were published that show how the State is acting on the 2014 recommendations (CNRA 2016).

### L.3.3 Regional and Local Regulations

The following air pollution control districts (APCDs) and air quality management districts (AQMDs) regulate air quality within the area of analysis:

- Bay Area AQMD
- Butte County AQMD
- Colusa County APCD
- Feather River AQMD
- Glenn County APCD
- Monterey Bay Unified APCD
- Placer County APCD
- Sacramento Metropolitan AQMD
- San Joaquin Valley APCD
- Shasta County AQMD
- Tehama County APCD
- Yolo-Solano APCD

Although these air districts do not regulate GHG emissions directly, they may have GHG-specific significance criteria in their respective CEQA guidelines.

[5] In evaluating significance, CEQA defines "direct" physical changes in the environment to be those caused by and immediately related to the project. "Indirect" physical changes are not immediately related to the project but are caused by the project. These definitions are consistent with NEPA's interpretation of direct and indirect effects.

# L.4 References

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# Appendix M

# Natural Communities Descriptions

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# Appendix M
# Natural Communities Descriptions

The list of special-status species considered for analysis was based on a search of the California Department of Fish and Wildlife [CDFW] California Natural Diversity Database (CNDDB), USFWS species lists for the counties within the area of analysis, and active HCPs in the vicinity of the area of analysis. The complete list of special-status species evaluated is provided in Tables N-1 (fish and wildlife) and N-2 (plants) contained within Appendix N. Figure 3.8-3 in Section 3.8 shows Federal national wildlife refuges (NWRs) and State wildlife management areas in the area of analysis.

## M.1 Natural Communities and Agricultural Habitats in Seller Service Area

This section describes the natural communities in the Seller Service Area that could be affected by long-term water transfers. The Seller Service Area includes the Sacramento and San Joaquin rivers watershed. Although the Central Valley is dominated by agricultural land, remnant grassland, oak woodlands, riparian and wetland habitats remain (Central Valley Joint Venture 2006; Point Reyes Bird Observatory 2005).

### M.1.1 Tidal Perennial Aquatic Natural Community

The tidal perennial aquatic natural community is defined as deepwater aquatic (greater than ten feet deep from mean lower low water[1]), shallow aquatic (less than or equal to ten feet deep from mean lower low water), and unvegetated intertidal (tideflats) zones of estuarine bays, river channels, and sloughs.

Tidal perennial aquatic natural community occurs in open water including sloughs and channels in the Bay Delta and bays. Deep, open water areas are largely unvegetated; beds of aquatic plants occur in shallower open-water areas. Over 50 species of fish use tidal perennial aquatic habitat at some stage of their life cycle, and many spend their entire lives within this natural community. Shorebirds, wadingbirds, waterfowl, river otters (*Lutra canadensis*), and beavers (*Castor canadensis*) are some of the terrestrial species that use this natural community.

### M.1.2 Saline Emergent Wetland Natural Community

Portions of San Francisco, San Pablo, and Suisun Bays and the Delta support emergent salt-tolerant or brackish-tolerant wetland plant species, collectively considered saline emergent wetland. This natural community is typically located within the intertidal zone

[1] Mean lower low water is the average height of the lowest tide recorded at a tide station each day during the recording period.

or on lands such as diked wetlands that historically experienced tidal exchange (Reclamation and Department of Water Resources [DWR] 2004). Cordgrass (*Spartina* sp.), pickleweed (*Salicornia* sp.), bulrush (*Schoenoplectus* spp.), saltgrass *(Distichlis spicata*), arrowgrass (*Triglochin* sp.), seablite (*Suaeda* sp.), hairgrass (*Deschampsia* sp.), cattails (*Typha* spp.), common reed (*Phragmites australis*), and algae are common dominant plant species in this natural community.

Over 25 species of birds and mammals have been documented in saline emergent wetlands (CALFED 2000). Over 220 species of birds, 45 species of mammals, 16 species of amphibians and reptiles, and over 40 fish species inhabit the Suisun Marsh environs (CDFG, USFWS, Reclamation 2011). Herons, egrets, ducks, hawks, and rodents are representative wildlife that occur in saline emergent wetlands.

### M.1.3 Tidal Fresh Emergent Wetland Natural Community

The tidal fresh emergent wetland natural community includes portions of the intertidal zones of the Delta that support emergent wetland plant species that are not tolerant of saline or brackish conditions. Tidal fresh emergent wetlands and brackish-water emergent marsh natural communities occur on in-stream islands and along mostly unleveed, tidally influenced waterways. Tidal emergent marsh provides habitat for many special-status species. The dominant vegetation in the tidal freshwater emergent natural community includes California bulrush (*Schoenoplectus californicus*), river bulrush (*Bolboschoenus fluviatilis*), big bulrush (*S. mucronatus*), tules (*Schoenoplectus acutus* var. *occidentalis*), cattails, and common reed.

Freshwater emergent wetlands are among the most productive wildlife habitats in California. They provide food, cover, and water for more than 160 species of birds as well as numerous mammals, reptiles, and amphibians (CDFG 2008). Over 50 species of birds, mammals, reptiles, and amphibians use freshwater emergent wetlands in the Delta (CALFED 2000).

### M.1.4 Non-tidal Fresh Emergent Wetland Natural Community

Non-tidal fresh emergent wetlands are scattered along the Sacramento River, typically in areas with slow-moving backwaters. Substantial portions of this natural community occur at the Colusa, Sutter, and Tisdale Bypasses, the Butte Sink, and at the Fremont Weir. Non-tidal fresh emergent wetland also occurs on the landward side of levees in the Delta, often in constructed waterways and ponds within agricultural lands. This natural community often occurs where soils are inundated or saturated for all or most of the growing season, such as around backwater areas.

Non-tidal fresh emergent wetland consists of permanent wetlands comprised of vegetation that is not tolerant of salt or brackish water, such as meadows (Barbour et al. 2007). These areas may be natural or managed. The dominant vegetation for this natural community includes thingrass (*Agrostis pallens*), spikerush (*Eleocharis* sp.), big leaf sedge (*Carex amplifolia*), bulrush, redroot nutgrass (*Cyperus erythrorhizos*), tules, cattails, common reed, and water grass (*Echinochloa oryzoides*).

Many wildlife species depend on non-tidal fresh emergent wetland for the entirety of their life cycles. In addition, this natural community is seasonally important to migratory species. Over 50 species of birds, mammals, reptiles, and amphibians use this natural community in the Delta (CALFED 2000). Examples of amphibians that occur within this natural community type include bullfrogs (*Rana catesbeiana*), western toads (*Bufo boreas*), and Pacific tree frogs (*Pseudacris regilla*). Birds typically found in non-tidal fresh emergent wetlands include herons, egrets, bitterns, mergansers, wood ducks (*Aix sponsa*), and yellow warblers (*Dendroica petechia*) (CDFG 2008).

### M.1.5 Natural Seasonal Wetland Natural Community

The natural seasonal wetland natural community can be found scattered along the Sacramento and American Rivers, typically in areas with slow-moving backwaters. Substantial portions of these natural communities occur at the Colusa, Sutter, and Tisdale Bypasses, the Butte Sink, and at the Fremont Weir. Seasonal wetlands, including vernal pools, are interspersed with other natural communities throughout Merced County.

Natural seasonal wetlands encompass non-managed systems with natural hydrologic connections. Typically, ponded water or saturated soils are present for an extended period of time in these natural communities, supporting obligate or facultative herbaceous wetland species (Reclamation and DWR 2004). Dominant vegetation in this natural community type includes big leaf sedge, bulrush, and redroot nutgrass.

Shorebirds and waterfowl such as killdeer (*Charadrius vociferus*), western sandpiper (*Calidris mauri*), greater yellow-legs (*Tringa melanoleuca*), American coot (*Fulica americana*), American widgeon (*Anas americana*), gadwall (*Anas strepera*), mallard (*Anas platyrhynchos*), canvasback (*Aythya valisineria*), and common moorhen (*Gallinula chloropus*) utilize natural seasonal wetlands. These birds prey extensively on invertebrates in the wetlands. This natural community also supports large mammals as well as several species of reptiles and amphibians. Many special-status wildlife species are associated with natural seasonal wetlands, including vernal pool species, which have substantially declined due to impacts of various land practices (e.g., development, invasion of non-native species, flood control activities restricting water movement, and lowered groundwater levels (Barbour et al. 2007). Special-status species are discussed in greater detail in Section 3.8.1.3.3.

### M.1.6 Managed Seasonal Wetland Natural Community

The managed seasonal wetland natural community occurs west of the Sacramento Deep Water Ship Channel, on the west side of the Sacramento River, between Willows and Dunnigan along the Colusa Basin Drain. Substantial portions of this natural community also occur at the Colusa, Sutter (including the Sutter Bypass Wildlife Area), Tisdale, and Yolo (including the Yolo Bypass Wildlife Area) Bypasses, at the Fremont Weir, and as a part of the Sacramento NWR Complex (six refuges totaling 38,486 acres). Privately managed wetlands occur in the Suisun Bay area, with water supplies provided by landowners' riparian or appropriative rights distributed by diversion from Delta channels and tributaries. Managed seasonal wetland natural communities on the east side of the Sacramento River generally occur along Butte Creek (Upper Butte Basin Wildlife Area) and along Angel Slough north of Butte City (Llano Seco Rancho Wildlife Area).

Managed seasonal wetland includes wetland areas that are flooded and drained by land managers in order to enhance habitat for wildlife species. Wetlands dominated by native or non-native herbaceous plants, as well as associated ditches and drains, are encompassed by this natural community type, excluding farmed croplands (California Waterfowl Association 2011).

The dominant vegetation in managed seasonal wetlands is comparable to that found in natural seasonal wetlands. Managed seasonal wetland natural communities are often managed for waterfowl such as mallards, northern pintails (*Anas acuta*), American widgeon, and Canada goose (*Branta canadensis*) and other geese. These natural communities also support a variety of wading birds and shorebirds, such as herons, egrets, terns, and gulls. Managed seasonal wetlands are of great importance to migratory waterfowl and shorebird populations during fall, winter, and spring, when bird populations in the Delta increase dramatically (USFWS 2007, California Waterfowl Association 2011). Many special-status species also utilize this natural community (CDFG 2008).

### M.1.7 Lacustrine Natural Community

The lacustrine natural community consist of permanent or intermittent lakes and ponds, and may also include dammed river channels and large reservoirs (Grenfell Jr. 1988a, 1988b, 1988c,1988d). Low-lying areas historically supported this natural community, and some additional areas have been created due to dam, dike and levee construction. Dead end sloughs, forebays, and flooded islands are other examples of the lacustrine natural community that can be found throughout the Delta. The lacustrine natural communities in the Seller Service Area that would be potentially impacted by the alternatives include the following reservoirs: Shasta, Oroville, New Bullards Bar, Camp Far West, Collins, Folsom, Hell Hole, French Meadows, and McClure. Unlike lakes and ponds, the reservoirs have been designed for water supply, flood control, and/or hydroelectric power production, although not all reservoirs serve all of these functions. Reservoirs are characterized by fluctuations in water surface elevation each year.

A wide variety of birds, mammals, reptiles and amphibians use the margins of reservoirs for reproduction, food, water, and cover resources. Fish-eating terns, grebes, cormorants, herons, waterfowl, beaver, river otter, and muskrat (*Ondatra zibethicus*) are some of the resident species (CALFED 2000; CDFG 2008).

### M.1.8 Valley/Foothill Riparian Natural Community

Valley/foothill riparian natural community generally occurs along river and stream corridors on the east side of the Sacramento Valley and is found in narrow bands within the upper reach of the San Joaquin River. Historically, the Merced River likely also supported this habitat type (Barbour et al. 2007). Riparian vegetation is also scattered throughout the Delta on islands, along levees, in backwater areas and sloughs, and in thin bands along river channels. This habitat type is associated with low-gradient reaches of non-tidal streams and rivers (generally below an elevation of 300 feet) and is comprised of the successional stages of woody vegetation within the active and historical floodplains and may be associated with gravel bars and bare cut banks, shady vegetated banks, and sheltered wetlands such as sloughs, side channels, and oxbow lakes

(Sacramento River Advisory Council 2001). Trees typically associated with the valley/foothill riparian natural community include willows (*Salix* spp.), Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*), and western sycamore (*Platanus racemosa*) (Barbour et al. 2007). Shaded riverine aquatic, pool, riffle, run, unvegetated channel, sloughs, backwaters, overflow channels, and flood bypasses with hydrologic connection to stream and river channels are the aquatic habitats associated with the valley/foothill riparian natural community type (Barbour et al. 2007).

In California, over 225 species of birds, mammals, reptiles, and amphibians depend on riparian habitats. Cottonwood-willow riparian areas support more breeding avian species than any other comparable broad California habitat type (Sacramento River Advisory Council 2001, Stillwater Sciences 2002). Riparian habitat supports a myriad of invertebrates, such as wood-boring larvae. Woodpeckers, warblers, flycatchers, and owls are common inhabitants of this natural community, as are wintering and breeding raptors and passerines (Reclamation and San Joaquin River Group Authority 1999). Other wildlife species that use riparian habitats include western fence lizard (*Sceloporus occidentalis*), Pacific tree frog, western toad, bullfrog, western skink (*Eumeces skiltonianus*), western whiptail (*Cnemidophorus tigris*), southern alligator lizard (*Elgaria multicarinata*), racer (*Coluber constrictor*), gopher snake (*Pituophis catenifer*), king snake (*Lampropeltis* sp.), garter snake (*Thamnophis* sp.), northern Pacific rattlesnake (*Crotalus oreganus oreganus*), opossum (*Didelphis virginiana*), black-tailed jackrabbit (*Lepus californicus*), western gray squirrel (*Sciurus griseus*), ringtail (*Bassariscus astutus*), river otter, striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), beaver, mule deer (*Odocoileus hemionus*), and a number of bat species. Riparian areas serve as significant corridors for wildlife movement (Sacramento River Advisory Council 2001).

### M.1.9 Montane Riparian Natural Community

The montane riparian natural community occurs in the floodplain of streams and rivers at elevations above approximately 300 feet (Reclamation and DWR 2004). Within the area of analysis, montane riparian natural community is found on the Yuba River northward from the Timbuctoo Bend, just upstream of Highway 20, as well as on the segment of American River located northeast of Folsom Reservoir. Montane riparian vegetation is dominated by black cottonwood (*Populus trichocarpa*) and Fremont cottonwood (at lower altitudes), white alder (*Alnus rhombifolia*), bigleaf maple (*Acer macrophyllum*), dogwood (*Cornus* sp.), box elder (*Acer negundo*), quaking aspen (*P. tremuloides*), western azalea (*Rhododendron* sp.), water birch (*Betula occidentalis*), and buttonbush (*Cephalanthus occidentalis*). Montane riparian natural community supports a diversity of wildlife species comparable to that of the valley/foothill riparian natural community.

### M.1.10 Grassland Natural Community

Grasslands are most prevalent at the eastern and western edges of the Central Valley. Areas downstream of Lake Oroville along the Feather River and portions of the American River (Folsom Reservoir Shoreline) also contain the grassland natural community (Barbour et al. 2007). The grassland natural community occurs in many outlying areas surrounding the Delta, as well as on islands within the Delta region (Reclamation and DWR 2004). The Delta historically supported perennial grasslands associated with wetland and riparian areas, as well as in association with vernal pools at

higher elevations in drier locations. Grasslands in the Delta estuary continue to decline due to land conversion, as well as invasion by non-native annual species.

Grasslands are an upland natural community often dominated by non-native annual species including wild oats (*Avena* sp.), soft chess (*Bromus hordeaceus*), brome (*Bromus* sp.), Italian ryegrass (*Festuca perennis*), mustards (Brassicaceae), foxtail (*Alopecurus* sp.), and barley *(Hordeum* sp.). Many grassland areas within the area of analysis are in active use as rangelands. Forbs commonly observed in this natural community include filarees (*Erodium* spp.), clovers (*Trifolium* spp.), popcorn flower (*Plagiobothrys* sp.), and mullein (*Verbascum* sp.). Wildlife species of the grassland natural community include western fence lizard, garter snake, rattlesnake, black-tailed jackrabbit, California ground squirrel (*Spermophilus beecheyi*), Botta's pocket gopher (*Thomomys bottae*), harvest mouse (*Reithrodontomys megalotis*), California vole (*Microtus californicus*), badger (*Taxidea taxus*), and coyote (*Canis latrans*). Bird species include western meadowlark (*Sturnella neglecta*), turkey vulture (*Cathartes aura*), and American kestrel (*Falco sparverius*) (Barbour et al. 2007; CDFG 2008).

### M.1.11 Inland Dune Scrub Natural Community

Inland dune scrub natural community consists of vegetated, stabilized sand dunes associated with river and estuarine systems, such as that at Antioch Dunes NWR and Brannan Island State Park. The Antioch-Oakley areas, Delta marshes, and small isolated dunes on the eastern edge of the Delta also historically supported inland dune scrub (Reclamation and DWR 2004).

This natural community is dominated by mostly sensitive species (see Appendix N), but also contains common plants such as primrose (*Camissonia* sp.), wallflower (*Erysimum* sp.), buckwheat (*Eriogonum* sp.), elegant clarkia (*Clarkia unguiculata*), California poppy (*Eschscholzia californica*), California croton (*Croton californicus*), gumplant (*Grindelia* sp.), deerweed (*Acmispon* sp.), telegraph weed (*Heterotheca grandiflora*), California matchweed (*Gutierrezia* sp.), and silver bush lupine (*Lupinus albifrons*). Common wildlife species known to occur within the inland dune scrub natural community include mink (*Mustela vison*), desert cottontail (*Sylvilagus audubonii*), beaver, muskrat, opossum, weasel (*Mustela* sp.), striped skunk, gopher (*Thomomys* sp.), gray fox (*Urocyon cinereoargenteus*), California ground squirrel, coyote, black-tailed jackrabbit, raccoon, Townsend's mole (*Scapanus townsendii*), weasel (*Mustela* sp.), red fox (*Vulpes vulpes*), California legless lizard (*Anniella pulchra*), sideblotched lizard (*Uta stansburiana*), coast horned lizard (*Phrynosoma coronatum*), San Joaquin whipsnake (*Masticophis flagellum ruddocki*), glossy snake (*Arizona elegans*), western whiptail lizard (*Cnemidophorus tigris*), and western fence lizard.

### M.1.12 Upland Scrub Natural Communities

Upland scrub natural communities in the area of analysis include mixed chaparral, sage scrub, saltbush scrub, and valley sink scrub. Mixed chaparral natural community occurs on steep south-facing slopes along the Middle and Lower North Forks of the American River and portions of Folsom Reservoir also provide upland scrub natural community (Placer County Development Resources Agency 2011; California State Parks 2007). In Contra Costa County, the surroundings of Los Vaqueros Reservoir support Diablan sage

scrub, chaparral, and remnants of valley sink scrub natural community (Contra Costa Water District [WD] 2005; East Contra Costa Habitat Conservancy 2006). Common plant species observed in these natural communities include buckbrush (*Ceanothus* spp.), manzanita (*Arctostaphylos* spp.), bitter cherry (*Prunus emarginata*), oaks, poison oak (*Toxicodendron diversilobum*), coffee berry (*Frangula* sp.), California buckeye (*Aesculus californica*), toyon (*Heteromeles arbutifolia*), sugar sumac (*Rhus ovata*), chamise (*Adenostoma fasciculatum*), California saltbush (*Atriplex californica*), sagebrush (*Artemisia* sp.), and creosote bush (*Larrea tridentata*) (Barbour et al. 2007).

Upland scrub natural communities support many common wildlife species. Spotted towhee (*Pipilo maculatus*), California quail (*Callipepla californica*), California thrasher (*Toxostoma redivivum*), and red-tailed hawk (*Buteo jamaicensis*) are frequently observed in upland scrub. Common mammals occurring within this habitat include brush rabbit (*Sylvilagus bachmani*), blacktailed jackrabbit, and mule deer (CDFG 2008).

### M.1.13 Seasonally Flooded Agriculture Habitat

Seasonally flooded agriculture is concentrated in the Sacramento Valley portion of the area of analysis. The central Delta also supports small grains croplands. Lands that fall within this habitat require seasonal flooding for at least one week at a time for irrigation or pest control purposes, and may include grain, rice (*Oryza* sp.), and other crops. Grain crops are typically post-harvest flooded in the winter season, which provides habitat for waterfowl and other wildlife.

Rice fields provide particularly important foraging habitat for a variety of wildlife species. Many species forage on post-harvest waste grain and other food found within the fields (Pitkin 2011; Central Valley Joint Venture 2006). Small birds and rodents that consume rice waste grain are a food source for raptors that forage in the seasonally flooded fields. Duckweed (*Lemna* sp.) and other moist soil plants, which may grow in fields where water level manipulation allows their germination, can provide high-quality food for waterfowl (California Waterfowl Association 2011). Fish are often entrained in the irrigation canals that supply water to the rice fields. Crayfish are found in the canal banks and berms of the rice fields. Other invertebrates and their larvae may be found in very shallow water, particularly during an early to midseason drawdown. Invertebrates found in these areas (e.g., bloodworms) are particularly important to shorebirds (California Waterfowl Association 2011).

Rice fields also provide resting, nesting, and breeding habitat similar to that in natural wetlands. Irrigation ditches can contain wetland vegetation such as cattails, which provide cover habitat for rails, egrets, herons, bitterns, marsh wrens (*Cistothorus palustris*), sparrows, and common yellowthroats (*Geothlypis trichas*). Rice fields provide pair, brood, and nesting habitat for birds such as mallard duck, northern pintail, and terns (Central Valley Joint Venture 2006, CDFG 2008).

### M.1.14 Upland Cropland Habitat

Upland cropland areas are found throughout the Sacramento and San Joaquin valleys, as well as adjacent to most leveed waterways. This habitat is considered to include agricultural lands that are not seasonally flooded. Sacramento Valley croplands are dominated by cereal rye (*Secale cereale*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), milo (*Sorghum* sp.), corn (*Zea mays*), dry beans, safflower (*Carthamus tinctorius*), sunflower (*Helianthus annuus*), alfalfa (*Medicago sativa*), cotton (*Gossypium* sp.), tomatoes (*Lycopersicon* sp.), lettuce (*Lactuca sativa*), Bermuda grass (*Cynodon dactylon*), Italian ryegrass, tall fescue (*Festuca arundinacea*), almonds (*Prunus dulcis*), walnuts (*Juglans* sp.), peaches (*Prunus persica*), plums (*Prunus* sp.), and grapes (*Vitis* sp.) and other fruits and vegetables. Most of these crops are annuals, planted in the spring and harvested during summer or fall. Wheat and other dryland grains are planted in the fall and harvested in the late spring, early summer. Sugar beets (*Beta vulgaris*) can also be left over winter and harvested in the spring.

Wildlife use of upland crop areas varies throughout the growing season with crop type, level of disturbance, and available cover. Upland crop fields provide important foraging habitat for a variety of wildlife species. Many species forage on crops (waste and otherwise) and other food found within the fields, such as invertebrates. Typically, various birds and rodents consume the crops and invertebrates and serve as a food source for predators. Irrigation ditches associated with upland cropland can contain wetland vegetation such as cattails, which provide cover habitat for rails, egrets, herons, bitterns, marsh wrens, sparrows, and common yellowthroats.

## M.2 Natural Communities and Agricultural Habitats in Buyer Service Area

This section describes the natural communities, agricultural habitats and associated plant and wildlife species that are present in the Buyer Service Area. The Buyer Service Area includes portions of Contra Costa and Alameda Counties (Contra Costa WD, East Bay Municipal Utility District), Santa Clara County (Santa Clara Valley WD), and northern San Benito County (San Benito County WD). The Buyer Service Area also includes the area that extends south from San Joaquin County to northwestern Kings County, which contains potential buyers that are member agencies of San Luis & Delta-Mendota Water Authority.

### M.2.1 Lacustrine Natural Community

The lacustrine natural community in the Buyer Service Area occurs within San Luis Reservoir on the western edge of the San Joaquin Valley.

Wildlife species that may be found within the lacustrine natural community in the Buyer Service Area include belted kingfisher (*Megaceryle alcyon*), Caspian tern (*Hydroprogne caspia*), ring-billed gull (*Larus delawarensis*), Clark's grebe (*Aechmophorus clarkii*), western grebe (*Aechmophorus occidentalis*), pied-billed grebe (*Podilymbus podiceps*), osprey (*Pandion haliaetus*), great egret (*Ardea alba*), spotted sandpiper (*Actitis macularius*), and killdeer.

### M.2.2 Valley/Foothill Riparian Natural Community

This natural community occurs in the Buyer Service Area along many of the segments of the San Joaquin River from Friant Dam through the Central Valley into the Delta and is comprised primarily of mixed oak, cottonwood, and willow. Valley/foothill riparian natural community is present at San Luis Reservoir in the form of sparse mule fat and willow patches. In addition to the plant species previously mentioned in the other regions, riparian habitats south of the Delta may support Northern California black walnut, a species considered sensitive by CDFW.

Common species that may occur in this vegetation community and associated aquatic habitat within the Buyer Service Area include black phoebe (*Sayornis nigricans*), red-winged blackbird (*Agelaius phoeniceus*), Brewer's blackbird (*Euphagus cyanocephalus*), ash-throated flycatcher (*Myiarchus cinerascens*), northern rough-winged swallow (*Stelgidopteryx serripennis*), western scrub jay (*Aphelocoma californica*), black-headed grosbeak (*Pheucticus melanocephalus*), California quail, Nuttall's woodpecker (*Picoides nuttallii*), oak titmouse (*Baeolophus inornatus*), California towhee (*Pipilo crissalis*), Merriam's chipmunk (*Tamias merriami*), mule deer, coyote, black bear (*Ursus americanus*), mountain lion (*Puma concolor*), and raccoon.

### M.2.3 Grassland Natural Community

Substantial areas of non-native grassland are present in Contra Costa, Santa Clara, and Merced Counties. This includes lands surrounding San Luis Reservoir. Non-native grasses in these locations intergrade with native species including purple needle grass (*Stipa pulchra*), beardless wild rye (*Elymus triticoides*), and onion grass (*Melica* sp.).

Killdeer, white-throated swift (*Aeronautes saxatalis*), ring-necked pheasant (*Phasianus colchicus*), American crow (*Corvus brachyrhynchos*), rufous-crown sparrow (*Aimophila ruficeps*), rock wren (*Salpinctes obsoletus*), western meadowlark, red-tailed hawk, American kestrel, common loon (*Gavia immer*), Barrow's goldeneye (*Bucephala islandica*), savannah sparrow (*Passerculus sandwichensis*), California vole, black-tailed jackrabbit, California ground squirrel, coyote, foxes, badgers, skunk, western rattlesnake, southern alligator lizard, two-striped garter snake (*Thamnophis hammondii*), California mountain kingsnake (*Lampropeltis zonata*), and western fence lizard are some of the species that would commonly be observed within grasslands in the Buyer Service Area.

### M.2.4 Oak Woodland Natural Community

Scattered blue oak (*Quercus douglasii*) woodlands occur on the western shore of the San Luis Reservoir. Remnant patches are often found at the edges of agricultural lands that were converted from woodland to cultivation, and occur in larger stands leading up to the Sierra Nevada foothills. The oak woodland natural community varies with respect to the mix of hardwoods, conifers or shrubs present, and also demonstrates a range of canopy densities. Valley oak, blue oak, interior live oak (*Quercus wislizeni*), coast live oak (*Q. agrifolia*), and foothill pine (*Pinus sabiniana*) are common dominant species (Barbour et al. 2007).

Acorn woodpecker (*Melanerpes formicivorus*), northern flicker (*Colaptes auratus*), wild turkey (*Meleagris gallopavo*), oak titmouse, black-tailed jackrabbit, American crow, California quail, western fence lizard, coyote, mule deer, western bluebird (*Sialia mexicana*), white-breasted nuthatch (*Sitta carolinensis*), and American kestrel are commonly observed wildlife species in oak woodland within the Buyer Service Area (CDFG 2008).

### M.2.5 Upland Cropland Habitat

Upland cropland areas are found throughout the San Joaquin Valley. Major crops in this area include alfalfa, almonds, corn, cotton, grapes, rice, and tomatoes (County of Fresno Department of Agriculture 2010; Merced County Department of Agriculture 2010; San Joaquin County 2010). These crops support common species, and may be important to common and sensitive wildlife, especially during irrigation periods. For example, cotton is known to harbor mourning doves (*Zenaida macroura*) and house mice (*Mus musculus*) and may also support species such as killdeer, American pipit (*Anthus rubescens*), and horned lark (*Eremophila alpestris*) (CDFG 2008). San Joaquin kit fox (*Vulpes macrotis mutica*), a federally endangered species, has been known to utilize croplands for forage as well (USFWS 1998). Ditches associated with intensive cropland are often chemically treated and therefore are less likely to serve as suitable habitat for wildlife species.

## M.3 References

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# Appendix N

# Special-Status Animals and Plants with Potential to Occur in the Area of Analysis

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# Appendix N
# Special-Status Animals and Plants with Potential to Occur in the Area of Analysis

**Table N-1.**
**Special-Status Animals with Potential to Occur in the Area of Analysis**

| **Common Name** *Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Invertebrates** | | | | | | |
| **Bay checkerspot butterfly** *Euphydryas editha bayensis* | T | -- | Historically occurred east, west, and south of SF bay, to Mt. Diablo south to Hollister. Currently, restricted to six core areas on the west and southern edges of the SF bay - SF peninsula, San Mateo County, and Santa Clara County, Any site with appropriate habitat within historic range should be considered potentially occupied (Black and Vaughan 2005a) | Restricted to native grasslands on outcrops of serpentine soil. The primary host plant for this butterfly is *Plantago erecta (*Dwarf plantain*)*. Secondary host plant include *Othocarpus densiflorou*s, *O.purpurscens,* and Purple owl's clover. Prefers shallow, serpentine-derived soils. | Adult present in spring. Flight season late February to early May. | None. Occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. However, no impacts are expected to native grasslands. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
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| **Conservancy fairy shrimp**<br>*Branchinecta conservatio* | E | -- | Northern two-thirds of the Central Valley. It ranges from Vina Plains of Tehama County; Sacramento NWR in Glenn County; Jepson Prairie Preserve and surrounding area east of Travis Air Force Base, Solano County; Mapes Ranch west of Modesto, Stanislaus County. | Inhabits the ephemeral water of swales and vernal pools. It is most commonly found in grass or mud bottomed swales, earth sump, or basalt flow depression pools in unplowed grasslands. | Has been collected from early December to early May. | None. Occurrences have been documented within the Seller Service Area. Suitable habitat occurs within the area of analysis. No impacts to vernal pool or other habitats occupied by this species are anticipated. The species is not likely to occur to occur in rice fields and canals due to predators (i.e. fish). |
| **Lange's metalmark butterfly**<br>*Apodemia mormo langei* | E | -- | Restricted to sand dunes along the southern bank of the Sacramento-San Joaquin River. Within Contra Costa County, it is currently found only at Antioch Sand Dunes. | Inhabits stabilized dunes along the San Joaquin river and is endemic to Antioch sand dunes, Contra Costa county. The butterfly's primary host plant is *Eriogonum nudum var. auriculatum*. It feeds on nectar of other wildflowers, as well as host plant. | Breeding season is August - September, Larvae hatch during rainy months. | None. CNDDB occurrences have been documented within the Buyer Service Area, however no impacts to sand dunes are anticipated. |
| **Longhorn fairy shrimp**<br>*Branchinecta longiantenna* | E | -- | Restricted to northern, central, and portions of southern California; populations along the eastern margin of the Central Coast Mountains from Concord, Contra Costa County south to Soda Lake in San Luis Obispo County; the Kellogg Creek watershed; the Altamont Pass area; the western and northern boundaries of Soda Lake on the Carrizo Plain; and Kesterson National Wildlife Refuge in the Central Valley. | Endemic to the eastern marring of the central coast mountains in seasonally astatic grassland vernal pools. Found in ephemeral freshwater habitats, such as vernal pools and swales. | Has been observed from late December until late April. | None. Occurrences have been documented within the Seller Service Area. Suitable habitat may occur within the area of analysis. The species is not likely to occur to occur in rice fields and canals due to predators (i.e. fish). Transfers are not expected to impact any suitable grassland vernal pools or swales. |

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|---|---|---|---|---|---|---|
| **San Bruno elfin butterfly** *Callophrys mossii bayensis* | E | -- | Found in vicinity of San Bruno mountains, San Mateo County (Black and Vaughan 2005b). | Found in coastal, mountainous areas with grassy ground cover. Colonies are located on steep, north-facing slopes within the fog belt. Larval host plant is *Sedum spathulifolium.* | Year round | None. Occurrences have been documented in the Buyer Service Area and suitable habitat is present in the area. No impacts are anticipated to mountainous areas near San Bruno. Therefore no impacts to the species are expected. |
| **Valley elderberry longhorn beetle** *Desmocerus californicus dimorphus* | T | -- | Occurs only in the Central Valley and surrounding foothills below 3,000 feet elevation (USFWS 1999a). | Dependent on elderberry shrubs (host plant) as a food source. Potential habitat consists of shrubs with stems one inch in diameter within Central Valley. | Year round for host plant and exit holes; March to June for adults | None. Occurrences have been documented within the Seller Service Area. Suitable habitat may occur within the area. However, elderberry shrubs would not be impacted by transfers, therefore no impacts are anticipated to the species. |
| **Vernal pool fairy shrimp** *Branchinecta lynchi* | T | -- | Endemic to the Central Valley, Central Coast Mountains, and South Coast Mountains of California. It ranges from the Vina Plains in Tehama County, through the Central Valley, and south along the Central Coast to northern Santa Barbara County. | Endemic to the grasslands of the Central Valley, central coast mountains, and south coast mountains. Inhabits the ephemeral water of swales and vernal pools. It is most commonly found in grassed or mud bottomed swales, earth sump, or basalt flow depression pools in unplowed grasslands. | Has been collected from early December to early May. | None. Occurrences have been documented in both the Buyer and the Seller Service areas. Rice fields and canals are not likely to support this species due to the presence of predators (i.e. fish), therefore no impacts are anticipated to the species. Transfers are not expected to impact vernal pools or natural wetlands. |

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| **Vernal pool tadpole shrimp**<br>*Lepidurus packardi* | E | -- | Endemic to the northern portion of the Central Valley of California. This species occurs from the Millville Plains and Stillwater Plains in Shasta County south throughout the Central Valley to Merced County. | Found in a variety of natural and artificial seasonally ponded Sacramento valley habitat types including: vernal pools, swales, ephemeral drainages, stock ponds, reservoirs, ditches, backhoe pits, and ruts caused by vehicular activities. | Has been collected from early December to early May. | None. Occurrences have been documented in both the Buyer and the Seller Service area. Suitable habitat is present in the area. Rice fields and canals are not likely to support this species due to the presence of predators (i.e. fish), therefore there is a low potential for impacts to the species. Transfers are not expected to impact vernal pools or natural wetlands. No impacts to the species are expected. |
| **Zayante band-winged grasshopper**<br>*Trimerotropis infantilis* | E | -- | Known only from Santa Cruz County. Found in local Santa Cruz mountains (the Zayanite Sand Hills ecosystem) (Santa Cruz Public Libraries 2012). | Found in isolated sandstone deposits. Inhabits mostly sand parkland habitat, but also in areas with well-developed ground cover and in sparse chaparral with grass. | Flight season from late May - Oct. | None. Occurrences have been documented in the Buyer Service Area and suitable habitat is present in the area, however, no impacts to suitable habitat are anticipated. |
| **Amphibians** | | | | | | |
| **California red-legged frog**<br>*Rana aurora draytonii* | T | SSC | Northwestern California, from Mendocino County south to northwestern Baja California. May now be extirpated in the southern Sierra Nevada; other Sierra Nevada foothill populations are small and highly localized. Nearly all current Central Valley sites are on the Coast Range slope, usually below 1,200m (3,936 ft). | Usually found in or near quiet permanent water of streams, freshwater marshes, or (less often) ponds and other quiet bodies of water; also damp woods and meadows some distance from water. Occurs in sites with dense vegetation (e.g., willows) close to water. | Year round. Little movement away from streamside habitats. Occasionally found on roads at night during winter and spring rains. | None. Suitable habitat is present within the area and occurrences of this species have been previously documented in the Buyer Service Area. Environmental Commitments would cause potential impacts to California red-legged frog to be negligible. |

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|---|---|---|---|---|---|---|
| **California tiger salamander**<br>*Ambystoma californiense* | T[1], E[2] | T | Found in annual grassland habitat, grassy understories of valley-foothill hardwood habitats, and uncommonly along stream courses in valley-foothill riparian habitats. Occurs from near Petaluma, Sonoma County, and east through the Central Valley to Yolo and Sacramento Counties and south to Tulare County.; and from the vicinity of San Francisco Bay south to Santa Barbara County. Occurs at elevations from 3m -1,054m (3200ft). | Lives in vacant or mammal-occupied burrows, occasionally other underground retreats, throughout most of the year, in grassland, savanna, or open woodland habitats. Lays eggs on submerged stems and leaves, usually in shallow ephemeral or semi permanent pools and ponds that fill during heavy winter rains, sometimes in permanent ponds; breeding takes place in fish free pools and ponds. | Migrates up to two km between terrestrial habitat and breeding pond. Migrations may occur from November through April. | None. Occurrences have been documented within both the Buyer and Seller Service Areas. Suitable habitat may occur within the area, but would not be impacted by transfers. This species is not expected to occur in rice fields due to predatory fish. Existing Environmental Commitments would maintain flow and temperature in streams. |
| **Foothill yellow-legged frog**<br>*Rana boylii* | -- | SSC | This species is known from the Pacific drainages from Oregon to the upper San Gabriel River, Los Angeles County, California, including the coast ranges (west pf Cascade crest) and Sierra Nevada foothills in the United States. Isolated populations in San Joaquin County on the floor of the Central Valley. Elevation range extends from near sea level to 1940m (6370ft). | This species inhabits partially shaded, rocky streams at low to moderate elevations, in areas of chaparral, open woodland, and forest. Rarely encountered far from permanent water. | Year round. Significant seasonal movements for migrations from breeding area have not been reported. | None. Occurrences have been documented within both the Buyer and Seller Service Areas. Suitable habitat is present within the area. However Transfers are not expected to impact any suitable rocky stream and woodland habitats. No impact to the species is expected. |

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| **Western spadefoot toad**<br>*Spea hammondii* | -- | SSC | This species occurs in the Central Valley and bordering foothills of California and along the Coast Ranges into northwestern Baja California, Mexico. In the Coast Ranges it is found from Point Conception, Santa Barbara County, south to Mexican border. Elevation ranges from near sea level to 1,363m (4,460 ft). | Lowlands to foothills, grasslands, open chaparral, pine-oak woodlands. Prefers short grass plains, sandy or gravelly soil. It is fossorial and breeds in temporary rain pools and slow-moving streams that do not contain bullfrogs, fish, or crayfish. | Year round. Usually in underground burrows most of year, but will travel several meters on rainy nights. Movement is rarely extensive. | None. Occurrences have been documented from both the Buyer and Seller Service Areas. Suitable habitat is present in the area. Transfers would not impact suitable upland habitat types. The species is not likely to occur in rice fields due to the presence of predatory fish, bullfrogs etc. Environmental Commitments to maintain flows will protect Western spadefoot toad. |
| **Reptiles** | | | | | | |
| **Alameda whipsnake**<br>*Masticophis lateralis euryxanthus* | T | T | Seven populations (recovery units) are known from Alameda and Contra Costa Counties, including the Mt. Diablo area and other East Bay Regional Parks, south almost to the border of Alameda and Santa Clara Counties. Likely occurred historically within San Joaquin and northern Santa Clara Counties. | The species is typically found in chaparral and scrub habitats, but it will also use adjacent grassland, oak savanna and woodland habitats. It is mostly found on south-facing slopes & ravines, with rock outcrops, deep crevices or abundant rodent burrows. | Year round. | None. Occurrences have been documented within the Buyers and Sellers Service Areas. No impacts to suitable habitat for Alameda whipsnake are anticipated. |
| **Blunt-nosed leopard lizard**<br>*Gambelia sila* | E | E | Currently known from undeveloped land within the San Joaquin Valley and the Coast Range foothills. Historically, the blunt-nosed leopard lizard ranged from the San Joaquin Valley and foothills from Stanislaus County south to northern Santa Barbara and Ventura Counties, with observations below 800m elevation. | This species is a resident of sparsely vegetated alkali and desert scrub habitats in areas of low topographic relief. The lizard seeks cover in mammal burrows, under shrubs or structures such as fence posts. | Year round. Hibernates during winter and active from late-March - July. | None. Occurrences have been documented within the Buyer Service Area and suitable habitat is present within the area of analysis. No impacts to suitable habitat for blunt-nosed leopard lizard are anticipated. |

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|---|---|---|---|---|---|---|
| **Coast horned lizard**<br>*Phrynosoma blainvillii* | -- | SSC | Occurs in the Sierra Nevada foothills from Butte County to Kern County and throughout the central and southern California coast. Its elevational range extends up to 1200m (4000ft) in the Sierra Nevada foothills and up to 1800m (6000ft) in the mountains of southern California. | The species frequents a wide variety of habitats and is most commonly found in lowlands along sandy washes with scattered low bushes. It inhabits open areas for sunning, bushes for cover, patches of loose soil for burial & abundant supply of ants and other insects. | Year round. | None. Occurrences have been documented within both the Buyer and Seller Service Areas. No potential impacts to suitable habitat are anticipated. |
| **Giant garter snake**<br>*Thamnophis gigas* | T | T | Endemic to wetlands in the Sacramento and San Joaquin Valleys from Chico, south to the Mendota Wildlife Area in Fresno County. | Marshes, sloughs, ponds, small lakes, streams and other waterways. Typically occurs in areas that provide adequate water during the active season with emergent wetland vegetation. Basking habitat consists of grassy areas or openings adjacent to aquatic habitat, and upland areas are also used for refuge from flood conditions (USFWS 2006) | Year round | High. Suitable habitat is present within the Buyer and Seller Service Areas. Suitable habitat in the Seller Service Area is intermittent based on normal variation in cropping. Direct impacts may include reduction in suitable aquatic habitat within the Seller Service Area. The greatest impact would occur during the breeding season. Conservation measures are in place to maintain aquatic habitat corridors within irrigation ditches. |
| **San Francisco garter snake**<br>*Thamnophis sirtalis tetrataenia* | E | E | Historically occurred from north of the San Francisco-San Mateo County line south to Ano Nuevo State Reserve, west of the Santa Cruz Mountains (USFWS 2017). | The species is found in the vicinity of freshwater marshes, ponds and slow moving streams in San Mateo county and the extreme northern Santa Cruz county. The snake prefers dense cover and water depths of at least 1ft. Upland areas near water are also very important for this species. | Year round | None. Suitable habitat may be present in a small portion of the Buyer Service Area within San Mateo County. No impacts to suitable San Francisco garter snake habitat are anticipated in association with the proposed Transfers. |

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| **San Joaquin whipsnake**<br>*Masticophis flagellum ruddocki* | -- | SSC | Known from as far north as Arbuckle, Colusa County through the San Joaquin Valley and Coast Ranges south into Kern and Santa Barbara Counties. | The species is found in open, dry habitats with little or no tree cover, generally at elevations 20 - 900m. It is also found in valley grassland and saltbush scrub in the San Joaquin valley. The snake requires mammal burrows for refuge and oviposition sites. | Year round. | None. Suitable habitat is present within the Buyer Service Area in the San Joaquin Valley. There is a very low potential that this species could occur in or adjacent to agriculture within the Buyer Service Area, but no conversion of suitable habitat would occur in association with the proposed Transfers. |
| **Silvery legless lizard**<br>*Anniella pulchra* | -- | SSC | The silvery legless lizard ranges from Antioch in Contra Costa County south through the Coast, Transverse, and Peninsular Ranges along the western edge of the Sierra Nevada Mountains. It occurs in the San Joaquin Valley and Mojave Desert down into Baja California. In the Sierra Nevada foothills it may occur at elevations up to 1,800m asl. (Contra Costa County 2006). | Sandy or loose loamy soil. May occur under sparse vegetation of beaches, chaparral, or pine-oak woodland, or near sycamores, cottonwoods, or oaks that grow on stream terraces. Often found under logs, rocks, old boards, or compacted debris of woodrat nests. Requires refugia with soil moisture during hot conditions. Agriculture and disturbed sites are not known to support the species (Contra Costa County 2006). | Year round | None. Suitable habitat is present within both the Buyer and Seller Service Areas, and previous records exist within the Buyer Service Area. Transfers are not expected to impact suitable habitat for the silvery legless lizard. |
| **Pacific pond turtle**<br>*Actinemys marmorata* | -- | SSC | Ranged from extreme western Washington and British Columbia to northern Baja California, mostly to the west of the Cascade-Sierra crest. | The western pond turtle occupies a wide variety of wetland habitats including rivers and streams (both permanent and intermittent), lakes, ponds, reservoirs, permanent and ephemeral shallow wetlands, abandoned gravel pits, stock ponds, and sewage treatment. | Year round | High. Suitable habitat occurs within the area of analysis. Pond turtles may occur in ditches, canals, rice fields, etc. Environmental Commitments would cause potential impacts to California red-legged frog to be negligible. |

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| **Birds[3]** | | | | | | |
| **Alameda song sparrow**<br>*Melospiza melodia pusillula* | -- | SSC | Endemic, restricted to fringes of south San Francisco Bay (east to El Cerrito, south to Alviso and west to San Francisco). Largest concentration near Dumbarton Point salt marsh, Alameda County. | The species is a resident of salt marshes. It inhabits salicornia marshes, nests low in grindelia bushes and in salicornia. | Year round, non-migratory. Breeds late-Feb to mid-August. | None. Occurrences have been documented within the Buyer Service Area. Suitable habitat may occur within the area of analysis. However, Transfers are not expected to impact any suitable habitat (i.e. salt marshes). |
| **American peregrine falcon**<br>*Falco peregrinus anatum* | D | E, FP | Throughout California. Uncommon resident that breeds along coast north of Santa Barbara, in the Sierra Nevada, and other northern CA mountains. Migrant birds occur along the coast and the western Sierra Nevada. | Breeds in woodland, forest and coastal habitats on protected cliffs and ledges. Riparian areas and coastal and inland wetlands are important habitats yearlong especially during the non-breeding season. | Year round. Coastal migrants occur in Spring and Fall. | None. Rice fields may provide suitable foraging habitat for the species, but birds could relocate to other habitat areas in the vicinity. No nesting habitat would be affected by Transfers. |
| **Bald eagle**<br>*Haliaeetus leucocephalus* | D | E | Throughout California. Breeding mostly in Butte, Lake, Lassen, Plumas, Shasta, Siskiyou, and Trinity counties. Winter migrant at inland waters. | Riparian areas near coasts, rivers, and lakes. Nesting generally occurs in large old-growth trees in areas with little disturbance. In flooded fields, occasionally hunts for small mammals. | Year round. Local winter movements. | None. Occurrences have been documented within both the Buyer and Seller Service Area and both areas provide suitable habitat. No impacts to suitable nesting habitat are anticipated. Rice fields represent marginal foraging habitat. Birds would be able to relocate to other suitable habitat areas in the vicinity if fields were fallowed. Environmental commitments limit the amount of land that can be fallowed in a given county. |

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| **Bank swallow**<br>*Riparia riparia* | -- | T | A neotropical migrant found primarily in riparian and other lowland habitats in California west of the deserts during the spring-fall period. Breeding population in California occurs along banks of the Sacramento and Feather rivers in the northern Central Valley. Casual in southern California in winter. Other colonies along the central coast from Monterey to San Mateo counties. | Requires vertical banks and cliffs with fine-textured or sandy soils near streams, rivers, ponds, lakes, and the ocean for nesting. Feeds primarily over grassland, shrub land, savannah, and open riparian areas during breeding season and over grassland, brushland, wetlands, and cropland during migration. | March-mid-September | None. Known from both the Buyer and Seller Service Areas. No suitable nesting habitat (i.e. cliffs) would be affected. There is potential that Transfers would reduce the area of cropland habitat used for foraging during migration (wetlands and croplands) due to changes in water application. However, fallow cropland would still providing suitable foraging habitat, and birds could forage at other croplands in the vicinity. Environmental commitments limit the amount of cropland idling that would occur. |
| **Black swift**<br>*Cypseloides niger* | -- | SSC | Breeds locally in Sierra Nevada and Cascade range, San Gabriel, San Bernardino and San Jacinto Mts. Also in coastal bluffs and mountains from San Mateo County to San Luis Obispo County. | The bird breeds in small colonies on cliffs behind or adjacent to waterfalls in deep canyons and sea-bluffs above the surf. Found in moist crevice or cave on sea cliffs above the surf. Forage widely over many habitats. Avoids arid regions such as Great Basin, southern deserts and Central Valley. | Absent from October - April. | None. Occurrences have been documented within the Buyer Service Area. Suitable habitat may occur within the area of analysis. Habitat within the Buyers Service Area would not be affected, as water in excess of their CVP contract amount could not be procured, nor could this water be used to grow permanent crops. Therefore any change in habitat would fall within the normal range expected under their existing contracts. |

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| **Black tern**<br>*Chlidonias niger* | -- | SSC | Common spring and summer visitor to fresh emergent wetlands of California. | Uses fresh emergent wetlands, lakes, ponds, moist grasslands, and agricultural fields. In migration, some take coastal routes and forage offshore. | April-September | High. No occurrences have been documented within either the Buyer or Seller Service Areas. However, suitable habitat (i.e. rice fields) is present, and the area of analysis is within the known range for the species. Therefore it has moderate potential to occur Water transfers could reduce suitable habitat for the species within the Seller Service Area. Conservation strategies are in place that would make potential impacts to this species to negligible. |
| **Black-crowned night heron**<br>*Nycticorax nycticorax*<br>(rookeries) | -- | -- | Year round resident and common in lowlands and foothills throughout most of California, including the Salton Sea and Colorado River areas, and very common locally in large nesting colonies. Uncommon in northwestern and rare in northeastern CA in midwinter. Uncommon in winter in southern deserts. | Feeds along the margins of lacustrine, large riverine, and fresh and saline emergent habitats. Nests and roosts in dense-foliaged trees and dense emergent wetlands. | Year round. Common nesting species from April -August. | None. No occurrences of black-crowned night heron have been documented within either the Buyer or Seller Service Areas. Suitable habitat is present in the area of analysis; however, no nesting or roosting habitats would be affected. |

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| **Cackling (=Aleutian Canada) goose**<br>*Branta hutchinsii leucopareia* | D | -- | The species is found in during the winter in Del Norte County, San Francisco Bay-Delta, and South Central Valley. | Forages on natural pasture or pastures that are cultivated to grain. The species occurs on lakes, reservoirs and ponds. Preferred habitats include lacustrine, fresh emergent wetlands, moist grasslands, croplands, pastures, and meadows. | Year-round in northeastern California, except when water freezes. Wintering population in California migrates north and east to northeastern California. Winters on lakes and inland prairies. | None. Occurrences have been documented within both the Buyer and Seller Service Areas. The species distribution does not overlap with the major area where fallowing would occur. Transfers are not expected to impact breeding habitat (i.e. prefers islands in lakes). |
| **California clapper rail**<br>*Rallus longirostris obsoletus* | E | E | Common locally around San Francisco, Monterey, and Morro bay. | Found in salt-water and brackish marshes traversed by tidal sloughs. The bird is associated with abundant growths of pickle weed, but feeds on mud-bottomed sloughs. | Year round. Non-migratory in coastal wetlands. Juveniles may disperse to freshwater wetlands late summer and autumn. | None. Occurrences have been documented within the Buyer Service Area. Suitable habitat may occur within the area of analysis. However, Transfers are not expected to impact any suitable habitat (i.e. salt-water marshes). |
| **California horned lark**<br>*Eremophila alpestris actia* | -- | WL | Found on coastal regions, chiefly from Sonoma to San Diego county, but also found in the main parts of San Joaquin Valley and east to the foothills. | Prefers short-grass prairie, mountain meadows, open coastal plains, alkali flats, "bald" hills, and fallow grain fields. | Year round in California. Some movement along the coast. May leave mountains in winter. | None. Occurrences have been documented within the Buyer Service Area. Suitable habitat occurs within the area of analysis. No impacts to breeding or foraging habitat are anticipated within the Buyer Service Area. |

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|---|---|---|---|---|---|---|
| **California least tern**<br>*Sternula antillarum browni* | E | E | Nests along the coast from San Francisco Bay south to northern Baja California. Migratory in California. Breeding colonies in Southern California near marine and estuarine shores. In SF Bay found near salt ponds and estuarine shores. | Breeds on bare or sparsely vegetated, flat substrates, sand beaches, alkali flats, landfills or paved areas. Feeds in shallow, estuarine waters. | Late April in southern California to mid-May in northern California. Winters south of California. Absent from mid-October to late April. | None. Occurrences have been documented in the Buyer Service Area. Suitable habitat may occur within the area of analysis. No impacts are expected to suitable foraging or breeding habitat (i.e. sand beaches, alkali flats). |
| **California yellow warbler**<br>*Dendroica petechia brewsteri* | -- | SSC | Throughout California. From coastal Del Norte County., east to Modoc, south along coast range to Santa Barbara and Ventura County. Also found along western slope of Sierra Nevada to Kern County. | Frequents open to medium-density woodlands and forests with a heavy brush understory in breeding season. In migration, found in a variety of sparse to dense woodland and forest habitats. Breeds in montane chaparral, ponderosa pine and mixed conifer habitats. | April-October. | None. No occurrences have been documented in the area of analysis. The species is not likely to occur in rice fields, and no suitable habitat would be impacted (i.e. dense woodland and forest habitats). |
| **Cooper's hawk**<br>*Accipiter cooperii* | -- | WL | Throughout California. Breeds in southern Sierra Nevada foothills, New York Mountains, Owens Valley and local areas in southern California. | Frequents landscapes where wooded areas occur in patches and groves- live oak, riparian deciduous, other forest habitat near water. Often uses patchy woodlands and edges with snags for perching. Dense stands with moderate crown-depths used for nesting. | Year round. Breeding resident throughout wooded portion of California. | None. Occurrences have been documented within both the Buyer and Seller Service Area. Suitable habitat occurs within the area of analysis. No potential impacts to preferred foraging or nesting habitat are anticipated. |
| **Double-crested cormorant**<br>*Phalacrocorax pelagicus* | -- | WL | Along the entire coast of California and on inland lakes, in fresh, salt and estuarine waters. Uncommon from San Luis Obispo County south and very rare to the north. Common on Colorado River reservoirs and common in the Central Valley. | Open water with offshore rocks, islands, steep cliffs, dead branches of trees, wharfs, jetties, or even transmission lines. Requires undisturbed nest-sites beside water, on islands or mainland. Uses wide rock ledges on cliffs; rugged slopes; and live or dead trees, especially tall ones. Found on inland lakes, fresh, and estuarine waters. | Year round along coastal regions. Winters inland. | None. No occurrences have been documented within the area of analysis, but the species could occur at reservoirs and inland ponds. No negative impacts to foraging or breeding habitat are expected. |

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|---|---|---|---|---|---|---|
| **Ferruginous hawk**<br>*Buteo regalis* | -- | WL | Winter resident and migrant at lower elevations and open grasslands in Modoc Plateau, Central Valley, and Coast ranges. Common winter resident of grassland and agriculture areas in southwestern California. Casual in northeast in summer. | Found in open grasslands, sagebrush flats, desert scrub, low foothills and fringes of pinyon-juniper habitats. | Migratory. Present in CA from Sept. to mid-April. | None. Occurrences have been documented within both the Buyer and Seller Service Areas. Suitable habitat occurs within the area of analysis. No potential impacts to preferred habitat are anticipated. |
| **Golden eagle**<br>*Aquila chrysaetos* | T | E | Throughout California. Uncommon permanent resident and migrant throughout California, except of Central Valley. More common in southern California. | Riparian areas near coasts, rivers, and lakes. Nesting generally occurs in large old-growth trees in areas with little disturbance. Also in foothills, mountain areas, sage-juniper flats and desert. | Year round. Mostly resident moves down slope for winter and upslope after breeding season. | None. Occurrences have been documented within both the Buyer and Seller Service Areas. Suitable habitat occurs within the area of analysis. No impacts to nesting habitat are expected. |
| **Grasshopper sparrow**<br>*Ammodramus savannarum* | -- | SSC | Uncommon and local, summer resident and breeder in foothills and lowlands west of Cascade-Sierra Nevada crest from Mendocino and Trinity counties south to San Diego County Also found in Shasta Valley, Siskiyou County, coastal southern California. | Found in dense grasslands on rolling hills, lowland plains, in valleys and on hillsides on lower mountain slopes. Favors native grasslands with a mix of grasses, forbs and scattered shrubs. | Winters chiefly in southern California, in coastal areas. Summer resident March to May, migrates south in August and September. Fall migrants occur on the Farallon Islands in late September to early October. | None. Occurrences have been documented in the Seller Service Area. Suitable habitat may occur with the area of analysis. The species' habitat (i.e. dense grassland, lowland plain areas) would not be affect by Transfers. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Great blue heron**<br>*Ardea herodias*<br>(rookeries) | -- | -- | Throughout California. Most rookeries are in southern California some scattered in northern California. | Found in shallow estuaries, fresh and saline emergent wetlands, along riverine and rocky marine shores, in croplands, pastures, salt ponds, and in mountains above foothills. Nests and roosts in large trees. | Year round. Near salt ponds from July to October. Near rookeries February to June or July. | None. Rookeries have been documented within the Buyer and Seller Service Areas. No impacts to rookeries are anticipated. Idling of cropland foraging habitat would be limited by the environmental commitments, and birds could use alternative suitable foraging areas in the vicinity. |
| **Great egret**<br>*Ardea alba*<br>(rookeries) | -- | -- | Throughout California, except for high mountains and deserts. | Feeds and rests in fresh, and saline emergent wetlands, along the margins of estuaries, lakes, and slow-moving streams, on mudflats and salt ponds, and in irrigated croplands and pastures. Nests roosts in large trees. | Year round | None. Occurrences have been documented in the Seller Service Area. No impacts to rookeries are anticipated. Idling of cropland foraging habitat would be limited by the environmental commitments, and birds could use alternative suitable foraging areas in the vicinity. |
| **Greater sandhill crane**<br>*Grus canadensis tabida* | -- | T, FP | Breeds only in Siskiyou, Modoc and Lassen counties and in Sierra Valley, Plumas and Sierra counties. Winters primarily in the Sacramento and San Joaquin valleys from Tehama south to Kings Counties. | In summer, this race occurs in and near wet meadow, shallow lacustrine, and fresh emergent wetland habitats. Frequents annual and perennial grassland habitats, moist croplands with rice or corn stubble, and open, emergent wetlands. It prefers relatively treeless plains. | Migration southward is September-October and northward is March-April. | High. No occurrences have been documented within the area of analysis, but occurrences have been recorded in Butte and Sutter Counties. Suitable foraging and winter roosting habitat is present within the area of analysis (i.e. rice fields). Conservation strategies are in place for this species and birds would have other suitable nesting sites available. |

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|---|---|---|---|---|---|---|
| **Least bell's vireo**<br>*Vireo bellii pusillus* | E | E | California to northern Baja. Rare, local, summer resident below about 600m (2000ft), mostly in San Benito and Monterey counties. Present in coastal southern CA from Santa Barbara County south. | Inhabits low, dense riparian growth along water or along dry parts of intermittent streams. Typically associated with willow, cottonwood, baccharis, wild blackberry, or mesquite in desert localities. | end of March to end of August | None. Occurrences have been documented in the Buyer Service Area. Suitable habitat may occur within the area of analysis. Transfers are not expected to impact any suitable willow or dense riparian habitat, therefore no impacts to the species are anticipated. |
| **LeConte's thrasher**<br>*Toxostoma lecontei* | -- | SSC | Uncommon to rare local resident of southern California deserts from southern Mono County south to Mexican border, western and southern San Joaquin Valley. Also in Joshua tree. Formerly north to Fresno County, rare north of Kern County. | A desert resident primarily of open desert wash, desert scrub, alkali desert scrub, and desert succulent scrub habitats. Nests in dense, spiny shrub or densely branched cactus in desert wash habitat. | Year round. Non migratory. | None. CNDDB occurrences have been documented in the Buyer Service Area. Suitable habitat is present in area of analysis. No impacts are anticipated to occur to suitable habitat (i.e. desert scrub). |
| **Little willow flycatcher**<br>*Empidonax traillii brewsteri* | -- | E | Migrant at lower elevations, primarily in riparian habitats throughout Sierra Nevada and Cascade Range. Not found in north coast. | Most numerous where extensive thickets of low, dense willows edge on wet meadows, ponds, or backwaters. Dense willow thicket required for nesting and roosting. Feeds in willow thickets or low perches adjacent to meadows. | Spring (mid-May to early June) and fall (mid-August to early September) | None. This species has not been documented within the area of analysis according to CNDDB. Suitable habitat may be present within the area of analysis (i.e. dense willows), but would not be impacted by Transfers. |
| **Loggerhead shrike**<br>*Lanius ludovicianus* | -- | SSC | Common resident and winter visitor in lowland and foothills throughout California. Rare on coastal slopes north of Mendocino County, occurring only in winter. | Found in broken woodlands, savannah, pinyon-juniper, Joshua tree, riparian woodlands, desert oases, scrub and washes. Prefers open country with perches for hunting, and fairly dense shrubs and brush for nesting. Rarely found in urbanized areas, but often found in open cropland. | Year round. In Great Basin, south to Inyo County, pop declines Nov.-March. Winter pop. More widespread in winter than during breeding season. | None. CNDDB occurrences have been documented in the Buyer Service Area. Suitable habitat may be present within the area of analysis. No impacts are anticipated to breeding or foraging habitats. |

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|---|---|---|---|---|---|---|
| **Long-billed curlew**<br>*Numenius americanus* | -- | WL | Along the California coast, and in the Central and Imperial valleys. | Upland short grass prairies and wet meadows are used for nesting; coastal estuaries, open grasslands, and croplands are used in winter. | Winter migrant from July-April | Low. No CNDDB occurrences have been documented within the area of analysis, but the species is known to occur within the action area during winter migration. There is potential for impacts to suitable foraging habitat (i.e. cropland), although this may be reduced by environmental commitments, which protect winter foraging habitat in Butte Sink, and other wildlife management areas downstream. Birds can relocate to other suitable habitats within the area. |
| **Long-eared owl**<br>*Asio otus* | -- | SSC | Throughout California, except for entire floor of the Central Valley and locally on the southern coast. | Frequents dense, riparian and live oak thickets near meadow edges, and nearby woodland and forest habitats. Also found in dense conifer stands at higher elevations. | Year round | None. Occurrences have been documented in the Buyer Service Area. Suitable habitat occurs within the area of analysis. Transfers are not expected to impact any suitable habitat (i.e. forest and woodland habitats). |
| **Merlin**<br>*Falco columbarius* | -- | WL | Occurs in most of the western half of California below 3,900 ft. Rare in Mojave Desert and Channel Islands. | Frequents coastlines, open grasslands, savannahs, woodlands, lakes, wetlands, edges, and early successional stages. Ranges from annual grasslands to ponderosa pine and montane hardwood-conifer habitats. | Winter migrant from September-May | None. CNDDB occurrences have been documented in the Buyer Service Area. Suitable habitat is present in area of analysis. Foraging habitat may be altered, but Transfers would not decrease suitability. No negative impacts are anticipated. |

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|---|---|---|---|---|---|---|
| **Mountain plover**<br>*Charadrius montanus* | -- | SSC | Found in Central Valley from Sutter and Yuba counties southward, foothill valleys west of San Joaquin Valley, Imperial Valley, plowed fields of Los Angeles and western San Bernardino County, and central Colorado river valley. Does not breed in California. | Found in short grasslands, freshly plowed fields, newly sprouting grain fields, and sod farms. Prefers grazed areas and areas with burrowing rodents. | Winter resident Sept. - March. | None. Occurrences have been documented within both the Buyer and Seller Service Area. Suitable habitat occurs within the area of analysis. Foraging habitat may be affected, but Transfers would not reduce suitability. Can relocate to other habitats within the area. |
| **Northern harrier**<br>*Circus cyaneus* | -- | SSC | Throughout lowland California, concentrated in the Central Valley and coastal valleys. | Breeds in annual grasslands and wetlands. Prefers marshes and grasslands for foraging and nesting. Also uses agricultural fields for nesting and foraging, although nests may be destroyed by agricultural activities. | Year round, nomadic | None. CNDDB occurrences have been documented in the Buyer Service Area. Suitable habitat is present in area of analysis. Foraging and breeding habitat may be affected, but fallow fields would still represent suitable habitat. Birds can relocate to other habitats within the area. |
| **Osprey**<br>*Pandion haliaetus* | -- | WL | Northern California from Cascade Ranges south to Lake Tahoe, and along the coast south to Marin County. | Associated strictly with large, fish-bearing waters, primarily in ponderosa pine through mixed conifer habitats. | Year round | None. Occurrences have been documented within both the Buyer and Seller Service Area. Suitable habitat occurs within the area of analysis. Water transfers would be subject to flow requirements. Therefore no impacts to foraging area expected. No impacts to nesting sites are anticipated. |
| **Prairie falcon**<br>*Falco mexicanus* | -- | WL | Found from southeastern deserts northwest throughout Central Valley and inner Coast Ranges and Sierra Nevada. Mostly absent from northern coastal fog belt. Not found in upper elevation of Sierra Nevada. | Inhabits dry, open level or hilly terrain. Breeds on cliffs, forages far afield. Annual grassland to alpine meadows, but primarily perennial grasslands, rangeland, agricultural fields and desert scrub. | Permanent resident. Northern migrants winter in California. Upslope in summer, down slope in winter. | None. CNDDB occurrences have been documented in the Buyer Service Area. Suitable habitat is present within the area of analysis. Foraging habitat (i.e. agricultural fields) may be altered, but Transfers would not reduce suitability. |

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|---|---|---|---|---|---|---|
| **Purple martin**<br>*Progne subis* | -- | SSC | In south, found on the coast and interior mountain ranges. Absent from higher desert regions. In north, found on coast and inland to Modoc and Lassen counties. Absent from higher slopes of Sierra Nevada. Current breeding populations are known from western Santa Clara and Alameda counties, and western Placer County. | Inhabits woodlands, low elevation coniferous forest of Douglas-fir, ponderosa pine and Monterey pine. Uses open habitats during migration, including grassland, wet meadows, and fresh emergent wetlands. | Summer resident throughout California. | Low. CNDDB occurrences have been documented in the Seller Service Area. This species is restricted to fairly limited nesting sites with suitable cavities free of brood parasites. When wetlands are unavailable, rice fields may represent relatively high quality foraging habitat. This habitat may be slightly reduced by Transfers, but the species can relocate to other suitable habitat in the vicinity. Crop idling limitations are in place in the environmental commitments. |
| **Saltmarsh common yellowthroat**<br>*Geothlypis trichas sinuosa* | -- | SSC | Resident and summer visitor in San Francisco Bay area. Winter south along coast to San Diego county. Found in No. CA in summer months. | Found in fresh and salt water marshes. Requires thick, continuous cover to water surface for foraging and tall grasses, tulle and willows for nesting. | Year-round in southern California and San Francisco Bay, Summer resident in northern California. | None. Occurrences have been documented in the Buyer Service area and suitable habitat may be present in the area of analysis. Not known from rice fields. Water transfers would not affect suitable breeding or foraging habitat. |
| **San Pablo song sparrow**<br>*Melospiza melodia samuelis* | -- | SSC | Confined to emergent wetland along north side of San Francisco and San Pablo bay. Highest density at Petaluma River mouth. | A resident of salt marshes. The species inhabits tidal sloughs in salicornia marshes and nests in grindelia bordering slough channels. | Year round | None. Occurrences have been documented in the Buyer Service area and suitable habitat may be present in the area of analysis. However, no impacts are expected to salt water marshes. |

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|---|---|---|---|---|---|---|
| **Short-eared owl**<br>*Asio flammeus* | -- | SSC | Endemic to marshes bordering the San Francisco, San Pablo Bays and Suisun Bay. Winter migrant in Central Valley, western Sierra Nevada foothills and coastline. Uncommon winter migrant in southern California. Breeding range includes: Del Norte, Humboldt, SF Bay Delta, northeastern Modoc plateau, south Lake Tahoe to Inyo County and San Joaquin valley. | Usually found in open areas with few trees, including grasslands, wet meadows, irrigated lands, saline and fresh emergent wetlands, and cleared forests. Occasionally in estuaries during breeding season. Ground nester in tall grasses, brush, ditches, and wetlands. | Year round. Migrants in CA from Sept. - April. | None. Occurrences have been documented in the Buyer Service Area. Suitable habitat occurs within the area of analysis. No impacts to breeding habitat would occur. Fallow rice fields would still represent suitable foraging habitat for the species. |
| **Snowy egret**<br>*Egretta thula*<br>(rookeries) | -- | -- | Throughout California. | Found along shores of coastal estuaries, fresh and saline emergent wetlands, ponds, slow-moving rivers, irrigation ditches, and wet fields. | Year round | None. Occurrences have been documented in the Buyer Service Area, however suitable habitat is present in both the Buyer and Seller Service area. No impacts to rookeries are anticipated. Idling of cropland foraging habitat would be limited by the environmental commitments, and birds could use alternative suitable foraging areas in the vicinity. |
| **Suisun song sparrow**<br>*Melospiza melodia maxillaris* | -- | SSC | Endemic, restrict to Suisun Marsh from Carquinez Strait east to the confluence of the Sacramento and San Joaquin rivers near Antioch. Highest numbers near Benicia State Park and Martinez shoreline. | Resident of brackish-water marshes. Inhabits cattails, tulles, sedges, and salicornia. | Year round. Non-migratory. Breeds early March to July. | None. Occurrences have been documented in the Buyer Service area and suitable habitat may be present in the area of analysis. However, no impacts are expected to brackish-water marshes. |

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|---|---|---|---|---|---|---|
| **Swainson's hawk**<br>*Buteo swainsoni* | -- | T | Lower Sacramento and San Joaquin Valleys, the Klamath Basin, Northeastern plateau, Lassen County, and Mojave desert. | Nests in mature trees, including valley oaks or cottonwoods in or near riparian habitats; forages in grasslands, irrigated pastures, and grain and row crop fields. | Spring and summer resident; small wintering population in the Delta. Moves south to southern and interior CA Sept.-Oct. Moves north March-May. | None. CNDDB occurrences have been documented within both the Seller and Buyer Service Area. Suitable habitat is present within the area of analysis. Transfers may alter the composition of foraging habitat in the Buyer and Seller Service Areas, but these areas would still be suitable for the species, and additional habitats in the vicinity would be available. No impacts to breeding habitat are expected. |
| **Tricolored blackbird**<br>*Agelaius tricolor* | -- | T | A resident in California found throughout the Central Valley and in coastal districts from Sonoma County south. Found locally in northeastern California. In winter, more widespread along central coast and San Francisco Bay area. | Breeds near fresh water, preferably in emergent wetlands with tall, dense cattails or tulles, but also in thickets of willow, blackberry, wild rose, tall herbs. Feeds in grassland and cropland habitats. | Year round. Leaves northeastern CA in fall and winter. | Low. CNDDB occurrences have been documented within both the Seller and Buyer Service Area. Suitable habitat is present within the area of analysis. Foraging habitat may be affected by Transfers. Environmental commitments limit cropland idling and birds can relocate to other adjacent foraging habitats within the area. |
| **Western burrowing owl**<br>*Athene cunicularia hypugaea* | -- | SSC | Central and southern coastal habitats, Central Valley, Great Basin, and deserts. Formerly common in appropriate habitat throughout the state, excluding humid northwest coastal forests and high mountains. Present on larger offshore islands. | Open annual grasslands or perennial grasslands, deserts, and scrublands characterized by low-growing vegetation. Dependent upon burrowing mammals (especially California ground squirrel) for burrows. | Year round | None. Occurrences have been documented within both the Buyer and Seller Service Area. Suitable habitat occurs within the area of analysis. Agricultural ditches may be suitable habitat for burrowing owl burrow and nesting activity. Water transfers would not affect the suitability of habitat for burrowing owl in the area of analysis. |

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|---|---|---|---|---|---|---|
| **Western snowy plover**<br>*Charadrius alexandrinus* | T | SSC | Along the west coast states, with inland nesting taking place at the Salton Sea, Mono Lake, and at isolated sites on the shores of alkali lakes in northeastern California, in the Central Valley, and southeastern deserts. | Nests, feeds, and takes cover on sandy or gravelly beaches along the coast, on estuarine salt ponds, alkali lakes, and at the Salton Sea. | Migration is from July-March (some year round populations). | None. Occurrences have been documented in the Buyer Service Area. There is a CNDDB occurrence in Yolo County, however this species is not likely to occur in rice fields. Suitable habitat may occur within the area of analysis. However, Transfers are not expected to impact any suitable breeding or foraging habitat (i.e. sandy beaches or estuarine salt ponds). |
| **Western yellow-billed cuckoo**<br>*Coccyzus americanus* | C, | E | Uncommon to rare summer resident in scattered locations throughout California. Breeding population along Colorado river, Sacramento and Owen Valley, along South Fork of Kern River, Santa Ana River and Amargosa River. May be present along San Luis Rey River. | Deciduous riparian thickets or forests with dense, low-level or understory foliage, and which abut on slow-moving watercourses, backwaters, or seeps. Willow almost always a dominant component of the vegetation. In Sacramento Valley, also utilizes adjacent orchards, especially of walnut. Nests in sites with some willows, dense low-level or understory foliage, high humidity, and wooded foraging spaces. | Summer migration is from June-September. | None. Occurrences have been documented in the Seller Service Area. Suitable habitat is present within the area of analysis. However, this species is not likely to occur in rice fields due to lack of suitable foraging and roosting habitat (i.e. dense riparian thickets). No impacts are anticipated. |

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|---|---|---|---|---|---|---|
| **White-faced ibis**<br>*Plegadis chihi* | -- | WL | Uncommon summer resident in sections of southern California, a rare visitor in the Central Valley, and is more widespread in migration. Uncommon to common in small pockets. | Feeds in fresh emergent wetlands, shallow lacustrine waters, muddy grounds of wet meadows, and irrigated or flooded pastures and croplands. Nests in dense, fresh emergent wetlands. | Present from April-October. | Low. Occurrences have been documented in the Seller Service Area. Suitable habitat is present in area of analysis. Low potential impact to foraging habitat in the Seller Service Area. No potential impacts are expected to roosting habitat. Can relocate to other habitats within the area. Environmental commitments would limit acreage of allowable cropland idling. |
| **White-tailed kite**<br>*Elanus leucurus* | -- | FP | Central Valley, coastal valleys, San Francisco Bay area, and low foothills of Sierra Nevada. | Savanna, open woodlands, marshes, partially cleared lands and cultivated fields, mostly in lowland situations. Rarely found away from agricultural areas. Feeds in open grasslands, meadows, farmlands and emergent wetlands. Nests located near open foraging area and placed on top of dense oak, willow or tree stands. | Year round | None. CNDDB occurrences have been documented within both the Seller and Buyer Service Area. Suitable habitat is present within the area of analysis. Foraging habitat may be altered, but would still be suitable for the species. No potential impacts to breeding habitat are anticipated. |
| **Yellow warbler**<br>*Dendroica petechia brewsteri* | -- | SSC | Breeding range from coastal Del Norte County, east to Modoc plateau & Inyo County, south to coastal Santa Barbara and Ventura County., west to Kern County. Winters in Imperial and Colorado river valleys. Found up to 2500m (8000ft) in Sierra Nevada. | Associates with riparian habitats and prefers willows, cottonwood, aspens, sycamores, and alders. Nests in montane shrubbery in open conifer forests. | Summer resident throughout California. | None. Occurrences have been documented in the Buyer Service Area and suitable habitat is present with the area of analysis. No potential impacts are anticipated to riparian habitats. |

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|---|---|---|---|---|---|---|
| **yellow-headed blackbird**<br>*Xanthocephalus xanthocephalus* | -- | SSC | Breeds east of Cascade range and Sierra Nevada, Imperial and Colorado River valley, in Central Valley and select locations in coast range west of Central Valley. Common in winter in Imperial Valley. Found as high as 2000m (6600ft) in San Bernardino Mountains. | Associated with freshwater emergent wetlands along lakes and ponds. Nesting timed with maximum emergence of aquatic insects. Feeds on cultivated grains, in emergent vegetation, and in nearby grasslands and croplands. | Year round, in parts of Central Valley. Summer range in eastern California, and parts of Central Valley. Present April through early May, and in September. | Low. Occurrences have been documented in the Buyer Service Area and suitable habitat is present within both the Buyer and Seller Service Area. Impacts to foraging habitat are expected in the Seller Service Area, but the birds can relocate to other habitat in the area. Environmental commitments would limit the amount of cropland idling in the area of analysis. |
| **Mammals** | | | | | | |
| **Alameda Island mole**<br>*Scapanus latimanus parvus* | -- | WL | Only known from Alameda Island, Alameda County. | Found in a variety of habitats, especially annual and perennial grasslands. Prefers moist, friable soils and avoids flooded soils. | Year round | None. Occurrences have been documented in the Buyer Service Area. Transfers would not impact suitable habitat. |
| **American badger**<br>*Taxidea taxus* | -- | SSC | Throughout California. | Found in dry, open stages of most shrub, forest, and herbaceous habitats with friable soils. | Year round. Permanent resident except in North Coast area. | None. Occurrences have been documented in both the Buyer and Seller Service area and suitable habitat is present within the area of analysis. Suitable habitats are not expected to be impacted. |
| **Big free-tailed bat**<br>*Nyctinomops macrotis* | -- | SSC | Rare in California. Vagrants found in San Diego County. and Alameda County (record is suspect). | Found in low-laying arid areas in Southern California and requires high cliffs or rocky outcrops for roosting sites. | Year round resident in San Diego County and Alameda County. | None. Occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. Transfers would not impact suitable arid, rocky terrain habitat. |

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|---|---|---|---|---|---|---|
| **California wolverine**<br>*Gulo gulo* | PT | T, FP | A scarce resident of North Coast mountains and Sierra Nevada. Sightings range from Del Norte and Trinity counties. east through Siskiyou and Shasta counties., and south through Tulare County. A few possible sightings occur in the north coastal region as far south as Lake County. Habitat distribution in California is poorly known for the North Coast and northern Sierra Nevada. | In north coastal areas, has been observed in Douglas-fir and mixed conifer habitats. In the northern Sierra Nevada, have been found in mixed conifer, red fir, and lodge pole habitats, and probably use subalpine conifer, alpine dwarf-shrub, wet meadow, and montane riparian habitats. In the southern Sierra Nevada occur in red fir, mixed conifer, lodge pole, subalpine conifer, alpine dwarf-shrub, barren, and probably wet meadows, montane chaparral, and Jeffrey pine. | Year round (largely nocturnal) | None. Suitable habitat may occur within the area of analysis, however no CNDDB occurrences have been documented in the Buyer or Seller Service area. The species is not likely to occur in agriculture fields. No impacts are anticipated. |
| **Fresno kangaroo rat**<br>*Dipodomys nitratoides exilis* | E | E | Western Fresno County. on the Alkali Sink Ecological Reserve and adjacent privately owned land. | Found in alkali sink-open grassland habitats. Prefers bare alkaline clay-based soils subject to seasonal inundation with more friable soil mounds around shrubs and grasses. | Year round. Breeds largely from March - June. | None. Occurrences have been documented in the Buyer Service Area. Suitable habitat present in the area of analysis. Transfers would not impact suitable habitat for this species (i.e. alkali sink grasslands). |
| **Giant kangaroo rat**<br>*Dipodomys ingens* | E | E | Found along western side of San Joaquin Valley (e.g. Carrizo Plain, Panoche Valley) | Found in annual grasslands and on and marginal habitat in alkali scrub. The species requires level terrain and sandy loam soils for burrowing. | Year round | None. Occurrences have been documented in the Buyer Service Area. Suitable habitat may be present in the area of analysis. However, no impacts are expected to suitable habitat (i.e. alkali desert scrub and annual grasslands). |

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|---|---|---|---|---|---|---|
| **Greater western mastiff bat**<br>E*umops perotis californicus* | -- | SSC | Uncommon resident in southeastern San Joaquin Valley and Coastal Ranges from Monterey County southward through southern California, from the coast eastward to the Colorado Desert. | Occurs in many open, semi-arid to arid habitats, including conifer and deciduous woodlands, coastal scrub, annual and perennial grasslands, palm oases, chaparral, desert scrub, and urban areas. Crevices in cliff faces, high buildings, trees, and tunnels are required for roosting. | Year round (nocturnal activity) | None. Occurrences have been documented in the Seller Service Area. Suitable habitat is present in the area of analysis, bur no impacts are anticipated. |
| **Nelson's antelope squirrel**<br>*Ammospermophilus nelsoni* | -- | T | Found in the western San Joaquin valley from 200-1,200 ft. elevation. Found from southern Merced County to Kern, Kings and Tulare counties. In eastern portions of San Luis Obispo and Santa Barbara counties. | Found on dry sparsely vegetated loam soils. Requires widely scattered shrubs, forbs and grasses in broken terrain with gullies and washes. | Year round. | None. Occurrences have been documented with the Buyer Service Area. Suitable habitat may occur within the area of analysis. No impacts are anticipated to suitable upland habitats. |
| **Pacific fisher**<br>*Martes pennati (pacifica) DPS* | C | SSC | Northern California coastal ranges up to Oregon, and the Sierra Nevada's. | Found in mature, dense, coniferous or mixed coniferous hardwood forest with closed canopies. | Year round | None. Occurrences have been documented with the Seller Service Area. Suitable habitat may occur within the area of analysis. No potential impacts are anticipated to suitable habitat (i.e. mixed conifer habitats). |
| **Pallid bat**<br>*Antrozous pallidus* | -- | SC | Throughout California, except for high Sierra Nevada from Shasta to Kern counties, northwestern corner of state from Del Norte & western Siskiyou cos. To northern Mendocino County. | Found in deserts, grasslands, scrublands, woodlands and forests. Most common in open, dry habitats with rocky areas for roosting. | Year round. | None. Occurrences have been documented with the Buyer Service Area. Suitable habitat may occur within the area of analysis. No impacts would occur to suitable habitat. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Ring-tailed cat**<br>*Brassariscus astutus* | -- | FP | Ringtails are found in a variety of habitats centered around the semi-arid to arid climates of the west and southwest. Little information available on distribution and relative abundance among habitats. | Occurs in various riparian habitats, and in brush stands of most forest and shrub habitats, at low to middle elevations. Uses hollow trees, logs, snags, cavities in talus and other rocky areas, and other recesses are for cover. | Year round (nocturnal) | None. No CNDDB records of this species have been documented in the area of analysis. Suitable habitat is present in the area of analysis, but the species is not likely to occur in rice fields. No potential impact to suitable habitat is expected. |
| **Riparian brush rabbit**<br>*Sylvilagus bachmani riparius* | E | E | Isolated populations on Caswell Memorial State Park on the Stanislaus River and along an overflow channel of the San Joaquin River. | Riparian thickets | Year round | None. No CNDDB records of this species have been documented in the area of analysis. Suitable habitat is present in the area of analysis, however, no potential impacts are expected to suitable habitat (i.e. riparian thickets). |
| **Riparian (San Joaquin Valley) woodrat**<br>*Neotoma fuscipes riparia* | E | SSC | Found along the lower portions of the San Joaquin and Stanislaus rivers in the northern San Joaquin Valley. Historical records for the riparian woodrat are distributed along the San Joaquin, Stanislaus, and Tuolumne rivers, and Corral Hollow, in San Joaquin, Stanislaus, and Merced Counties. | Most numerous where shrub cover is dense and least abundant in open areas. Dens are usually built in willow thickets with oak over story. | Year round (nocturnal activity) | None. Suitable habitat present (i.e. dense shrubs) in both the Buyer and Seller Service Areas, however no CNDDB occurrences have been documented. No potential impacts are expected. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Salt-marsh harvest mouse**<br>*Reithrodontomys raviventris* | E | E | Found in San Francisco Bay and its tributaries. | Found in saline emergent wetlands. Pickle weed is the primary habitat for the species. Requires higher grassland areas for flood escape. | Year round. | None. CNDDB occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. Transfers would not impact saline wetlands and salt marshes. |
| **Salt-marsh wandering shrew**<br>*Sorex vagrans halicoetes* | -- | SSC | Southern arm of the San Francisco Bay in San Mateo, Santa Clara, Alameda and Contra Costa counties (Bolster 1998). | Found in the salt marshes. Inhabits medium high marsh where abundant driftwood is scattered among salicornia. | Year round. Breeds February - June | None. CNDDB occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. Transfers would not impact salt marshes. |
| **San Francisco dusky-footed woodrat**<br>*Neotoma fuscipes annectens* | -- | SSC | Oregon, California and northwestern Baja California. Within California it is known from Alameda, Contra Costa, San Mateo, and Santa Clara, and Santa Cruz Counties. | Found in forest habitats of moderate canopy and moderate to dense understory. The species may prefer chaparral and redwood habitats. Nest sites include tree cavities, logs, and talus slopes (NatureServe 2011). | December - September | None. Occurrences have been documented within the Buyer Service area and suitable habitat may be present in the area of analysis. Transfers would not impact forest, chaparral and redwood habitat. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **San Joaquin kit fox**<br>*Vulpes macrotis mutica* | E | T | Found only in the Central Valley area of California. Kit foxes currently inhabit suitable habitat in the San Joaquin valley and in surrounding foothills of the Coast Ranges, Sierra Nevada, and Tehachapi Mountains; from southern Kern County north to Contra Costa, Alameda, and San Joaquin counties on the west; and near La Grange, Stanislaus County on the east. | Found in annual grasslands or grassy open stages of vegetation dominated by scattered brush, shrubs, and scrub. Build dens for cover. Some agricultural areas may support these foxes. | Year round (mostly nocturnal, but often active during daytime in cool weather) | None. Occurrences have been documented within both the Buyer and Seller Service Area. Suitable habitat is present within the area of analysis. San Joaquin kit fox have the potential to occur in inland and southern portions of the area of analysis. Changes in crop type could alter foraging habitat conditions in the Buyer Service Area, however buyers would not be allowed to buy more water than they were entitled to under their CVP contract. Transfer water would not be used to plant permanent crops, so cropping patterns would be within normal range considered under the CVP contracts and would be covered by the pertinent B.O. Conservation strategies are in place for this species. |
| **San Pablo vole**<br>*Microtus californicus sanpabloensis* | -- | SSC | Found in salt marshes of San Pablo creek on the south shore of San Pablo Bay. | Annual grassland, saline emergent wetlands, salt marsh. | Year round. | None. CNDDB occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. Transfers would not impact the wetlands and salt marshes of San Pablo Bay. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Short-nosed kangaroo rat**<br>*Dipodomys nitratoides brevinasus* | -- | WL | Found in the western side of San Joaquin valley, near the mouth of Panoche Creek in western Fresno County, south to near the mouth of San Emigdio Creek, in southwestern Kern County, and to northeast of Bakersfield. Also occurs in eastern San Benito Valley and Cuyama Valley, and Santa Barbara County (Bolster 1998). | Found in grassland and desert shrub, especially a triplex. Inhabits highly alkaline soils around soda lake and prefers flat to gently sloping terrain. | Year round | None. CNDDB occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. Transfers would not impact suitable habitat for this species. |
| **Tipton kangaroo rat**<br>*Dipodomys nitratoides nitratoides* | E | E | Found in the Tulare Lake basin of southern San Joaquin Valley, from approximately Lemoore and Hanford in Kings County to Visalia, Tipton, Delano and Bakersfield on the east. | The species is found in saltbush scrub and sink scrub communities. Requires soft friable soils. Currently limited to uncultivated ground with alkaline soils. | Year round | None. CNDDB occurrences have been documented in the Buyer Service Area and suitable habitat may be present in the area of analysis. Transfers would not impact suitable habitat for this species. |
| **Tulare grasshopper mouse**<br>*Onychomys torridus tularensis* | -- | SSC | Foothill and floor of the southern San Joaquin Valley from western Merced and eastern San Benito counties, east to Madera County, and south to foothills of Tehachapi and San Emigdio Mts. Also found on Carrizo Plains, eastern San Luis Obispo County, Cuyama Valley, parts of Kern County, Tulare Basin and Panoche Valley (Bolster 1998). | Found in hot, arid valleys and scrub deserts. Favors compact soils with sparse growth of perennial grasses. | Year round. | None. CNDDB occurrences have been documented in the Buyer Service Area. Suitable habitat is present within the area of analysis. Transfers would not impact suitable habitat for this species. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Western mastiff bat**<br>*Eumops perotis californicus* | -- | SSC | Found in southeastern San Joaquin Valley and Coastal ranges from Monterey County southward through southern California and from the coast eastward to Colorado Desert. | Found in open, semi-arid habitats, including conifer and deciduous woodlands, coastal scrub, grasslands, and chaparral. Roost in crevices in cliff faces, high buildings, trees and tunnels. | Year round | None. CNDDB occurrences have been documented in the Buyer Service Area and suitable habitat is present within the area of analysis. No impacts are anticipated to feeding or roosting habitat. |
| **Western red bat**<br>*Lasiurus blossevillii* | -- | SSC | Occurs from Shasta County to Mexican border, west of Sierra Nevada/Cascade crest and deserts. Winters in western lowlands and coastal regions south of SF bay. Not found in desert areas. | Found in trees 2-40ft above ground, from sea level up through mixed conifer forests. Prefers habitat edges and mosaics with trees. Feeds over a wide variety of habitats including grasslands, scrublands and croplands. | Year round. Migrates in spring (March-May) and autumn (Sept.-Oct). Migrates between summer and winter range. | None. Occurrences have been documented in the Buyer and Seller Service Area and suitable habitat is present within the area of analysis. No impacts to roosting habitat are anticipated. Transfers could alter the configuration of foraging habitat, but would not reduce suitability. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Fish** | | | | | | |
| **Sacramento River Winter-run Chinook Salmon**<br>*Oncorhynchus tshawytcha* | E | E | Occurs on the mainstem Sacramento River from Keswick Dam, Shasta County (RM 302) to Chipps Island (RM 0) at the westward margin of the Sacramento-San Joaquin Delta; and in the Bay-Delta system. The area downstream of Red Bluff Diversion Dam is principally a migration corridor, although some rearing may occur during emigration. | Migrate to upstream freshwater habitat to mature and spawn. Once juveniles emerge from the gravel they seek low velocity, shallow-water areas to finish absorbing their yolk sac. Some disperse downstream when high-flow events correspond with emergence. In general, there is a shift in microhabitat use by juvenile Chinook to deeper, faster water as they grow larger. For juveniles, positive growth occurs at temperatures between 5-19 C. Temperatures greater than 24 C, even for short periods, is lethal. Salmon fry tend to move downstream, and smolts emigrate to the ocean, under conditions of increased flow, increased turbidity, and decreased temperatures. | Upstream Migration: Dec-Jul.<br>Spawning: late Apr to early Aug<br>Fry remain in river for five to ten months, prior to emigration.<br>Emigration Sep.-Jan. | None. Species not present in the area of Analysis during period when transfers would occur. Potential impacts would not occur on the mainstem Sacramento River where flows are regulated by the Biological Opinions. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Central Valley Spring-run Chinook Salmon**<br>*Oncorhynchus tshawytcha* | T | T | Designated critical habitat for spring-run Chinook salmon includes San Francisco, San Pablo, and Suisun Bays, the Sacramento-San Joaquin Delta, and the Sacramento River from the Delta to Keswick Dam and the Feather River upstream to Thermalito Afterbay Dam. Spawning occurs above the valley floor in streams that have deep, cold pools where adult fish can hold over the summer before they spawn. Tributaries to the Sacramento River with independent spawning populations are Butte, Deer and Mill Creeks. Spawning may also occur on several other streams in the Area of Analysis including Thomes, Big Chico, and Antelope creeks, and the Yuba and Bear rivers.<br><br>Rearing occurs in these streams and other the downstream portions of other streams tributary to the Sacramento, as well as in the Sutter and Yolo Bypasses, and in the Delta during outmigration of the young fish. | See Sacramento River winter-run Chinook salmon. | Upstream Migration and holding: Mar-Sep.<br>Spawning: late Aug to Oct.<br>Fry remain in river for three to 15 months, prior to emigration.<br>Emigration Jan-Apr. | Low. Suitable habitat for over summer holding and spawning in the species primary spawning and rearing habitat is located upstream of the areas that would be affected by water transfers. Rearing habitat could potentially be affected by groundwater withdrawals in the lower sections of some streams. The sections of these waterways on the valley floor, where water transfers would occur, are typically too warm to support this species during the summer months.<br>Potential impacts would not occur on the mainstem Sacramento River or the Feather River where the operating requirements specified in the Biological Opinions and D1641 would be met. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Fall/Late-fall Chinook Salmon**<br>*Oncorhynchus tshawytcha* | SC | SSC | Occur in the ocean from Alaska to California. Freshwater habitat use in the Central Valley occurs in the Sacramento River and all major tributaries and many minor ones, as well as in tributaries to the major tributaries to San Joaquin River, including the Merced River. In the Sacramento River, most spawning occurs between the Red Bluff Diversion Dam and Keswick Dam, although some fish spawn downstream of Red Bluff Diversion Dam. Small numbers also spawn in Battle Creek, Cottonwood Creek, Clear Creek, Mill Creek, as well as the Yuba and Bear rivers. | See Sacramento River winter-run Chinook salmon. | Fall Run:<br>Upstream Migration: Jun-Dec.<br>Spawning: late Sep to Dec.<br>Fry remain in river one to seven months<br>Emigration Dec-Mar.<br>Late fall run:<br>Upstream Migration: Oct-Apr.<br>Spawning: Jan-Apr<br>Fry remain in river seven to 13 months<br>Emigration Dec-Mar. | Low. Operating requirements for all of the mainstem rivers would meet existing flow and temperature requirements as specified by the NMFS and USFWS BOs for the Long-term Operations of the State and Federal Water Projects and State Water Board Decision 1641. Water transfers from sellers upstream of the Delta may still result in some flow changes that would overlap spatially and temporally with the distribution of fall-run Chinook salmon emigrants, but flows would continue to meet regulatory requirements protective of this species. Transfers would not overlap the Chinook upstream migration, spawning or incubation periods. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **California Central Valley DPS Steelhead**<br>*Oncorhynchus mykiss* | T | SSC | Designated critical habitat includes all waters tributary to the San Francisco Bay from confluence of the Sacramento and San Joaquin River to the lowest impassible barrier. Within these reaches it includes all areas within the ordinary high water mark of the water body. Found in all major rivers and tributaries and may use smaller tributaries, and ephemeral tributaries when available. | Immigration from the ocean into the Delta, the Sacramento and San Joaquin River watersheds occurs when large amounts of cold water is available from winter rains. Spawning occurs in mainstem rivers and their tributaries to. The first year or two of life is spent in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, where there is ample cover in the form of riparian vegetation of undercut banks, and where invertebrate prey is diverse and abundant. Habitat preferences depend on fish size/age, with fry concentrating in shallow water along stream edges with low water velocities, juveniles occurring in deeper, faster water among rocks or other cover, and larger fish seeking out a wide variety of deeper habitats close to fast water. Optimal temperatures for growth are approximately 15-18 C. | Central Valley steelhead are mainly winter-run steelhead, which mature in the ocean and arrive in freshwater nearly ready to spawn. Upstream Migration: Aug-Apr.<br>Spawning: Dec to Apr.<br>Fry generally remain in river for one to three years.<br>Emigration Oct-Jul. | Moderate. Uses the upper Sacramento River above Red Bluff Diversion Dam and the portions of all accessible tributaries to the Sacramento and San Joaquin Rivers with suitable temperatures for spawning and rearing. The Sacramento River below RBDD is used primarily as a migratory corridor. Water transfers from July through September, from sellers upstream of the Delta could overlap spatially and temporally with California Central Valley steelhead rearing in this region where water temperatures are suitable. Stream sections on the valley floor, where transfers could affect stream flow, are generally too warm to support rearing during the summer months, but rearing may occur above the valley floor where suitable temperatures occur. Potential impacts would not occur on the mainstem Sacramento River or the Feather River where the operating requirements specified in the Biological Opinions and D1641 would be met. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **North American Green sturgeon**<br>*Acipenser medirostris* | T | SSC | Ranges from Mexico to Alaska. The southern DPS includes spawning population in the Sacramento River, fish living in the Sacramento River, the Sacramento-San Joaquin Delta, and the San Francisco estuary. Not known to occur in the San Joaquin River. Critical habitat include: coastal marine waters from Monterey Bay to the Washington/Canada boarder; coastal bays and estuaries in California, Oregon, and Washington; fresh water rivers in the Central Valley. Proposed inland critical habitat includes Sacramento River downstream of Keswick Dam, Feather River downstream of Thermalito Dam, Yuba River downstream of Daguerre Dam, portions of Sutter and Yolo Bypasses, and the legal Delta. | Southern DPS: Adults immigrate into the Delta from the ocean to begin spawning migration into the Sacramento River. Spawning occurs in the Sacramento River (upstream of Hamilton City and downstream of Keswick Dam), both downstream and upstream of RBDD; a small number have been observed spawning in the Feather River during high flow years (Moyle 2002). Preferred spawning habitat contain large cobble in deep and cool pools with turbulent water. Water temp in spawning and egg incubation are critical; temp greater than 19C are lethal. Rear in fresh and estuarine areas for one to four years before dispersing into salt water. Occur in shallow water and move to deeper more saline areas as they mature. Emigration occurs as larvae drift downriver from freshwater spawning/rearing areas of Sacramento River watershed through the Delta to the ocean. Subadults inhabit the Delta and bays during summer months, while adults are associated with seawater and mixing zones of bays and estuaries and found in lower stretches of some rivers. Adult and juvenile green sturgeon are thought to use the same migratory routes as Chinook salmon. | Immigration: late Feb. to Jun.<br>Spawning: March to July. After spawning, adults over-summer in deep pools of the Sacramento River from June to Nov. and emigrate to the ocean in fall and early winter and flows increase and temperatures decrease.<br>Rearing: year-round. | Low. Potential impacts would not occur on the mainstem Sacramento River or the Feather River where the operating requirements specified in the Biological Opinions and D1641 would be met. |

| **Common Name**<br>*Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Delta smelt**<br>*Hypomesus transpacificus* | T | E | Endemic to Bay-Delta estuary. Primarily distributed downstream of Isleton on the Sacramento River, downstream of Mossdale on the San Joaquin River, Suisun Bay and Suisun marsh, freshwater regions of the Delta. Designated critical habitat (59 FR 65256) extends throughout Suisun Bay, the length of Goodyear, Suisun, Cutoff, first Mallard and Montezuma sloughs, and the contiguous waters of the legal Delta. | Primarily inhabit low salinity waters of estuary prior to migrating into freshwater habitats to spawn. Spawning occurs in slough and shallow edge area in the Delta and Sacramento River; spawning can occur in the Sacramento River as far upstream as Sacramento and in the Cache Slough region, the Mokelumne River system, and the San Joaquin River upstream as far as Prisoner's Point. Spawning occurs at water temperatures ranging from approximately 7C to 22C. Rearing juveniles remain in spawning areas, near or just above the X2 region of the Delta. Adult delta smelt abundance in the fall has been in the northwestern Delta in the channel of the Sacramento River. Although delta smelt tolerate a wide range of temperatures (<6C to > 25C), warm water temperatures restrict their distribution more than colder water temperatures. | Delta and Suisun Bay – year round | Low. Potential impacts would not occur in the Delta as the operating requirements specified in the Biological Opinions and D1641 would be met. Minor changes in flow could occur in the Delta as a result of water transfers, but these flows would be small. Principal rearing areas during the summer and fall are in and around Suisun Bay and in the Cache Slough region. |

| Common Name<br>*Scientific Name* | Federal Special Status* | State Special Status* | Distribution | Habitat Association | Seasonal Occurrence | Potential Impact |
|---|---|---|---|---|---|---|
| **Longfin smelt**<br>*Spirinchus thaleichthys* | C [4] | T | Occur along the Pacific coast of North America; widespread within the Bay-Delta estuary, in the lower Sacramento River (downstream of Rio Vista), in the San Joaquin River (downstream of Medford Island). Also common in nearshore coastal marine waters. | Spawns at the transition zone between freshwater and slightly brackish water over sandy or gravel substrates at temperatures from 7 C to 14.5 C. Spawning occurs in the Sacramento River mainstem, as far upstream as Rio Vista, the San Joaquin River as far upstream as Medford Island, and in other waterways within the Delta. Hatching coincides with annual peak Delta outflows, which coincide with high turbidity. Larval smelt concentrate in near-surface, fresh and brackish waters. Distribution of larval and juvenile smelt depends on freshwater outflows from the Delta during the late-spring, eventually inhabiting the bays as well as nearshore coastal marine habitats. Longfin smelt do not occupy areas with temperatures greater than 22 C in combination with salinities greater than 26 ppt. | Spawning: November to June.<br>Fry and juveniles have generally left the Delta by May or June. | None. Potential impacts would not occur in the Delta as the operating requirements specified in the Biological Opinions and D1641 would be met. Minor changes in flow could occur in the Delta as a result of water transfers, but these flows would be small. Longfin smelt do not occur in the Delta during the transfer period. |
| **Hardhead** | -- | SSC | Hardhead are widely distributed in low to mid elevation streams in the Main Sacramento-San Joaquin river drainage as well as the Russian River drainage. Their range extends from the Ken River, in Kern County to the Pit River south of the Goose Lake drainage but are absent in the valley reaches. | Hardhead are typically found in undisturbed areas of the larger middle- and low elevation streams. Elevational range of hardhead is 10-1,450 m. Most streams in which they occur have summer temperatures in excess of 20°C. | Year-round | Low. Hardhead are largely excluded from the valley floor reaches of the streams and rivers within the Area of Analysis due to warm summer temperatures and the abundance of introduced fish. |

| **Common Name** *Scientific Name* | **Federal Special Status*** | **State Special Status*** | **Distribution** | **Habitat Association** | **Seasonal Occurrence** | **Potential Impact** |
|---|---|---|---|---|---|---|
| **Sacramento splittail** | -- | SSC | Endemic to the lakes and rivers of the Central Valley. Current distribution generally restricted to the Delta, Suisun Bay, Suisun Marsh, the lower portions of the Napa and Petaluma rivers, and other parts of the San Francisco estuary. They may occur in the Sacramento River upstream as far as Red Bluff Diversion Dam and on the San Joaquin as far upstream as Salt Slough in wet years. They may also occur in the lower Feather and American rivers during these wetter periods. The Sutter and Yolo bypasses are important spawning areas today. | Inhabit estuarine to fresh waters. Spawning occurs primarily on inundated floodplains. Tend to be found in slow-moving sections of rivers and sloughs, and in the Delta and Suisun Marsh. YOY splittail are commonly found between Rio Vista and Chipps island indicating that juveniles prefer more riverine habitat. | Year round in the Delta, Sacramento and San Joaquin Rivers. | Low. Operating requirements for all of the mainstem rivers would meet existing flow and temperature requirements as specified by the NMFS and USFWS BOs for the Long-term Operations of the State and Federal Water Projects and State Water Board Decision 1641. |

[1] Central CA DPS

[2] Santa Barbara and Sonoma Counties

[3] All bird species listed below and many other birds are protected during the nesting season under the federal Migratory Bird Treaty Act.

[4] USFWS has found that the San Francisco Bay-Delta Distinct Population Segment (DPS) of longfin smelt warrants protection under the federal Endangered Species Act, but higher priority listing actions currently preclude their listing.

*Status explanations:

F=Federal

E= listed as endangered under the federal Endangered Species Act

T= listed as threatened under the federal Endangered Species Act

PT= proposed for listing as threatened under the federal Endangered Species Act.

C = Candidate for listing under the federal Endangered Species Act

D= delisted.

S=State

E= listed as endangered under the California Endangered Species Act.

T= listed as threatened under the California Endangered Species Act.

SSC=Species of Special Concern

**Table N-2.**
**Special-Status Plants with Potential to Occur in the Area of Analysis**

| **Common Name** *Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Adobe sanicle** *Sanicula maritima* | -/R/ 1B.1 | Alameda, Monterey, San Francisco, and San Luis Obispo Counties. | Meadows and seeps, valley and foothill grassland, chaparral, coastal prairie. Moist clay or ultramafic soils from 30-240m asl. | February - May | **None.** Adobe sanicle has been previously documented in the Buyer Service Area. Water transfer may increase the area of marginal habitat for this species in the Buyer Service Area. No negative impacts are expected. |
| **Ahart's dwarf rush** *Juncus leiospermus* var. *ahartii* | -/-/ 1B | Butte, Calaveras, Placer, Sacramento, Tehama, and Yuba Counties. | Valley and foothill grassland (mesic). May occur in disturbed areas including agricultural fields and locations with gopher digging activity (Butte County Association of Governments 2011). | March-May | **Low.** Suitable grassland habitat occurs within the area of analysis and this species has been previously documented within the Seller Service Area. There is a low potential that this species would occur in managed rice fields. |
| **Alkali milk-vetch** *Astragalus tener var. tener* | -/-/ 1B.2 | Central western California including Yolo County. | Subalkaline flats and areas around vernal pools. | March-June | **None.** Not likely to occur in rice fields, no suitable habitat (i.e. subalkali flats) would be affected by Transfers. |
| **Anderson's manzanita** *Arctostaphylos andersonii* | -/-/ 1B.2 | Santa Clara, Santa Cruz, and San Mateo Counties. | Broadleaved upland forest, chaparral, North coast coniferous forest. Open sites in redwood forest from 180 - 800m asl. | November - May | **None.** Previously documented within the Buyer Service Area. No suitable habitat would be affected by the proposed Transfers. |
| **Antioch Dunes evening-primrose** *Oenothera deltoides* ssp. *howellii* | E/E/ 1B.1 | Found only in Contra Costa and Sacramento Counties. | Occurs in inland dunes. | March-September | **None.** CNDDB records for this species have been documented within the Buyer Service Area. Not likely to occur in rice fields, and no inland dune habitat should be affected by Transfers. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Arcuate bush-mallow**<br>*Malacothamnus arcuatus* | -/-/ 1B.2 | Santa Clara, Santa Cruz, and San Mateo Counties. | Chaparral within gravelly alluvium from 80 - 335m asl. | April - September | **None.** Previously observed within the Buyer Service Area. No impacts to suitable habitat are anticipated in association with the proposed Transfers. |
| **Baker's navarretia**<br>*Navarretia leucocephala* ssp. *bakeri* | -/-/ 1B.1 | Colusa, Glenn, Lake, Lassen, Mendocino, Marin, Napa, Solano, Sonoma, Sutter, Tehama, and Yolo Counties. | Cismontane woodland, meadows and seeps, vernal pools, valley and foothill grassland, lower montane coniferous forest. Vernal pools and swales, adobe or alkaline soils from 5 - 950m. | April - July | **None.** The CNDDB contains records of this species within the Seller Service Area. It is very unlikely that Baker's navarretia would establish in rice fields, given the lack of adobe or alkaline soils. |
| **Bearded popcorn-flower**<br>*Plagiobothrys hystriculus* | -/-/ 1B.1 | Napa, Solano, and Yolo Counties. | Vernal pools, valley and foothill grassland in wet sites from 10-50m. This species is only known from a few very limited occurrences at the edges of vernal pools, such as at Jepson Prairie and in the Montezuma Hills. | April - May | **None.** Previous records of bearded popcorn-flower exist within the Seller Service Area. This species is not expected to occur in rice fields. No vernal pools or grassland habitats would be affected by the proposed Transfers. |
| **Ben Lomond buckwheat**<br>*Eriogonum nudum* var. *decurrens* | -/-/ 1B.1 | Alameda, Santa Clara, and Santa Cruz Counties. | Chaparral, cismontane woodland, lower montane coniferous forest. Ponderosa pine sandhills in Santa Cruz County from 50 - 800m asl. | June - October | **None.** The CNDDB contains occurrences of this species in the Buyer Service Area. No chaparral or woodland habitats would be affected by the proposed Transfers. |
| **Bent-flowered fiddleneck**<br>*Amsinckia lunaris* | -/-/ 1B.2 | Alameda, Contra Costa, Colusa, Lake, Marin, Napa, San Benito, Santa Clara, Santa Cruz, San Mateo, Sonoma, and Yolo Counties. | Cismontane woodland, valley and foothill grassland from 50 - 500m. | March - June | **None.** Bent-flowered fiddleneck has been previously documented within the Buyer Service Area. Although suitable habitat occurs within the area of analysis, none would be affected by the proposed actions. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Big-scale balsamroot**<br>*Balsamorhiza macrolepis* var. *macrolepis* | -/-/ 1B.2 | Alameda, Butte, Colusa, El Dorado, Lake, Mariposa, Napa, Placer, Santa Clara, Solano, Sonoma, Tehama, and Tuolumne Counties. | Valley and foothill grassland, cismontane woodland. Sometimes on serpentine. 35 - 1000m | March - June | **None.** This species has been previously documented within both the Buyer and Seller Service Areas. However, it is not expected to occur in rice fields due to lack of suitable habitat. |
| **Big tarplant**<br>*Blepharizonia plumosa* | -/-/ 1B.1 | Alameda, Contra Costa, San Joaquin, Solano, and Stanislaus Counties. | Valley and foothill grassland. Dry hills and plains in annual grassland. Clay to clay-loam soils, usually on slopes and often in burned areas 15 - 455m asl. | July - October | **None.** Big tarplant has been observed within the Buyer Service Area. Transfers would not affect suitable habitat for this species. |
| **Boggs Lake hedge-hyssop**<br>*Gratiola hetersepela* | -/E/1B | Dispersed throughout the Sacramento and Central Valley. Also in Oregon. | Marshes, swamps, and vernal pools (clay). | April - August | **None.** A CNDDB occurrence has been documented within the Seller Service Area. This species may withstand some disturbances, such as cattle. However, modifications of natural hydrology by agriculture or other activities are considered a threat to the species, and Boggs Lake hedge-hyssop is not expected to occur within planted rice fields. No marsh or vernal pool habitat would be affected by the proposed Transfers. |
| **Bolander's water-hemlock**<br>*Cicuta maculata var. bolanderi* | -/-/ 2.1 | Occurs within California, Arizona, New Mexico, and Washington. In California it is found in Contra Costa, Los Angeles, Marin, Sacramento, Santa Barbara, San Luis Obispo, and Solano Counties. | Marshes, fresh or brackish water 0 - 200m asl. | July - September | **None.** Bolander's water hemlock has been previously documented within the Buyer Service Area. No marsh, fresh or brackish water habitat would be affected by the proposed Transfers. |

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|---|---|---|---|---|---|
| **Brandegee's clarkia**<br>*Clarkia biloba* ssp. *brandegeeae* | -/-/ 1B.2 | Butte, El Dorado, Nevada, Placer, Sacramento, Sierra, and Yuba Counties. | Chaparral, cismontane woodland, often in roadcuts 295 - 885m asl. | May - July | **None.** This species has been previously recorded within the Seller Service Area. No impacts to suitable habitat are expected. |
| **Brandegee's eriastrum**<br>*Eriastrum brandegeeae* | -/-/ 1B.2 | Contra Costa, Colusa, Glenn, Lake, Santa Clara, Shasta, San Mateo, Tehama, and Trinity Counties. | Chaparral, cismontane woodland. On barren volcanic soils, often in open areas from 345 - 1000m asl. | April - August | **None.** Records of Brandegee's eriastrum exist for the Buyer Service Area. Suitable habitat would not be affected by Transfers. |
| **Brewer's western flax**<br>*Hesperolinon breweri* | -/-/ 1B.2 | Contra Costa, Napa and Solano Counties. | Chaparral, cismontane woodland, valley and foothill grassland. Often in rocky serpentine soils in serpentine chaparral and serpentine grassland from 30 - 885m asl. | May - July | **None.** Brewer's western flax has been previously observed within the Buyer Service Area. Suitable habitat would not be affected by Transfers. |
| **Brittlescale**<br>*Atriplex depressa* | -/-/1B.2 | Western Central Valley and valleys of adjacent foothills. | Alkali grassland, alkali meadow, alkali scrub, and vernal pools. Usually in alkali scalds or alkaline clay in meadows or annual grassland. Rarely associated with riparian areas, marshes, or vernal pools 1 - 320m asl. | April-October | **None.** Occurrences of this species have been documented in both the Buyer and Seller Service Areas in the CNDDB. This species is not likely to occur in rice fields due to lack of suitable habitat (i.e. alkali and vernal pools). |
| **Butte County fritillary**<br>*Fritillaria eastwoodiae* | -/-/3.2 | Butte, El Dorado, Nevada, Placer, Placer, Shasta, Tehama and Yuba Counties. | Chaparral, cismontane woodland, lower montane coniferous forest. Usually on dry slopes but also found in wet places. Soils can be serpentine, red clay, or sandy loam 40 - 1500m asl. | March - June | **None.** Butte County fritillary has been previously observed within the Seller Service Area. Rice fields do not provide suitable habitat for this species, and it is therefore not expected to be impacted by Transfers. |

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|---|---|---|---|---|---|
| **California jewel-flower**<br>*Caulanthus californicus* | E/E/ 1B.1 | Fresno, Kings, Kern, Santa Barbara, San Luis Obispo, and Tulare Counties. | Chenopod scrub, valley and foothill grassland, pinyon-juniper woodland. From various valley habitats in both the Central Valley and Carrizo Plain 65 - 900m asl. | February - May | **None.** CNDDB records of this species exist for the Buyer Service Area. Suitable habitat would not be affected by Transfers. |
| **California seablite**<br>*Suaeda californica* | E/-/ 1B.1 | Alameda, Contra Costa, Santa Clara, San Francisco, and San Luis Obispo Counties. | Marshes and swamps. Margins of coastal salt marshes 0 - 5m asl. | July - October | **None.** California seablite has been previously observed within the Buyer Service Area. No impacts to suitable habitat within the Buyer Service Area are expected to occur. |
| **Caper-fruited tropidocarpum**<br>*Tropidocarpum capparideum* | -/-/ 1B.1 | Alameda, Contra Costa, Fresno, Glenn, Monterey, Santa Clara, San Joaquin, and San Luis Obispo Counties. | Valley and foothill grassland in alkaline clay 0 - 455m asl. | March - April | **None.** CNDDB records exist for the Buyer Service Area. Transfers are not expected to impact suitable habitat for this species. |
| **Carquinez goldenbush**<br>*Isocoma arguta* | -/-/ 1B.1 | Occurs in Solano County. | Valley and foothill grassland. Alkaline soils, flats, lower hills. On low benches near drainages and on tops and sides of mounds in swale habitat 1 - 20m asl. | August - December | **None.** Previously documented within the Buyer Service Area. Transfers would not affect water levels in the Seller Service Area and would only increase the levels in the Buyer Service Area. |
| **Chaparral harebell**<br>*Campanula exigua* | -/-/ 1B.2 | Alameda, Contra Costa, San Benito, Santa Clara, and Stanislaus Counties. | Chaparral on rocky sites, usually on serpentine soils 300 - 1250m asl. | May - June | **None.** Chaparral harebell has been observed within the Buyer Service Area. However, Transfers are not expected to affect suitable habitat for this species. |

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|---|---|---|---|---|---|
| **Chaparral ragwort**<br>*Senecio aphanactis* | -/-/ 2.2 | California and Baja California. Within California, the species occurs in Alameda, Contra Costa, Fresno, Los Angeles, Merced, Monterey, Orange, Riverside, Santa Barbara, Santa Clara, the Channel Islands, San Diego, San Luis Obispo, Solano and Ventura Counties. | Cismontane woodland, coastal scrub. Drying alkaline flats 20 - 575m asl. | January - April | **None.** Previous records of this species exist within the Buyer Service Area. Transfers are not expected to affect suitable habitat for chaparral ragwort. |
| **Choris' popcorn-flower**<br>*Plagiobothrys chorisianus* var. *chorisianus* | -/-/ 1B.2 | Alameda, Santa Cruz, San Francisco, and San Mateo Counties. | Chaparral, coastal scrub, coastal prairie (mesic sites) 15 - 100m asl. | March - June | **None.** Choris' popcorn flower has been documented within the Buyer Service Area. No impacts to suitable habitat are anticipated in association with the proposed Transfers. |
| **Colusa grass**<br>*Neostapfia colusana* | T/E/1B.1 | Southern Sacramento Valley, and northern San Joaquin Valley. | Vernal pools. | May-July | **None.** According to the CNDDB, this species has been previously documented in the Seller Service Area. However, this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |
| **Colusa layia**<br>*Layia septentrionalis* | -/-/ 1B.2 | Colusa, Glenn, Lake, Mendocino, Napa, Sonoma, Sutter, Tehama, and Yolo Counties. | Chaparral, cismontane woodland, valley and foothill grassland. Scattered colonies in fields and grassy slopes in sandy or serpentine soil 145 - 1095m asl. | April - May | **None.** CNDDB records exist for the Seller Service Area. Transfers are not expected to impact suitable habitat for this species given that rice fields do not provide appropriate conditions. |
| **Congdon's tarplant**<br>*Centromadia parryi* ssp. *congdonii* | -/-/ 1B.2 | Alameda, Contra Costa, Monterey, Santa Clara, Santa Cruz, San Luis Obispo, San Mateo, and Solano Counties. | Valley and foothill grassland. Alkaline soils, sometimes described as heavy white clay 1 - 230m asl. | May - November | **None.** Although this species has been documented within the Buyer Service Area (CNDDB), no impacts to suitable habitat are expected. |

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|---|---|---|---|---|---|
| **Contra Costa goldfields**<br>*Lasthenia conjugens* | E/-/1B.1 | San Francisco Bay Delta Regions, and scattered coastal areas. | Cismontane woodlands, playas, valley and foothill grasslands, and vernal pools. Often occurs in vernal pools, swales, and low depressions in open grassy areas 1 - 445m asl. | March-June | **None.** According to the CNDDB, this species has been previously documented within the Buyer Service Area. No impacts to suitable habitat (i.e. vernal pools, playas) are expected. |
| **Contra Costa manzanita**<br>*Arctostaphylos manzanita* ssp. *laevigata* | -/-/1B.2 | Contra Costa County. | Chaparral on rocky slopes 500 - 1100m asl. | January - April | **None.** Contra Costa manzanita has been observed within the Buyer Service Area. No impacts to suitable habitat for this species are expected. |
| **Contra Costa wallflower**<br>*Erysimum capitatum* var. *angustatum* | E/E/1B.1 | Contra Costa County | Inland dunes. Stabilized dunes of sand and clay near Antioch along the San Joaquin River 3 - 20m asl. | March - July | **None.** Records of this species exist within the Buyer Service Area. Suitable habitat would not be affected by Transfers. |
| **Coyote ceanothus**<br>*Ceanothus ferrisiae* | E/-/1B.1 | Santa Clara County | Chaparral, valley and foothill grassland, coastal scrub. Serpentine sites in the Mt. Hamilton Range 120 - 455m asl. | January - May | **None.** The CNDDB contains records of this species within the Buyer Service Area. No suitable habitat for coyote ceanothus is expected to be impacted by the proposed Transfers. |
| **Crampton's tuctoria (Solano grass)**<br>*Tuctoria mucronata* | E/E/1B | Located only in Yolo and Solano Counties. | Valley and foothill grassland (mesic), and vernal pools. | April-August | **None.** Occurrences have been documented outside of the area of analysis. Not likely to occur in rice fields. Suitable habitat within the Seller Service Area would not be impacted by Transfers. |

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|---|---|---|---|---|---|
| **Delta coyote-thistle(button celery)** *Eryngium racemosum* | -/E/1B | Calaveras, Contra Costa, Merced, San Joaquin, and Stanislaus Counties. | Riparian scrub and vernally mesic clay depressions. | June-October | **None.** No occurrences have been documented within the area of analysis, but the species is known from Contra Costa, Merced, San Joaquin and Stanislaus Counties. No suitable habitat would be impacted by the proposed Transfers. |
| **Delta mudwort** *Limosella subulata* | -/-/ 2.1 | Contra Costa, Marin, Sacramento, San Joaquin, Solano Counties. | Riparian scrub, freshwater marsh, brackish marsh. Usually on intertidal flats and muddy banks of the Delta in marshy or scrubby riparian associations, often with Lilaeopsis masonii 0 - 3m asl. Typically occurs with other rare plant species. | May - August | **None.** Previous CNDDB records exist within the Buyer Service Area, and suitable habitat is also present within the Seller Service Area. This species is not expected to occur within rice fields given that it is sensitive to alteration of natural hydrology and other disturbances (Solano County Water Agency 2012). |
| **Delta tule pea** *Lathyrus jepsonii* var. *jepsonii* | -/-/ 1B.2 | Contra Costa, Napa, Sacramento, San Joaquin, Solano, Sonoma, Yolo Counties. | Coastal salt marsh. In coastal salt marsh with Distichlis, Salicornia, Frankenia, etc. from 0-3m asl. | May - September | **None.** Suitable habitat is present within the area of analysis, and CNDDB records exist for the Buyers Service Area. Transfers are not expected to impact suitable habitat for this species (i.e. coastal salt marshes). |
| **Diablo helianthella** *Helianthella castanea* | -/-/ 1B.2 | Alameda, Contra Costa, Marin, San Francisco, San Mateo. | Broadleaved upland forest, chaparral, cismontane woodland, coastal scrub, riparian woodland, valley and foothill grassland. Usually in chaparral/oak woodland interface in rocky, azonal soils. Often in partial shade 25-1150m asl. | March - June | **None.** Diablo helianthella has been previously documented within the Buyer Service Area. No impacts to suitable habitat for this species are anticipated. |

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|---|---|---|---|---|---|
| **Diamond-petaled California poppy**<br>*Eschscholzia rhombipetala* | -/-/ 1B.1 | Alameda, Contra Costa, Colusa, San Joaquin, San Luis Obispo, Stanislaus Counties. | Valley and foothill grassland. Alkaline clay slopes and flats. 0 - 975m asl. | March - April | **None.** This species has been previously documented within the Buyer Service Area. No impacts to suitable habitat are anticipated. |
| **Dubious pea**<br>*Lathyrus sulphureus* var. *argillaceus* | -/-/ 3 | Calaveras, El Dorado, Nevada, Placer, Shasta, Tehama Counties. | Cismontane woodland, lower montane coniferous forest, upper montane coniferous forest 150-305m asl. | April - May | **None.** CNDDB records of dubious pea exist within the Seller Service Area. Transfers actions would not affect suitable habitat for this species. |
| **Dwarf downingia**<br>*Downingia pusilla* | -/-/ 2.2 | Occurs in California and South America. Within California: Amador, Fresno, Merced, Napa, Placer, Sacramento, San Joaquin, Solano, Sonoma, Stanislaus, Tehama, Yuba. | Vernal pools. Many historical occurrences are extirpated. In beds of vernal pools 1 - 880m asl. | March - May | **None.** Previously observed within the Seller Service Area. Not likely to establish in rice fields, due to lack of suitable habitat (i.e., vernal pools). |
| **Elongate copper moss**<br>*Mielichhoferia elongata* | -/-/ 2.2 | Occurs in California, Colorado and Oregon. Within California, occurs in Fresno, Humboldt, Lake, Mariposa, Marin, Nevada, Placer, Plumas, Santa Cruz, Trinity, and Tulare Counties. | Cismontane woodland on very acidic, metamorphic rock or substrate, usually in higher portions in fens. | -- | **None.** CNDDB records exist for the Seller Service Area. Transfers are not expected to affect suitable habitat for this species. |
| **Ferris' milk-vetch**<br>*Astragalus tener* var. *ferrisae* | -/-/1B.1 | Sacramento Valley. | Subalkaline flats and areas around vernal pools. | March-June | **None.** The species has been previously documented within the Seller Service Area. Not likely to occur in rice fields, due to lack of suitable habitat. |
| **Fragrant fritillary**<br>*Fritillaria liliacea* | -/-/ 1B.2 | Alameda, Contra Costa, Monterey, Marin, San Benito, Santa Clara, San Francisco, San Mateo, Solano, Sonoma Counties. | Cismontane woodland, valley and foothill grassland. Grassy areas from 635 - 855m asl. | February - April | **None.** Previous records exist within the Buyer Service Area. Transfers are not expected to impact suitable habitat for fragrant fritillary. |

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|---|---|---|---|---|---|
| **Franciscan onion**<br>*Allium peninsulare* var. *franciscanum* | -/-/ 1B.2 | Mendocino, Santa Clara, San Mateo, Sonoma Counties. | Cismontane woodland, valley and foothill grassland. Clay soils, often on serpentine. Dry hillsides from 100 - 300m asl. | May - June | **None.** Previous records of franciscan onion exist for the Buyer Service Area. The proposed Transfers is not expected to impact suitable habitat for this species. |
| **Franciscan thistle**<br>*Cirsium andrewsii* | -/-/ 1B.2 | Contra Costa, Marin, San Francisco, San Mateo, Sonoma Counties. | Coastal bluff scrub, broadleaved upland forest, coastal scrub. Sometimes serpentine seeps 0 - 135m asl. | March - July | **None.** Has been observed within the Buyer Service Area. No impacts to suitable habitat for Franciscan thistle are anticipated. |
| **Greene's tuctoria**<br>*Tuctoria greeni* | E/R/1B.1 | Butte, Colusa, Fresno, Glenn, Madera, Merced, Modoc, Shasta, San Joaquin, Stanislaus, Tehama, and Tulare Counties. | Vernal pools. | May-July | **None.** There is a CNDDB occurrence within the Seller Service Area, however this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |
| **Hairless popcorn-flower**<br>*Plagiobothrys glaber* | -/-/ 1A | Alameda, Marin, San Benito, Santa Clara Counties. | Meadows and seeps, marshes and swamps. Coastal salt marshes and alkaline meadows 5-180m asl. | March - May | **None.** This species has been documented by CNDDB within the Buyer Service Area. Transfers are not expected to impact suitable habitat for this species within the Buyer Service Area. |
| **Hairy Orcutt grass**<br>*Orcuttia pilosa* | E/E/1B.1 | Northern Sacramento Valley, Pit River Valley; isolated populations in Lake and Sacramento counties. | Vernal pools. | May - September | **None.** Hairy Orcutt grass has previously been documented by the CNDDB in the Seller Service Area. However, this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |
| **Hall's bush-mallow**<br>*Malacothamnus hallii* | -/-/ 1B.2 | Contra Costa, Lake, Mendocino, Merced, Santa Clara, San Mateo, Stanislaus Counties. | Chaparral. Some populations on serpentine 10 - 550m asl. | May - October | **None.** Previous records exist within the Buyer Service Area. Transfers are not expected to impact suitable habitat for Hall's bush-mallow. |

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|---|---|---|---|---|---|
| **Hall's tarplant**<br>*Deinandra halliana* | -/-/ 1B.1 | Fresno, Monterey, San Benito, San Luis Obispo Counties. | Cismontane woodland, valley and foothill grassland, vernal pools. In grassland and not necessarily in vernal pools 200 - 1000m asl. | April - May | **None.** Hall's tarplant has been observed within the Buyer Service Area. Transfers are not expected to impact vernal pools or other suitable habitat for this species within the Buyer Service Area. |
| **Hartweg's golden sunburst**<br>*Pseudobahia bahiifolia* | E/E/1B | Found in El Dorado, Fresno, Madera, Merced, Stanislaus, Tuolumne, and Yuba Counties. | Cismontane woodland, valley and foothill grassland, often acidic. | April - May | **None.** There are CNDDB occurrences within Yolo County outside of the area of analysis. This species is not likely to be affected by Transfers given that it is not likely to occur in rice fields. |
| **Heartscale**<br>*Atriplex cordulata* | -/-/1B | Western Central Valley and valleys of adjacent foothills. | Alkali grasslands, alkali meadows, and alkali scrub. | May - October | **None.** CNDDB occurrences have been documented within the Seller Service Area (Butte, Colusa, Yolo, and Glenn Counties). However, this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. alkali areas). |
| **Heckard's pepper-grass**<br>*Lepidium latipes* var**.** *heckardii* | -/-/1B | Glenn, Solano, and Yolo Counties. | Valley and foothill grassland alkaline flats. | March-May | **None.** This species has been previously documented within the Seller Service Area. However, it is not likely to occur in rice fields due to lack of suitable habitat (i.e. alkali flats). |
| **Henderson's bent grass**<br>*Agrostis hendersonii* | - /-/ 3.2 | Found in Butte, Calaveras, Merced, Placer, Shasta, and Tehama Counties. Also found in Oregon. | Vernal pools. | March- June | **None.** CNDDB records for this species occur within the Seller Service Area. Not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |

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|---|---|---|---|---|---|
| **Hispid bird's beak**<br>*Cordylanthus mollis* ssp. *hispidus* | -/-/1B.1 | Alameda, Kern, Fresno, Merced, Placer, and Solano Counties. | Meadows and seeps, playas, valley and foothill grasslands (alkali). | June-September | **None.** Previously observed within the Seller Service Area according to CNDDB records. Not likely to occur in rice fields, no suitable habitat present. |
| **Hooked popcorn-flower**<br>*Plagiobothrys uncinatus* | -/-/ 1B.2 | Monterey, San Benito, Santa Clara, San Luis Obispo, and Stanislaus Counties. | Chaparral, cismontane woodland, valley and foothill grassland, coastal bluff scrub. Sandstone outcrops and canyon sides, often in burned or disturbed areas 300 - 820m asl. | April - May | **None.** Hooked popcorn-flower has been documented within the Buyer Service Area. No impacts to suitable habitat for this species are anticipated. |
| **Hoover's button-celery**<br>*Eryngium aristulatum* var. *hooverii* | -/-/ 1B.1 | Alameda, San Benito, Santa Clara, San Diego, San Luis Obispo Counties. | Vernal pools. Alkaline depressions, vernal pools, roadside ditches and other wet places near the coast 5 - 45m asl. | July - August | **None.** This species has been documented within the Buyer Service Area. Suitable habitat for the species is present (e.g. irrigated agriculture and ditches), but no impacts to suitable habitat are expected within the Buyer Service Area. |
| **Hoover's cryptantha**<br>*Cryptantha hooveri* | -/-/ 1A | Contra Costa, Kern, Madera, Stanislaus Counties. | Valley and foothill grassland in coarse sand up to 150m asl. | April - May | **None.** Hoover's cryptantha has been observed within the Buyer Service Area. No impacts to suitable habitat for this species are anticipated. |
| **Hoover's eriastrum**<br>*Eriastrum hooveri* | D/-/ 4.2 | Contra Costa, Kern, Madera, Stanislaus Counties. | Chenopod scrub, valley and foothill grassland, pinyon-juniper woodland. On sparsely vegetated alkaline alluvial fans, also in the Temblor Range on sandy soils 50 - 915m asl. | April - May | **None.** This species has previously been documented within the Buyer Service Area. No suitable habitat for this species would be impacted by the proposed Transfers. |

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|---|---|---|---|---|---|
| **Hoover's spurge**<br>*Chamaesyce hooveri* | T/-/ 1B.2 | Scattered in Glenn, Butte, Colusa, Merced, Stanislaus, Tehama, and Tulare Counties. | Vernal pools. | July-September | **None.** According to the CNDDB occurrences have been documented in the Seller Service Area. However, this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |
| **Hospital Canyon larkspur**<br>*Delphinium californicum* ssp. *interius* | -/-/ 1B.2 | Alameda, Contra Costa, Merced, Monterey, San Benito, Santa Clara, San Joaquin, and Stanislaus Counties. | Cismontane woodland, chaparral. In wet, boggy meadows, openings in chaparral and in canyons 225 - 1060m asl. | April - June | **None.** Hospital Canyon larkspur has been observed within the Buyer Service Area. There is suitable habitat for this species in the area of analysis, but the proposed actions are not expected to impact these habitat in the Buyer Service Area. |
| **Indian valley brodiaea**<br>*Broiaea coronaria* ssp. *rosea* | -/E/1B | Scattered in Glenn, Lake, Colusa, and Tehama Counties. | Closed cone coniferous forest, chaparral, valley and foothill grasslands (serpentinite). | May-June | **None.** CNDDB occurrences have been documented outside of the area of analysis. This species is not likely to occur in rice fields due to lack of suitable habitat. |
| **Indian Valley bush-mallow**<br>*Malacothamnus aboriginum* | -/-/ 1B.2 | Alameda, Contra Costa, Merced, Monterey, San Benito, Santa Clara, San Joaquin, and Stanislaus Counties. | Cismontane woodland, chaparral. Granitic outcrops and sandy bare soil, often in disturbed soils 150 - 1700m asl. | April - June | **None.** Indian Valley bush-mallow has been observed within the Buyers Service Area. The proposed Transfers should not affect suitable habitat for this species. |

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|---|---|---|---|---|---|
| **Jepson's milk-vetch**<br>*Astragalus rattanii var. jepsonianus* | -/-/1B.2 | Colusa, Glenn, Lake, Napa, Tehama, and Yolo Counties. | Chaparral, cismontane woodland, valley and foothill grassland, often serpentinite. | April-June | **None.** Although suitable habitat exists, no CNDDB records have been documented within the area of analysis. This species is not likely to be impacted as rice fields do not provide suitable habitat. |
| **Keck's checkerbloom**<br>*Sidalcea keckii* | E/-/1B.1 | Colusa, Fresno, Merced, Napa, Solano, Tulare, and Yolo Counties. | Cismontane woodlands, foothill and valley grasslands (serpentinite). | April-May | **None.** No CNDDB occurrences of this species are known for the area of analysis. Suitable habitat is present, but would not be impacted by the proposed Transfers. |
| **Kellogg's horkelia**<br>*Horkelia cuneata* ssp*. sericea* | -/-/ 1B.1 | Alameda, Monterey, Marin, Santa Barbara, Santa Cruz, San Francisco, San Luis Obispo, and San Mateo Counties. | Closed-cone coniferous forest, coastal scrub, chaparral. Within old dunes, coastal sandhills, openings from 10 - 200m asl. | April - September | **None.** Records of Kellog's horkelia exist in the Buyer Service Area. Transfers are not expected to affect suitable habitat for this species within the area of analysis. |
| **Kings Mountain manzanita**<br>*Arctostaphylos regismontana* | -/-/ 1B.2 | Santa Clara, Santa Cruz, and San Mateo Counties. | Broadleaved upland forest, chaparral, north coast coniferous forest. Granitic or sandstone outcrops 305 - 730m asl. | January - April | **None.** This species has been previously observed within the Buyer Service Area. Suitable habitat is presented but would not be impacted by the proposed Transfers. |
| **Large-flowered fiddleneck**<br>*Amsinckia grandiflora* | E/E/ 1B.1 | Alameda, Contra Costa, and San Joaquin Counties. | Cismontane woodland, valley and foothill grassland. Annual grassland in various soils 275 - 550m asl. | April - May | **None.** Large-flowered fiddleneck has been recorded by the CNDDB within the Buyer Service Area. No impacts would occur to suitable habitat. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Layne's ragwort**<br>*Packera layneae* | T/-/1B | Butte, El Dorado, Tuolumne, and Yuba Counties. | Chaparral and cismontane woodland, rocky and often serpentinite. | April-August | **None.** There is a CNDDB occurrence within Butte County, outside the area of analysis. Although suitable habitat is present within the area of analysis, it is not expected to be impacted by the proposed Transfers. |
| **Legenere**<br>*Legenere limosa* | -/-/1B.1 | Sacramento Valley and south of the North Coast Ranges. | Vernal pools from 1-880m asl. | April-June | **None.** Legenere has been documented within both the Buyer and Seller Service Areas. Not likely to occur in rice fields, no suitable habitat present (i.e. vernal pools). |
| **Lesser saltscale**<br>*Atriplex minuscula* | -/-/1B | Found in Butte, Fresno, Kern, Madera, Merced, Stanislaus, and Tulare Counties. | Chenopod scrub, playas, valley and foothill grasslands (alkali and sandy). | May-October | **None.** No CNDDB records exist for the area of analysis, but it has been documented within some of the counties. Suitable habitat occurs within the Buyer Service Area, but would not be impacted by the proposed Transfers. |
| **Lime Ridge navarretia**<br>*Navarretia gowenii* | -/-/ 1B.1 | Occurs within Contra Costa and Stanislaus Counties in California. | Chaparral on calcium carbonate rich soil with high clay content, 180 - 305m asl. | May - June | **None.** Previously documented within the Buyer Service Area. No suitable habitat for Lime Ridge navarretia would be affected by the proposed Transfers. |
| **Loma Prieta hoita**<br>*Hoita strobilina* | -/-/ 1B.1 | Alameda, Contra Costa, Santa Clara, Santa Cruz Counties. | Chaparral, cismontane woodland, riparian woodland. Within serpentine at mesic sites. | May - October | **None.** CNDDB records of Loma Prieta hoita exist for the Buyer Service Area. No impacts are expected within suitable habitat for this species. |

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|---|---|---|---|---|---|
| **Lone buckwheat** *Eriogonum apricum* var. *apricum* | E/E/1B | Found in Amador and Sacramento Counties. | Chaparral. | July-October | **None.** Although it has been documented, no CNDDB records exist within the area of analysis. This species is not likely to occur in rice fields due to lack of suitable habitat. |
| **Lost Hills crownscale** *Atriplex coronata* var. *vallicola* | -/-/ 1B.2 | Fresno, Kings, Kern, Merced, and San Luis Obispo Counties. | Chenopod scrub, valley and foothill grassland, vernal pools. In powdery, alkaline soils that are vernally moist with Frankenia, Atriplex spp. And Distichlis. 0 - 605m asl. | April - August | **None.** This species has been documented within the Buyer Service Area. No impacts to suitable habitat are expected. |
| **Lost thistle** *Cirsium praeteriens* | -/-/ 1A | Little information exists on this plant. San Mateo and Santa Clara Counties. Little information exists on this species. It was collected from the Palo Alto area at the turn of the 20th century. Not observed since 1901. | 0 - 100m asl. | June - July | **None.** CNDDB records of lost thistle exist for the Buyer Service Area. Very limited information is available. Based on status information it is likely to be extirpated and would therefore be unlikely to occur within an area impacted by transfers. |
| **Maple-leaved checkerbloom** *Sidalcea malachroides* | -/-/ 4.2 | Occurs within California and Oregon. In California the species occurs in Del Norte, Humboldt, Mendocino, Monterey, Santa Clara, Santa Cruz, and Sonoma Counties. | Broadleafed upland forest, coastal prairie, coastal scrub, North Coast coniferous forest. Woodlands and clearings near coast, often in disturbed areas 2 - 760m asl. | March - August | **None.** This species has been previously documented within the Buyer Service Area. No impacts to areas of suitable habitat are anticipated. |
| **Marsh checkerbloom** *Sidalcea oregana* ssp. *hydrophila* | -/-/1B | Glenn, Lake, Mendocino, and Napa Counties. | Meadows and seeps, and riparian forest. | June-August | **None.** Suitable habitat present within Glenn County in the area of analysis. This species is not expected to establish in rice fields, and therefore no impacts are anticipated. |

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|---|---|---|---|---|---|
| **Mason's lilaeopsis**<br>*Lilaeopsis masonii* | -/R/ 1B.1 | Alameda, Contra Costa, Marin, Napa, Sacramento, San Joaquin, Solano, and Yolo Counties. | Freshwater and brackish marshes, riparian scrub. Tidal zones, in muddy or silty soil formed through river deposition or river bank erosion 0 - 10m asl. Populations may be ephemeral, using freshly deposited or exposed sediments (Solano County Water Agency 2012). | April - November | **None.** Previous records of this species exist within the Buyer Service Area. This species is not expected to establish within rice fields. |
| **Merced phacelia**<br>*Phacelia ciliata var. opaca* | -/-/ 1B.2 | Merced County. | Valley and foothill grassland. Adobe or clay soils of valley floors, open hills or alkaline flats 60 - 150m asl. | February - May | **None.** Merced phacelia has been documented within the Seller Service Area. Transfers are not expected to affect suitable habitat for this species. |
| **Metcalf Canyon jewel-flower**<br>*Streptanthus albidus* ssp. *albidus* | E/-/ 1B.1 | Santa Clara County. | Valley and foothill grassland. Relatively open areas in dry grassy meadows on serpentine soils 45 - 245m asl. | April - July | **None.** This species was previously observed within the Buyer Service Area according to CNDDB. No Transfers-related impacts to suitable habitat for Metcalf Canyon jewel-flower are anticipated. |
| **Milo Baker's lupine**<br>*Lupinus milo-bakeri* | -/T/1B | Glenn and Mendocino Counties. | Cismontane woodlands, foothill and valley grasslands. | June-September | **None.** Although suitable habitat is present within the area of analysis, no CNDDB records have been documented in either the Buyer or Seller Service Areas. This species is not likely to occur in rice fields due to lack of suitable habitat. |

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|---|---|---|---|---|---|
| **Most beautiful jewel-flower**<br>*Streptanthus albidus* ssp. *peramoenus* | -/-/ 1B.2 | Alameda, Contra Costa, Monterey, Santa Clara, and San Luis Obispo Counties. | Chaparral, valley and foothill grassland, cismontane woodland, serpentine outcrops, on ridges and slopes 120 - 730m asl. | March - October | **None.** Most beautiful jewel-flower has been previously observed within the Buyer Service Area. No Transfers-related impacts to suitable habitat for this species are expected. |
| **Mount Day rockcress**<br>*Boechera rubicundula* | -/-/ 1B.1 | Santa Clara County. | Rocky slopes in chaparral at 1200m asl. | April - May | **None.** According to CNDDB, this species was documented within the Buyer Service Area. No suitable habitat for this species would be affected by Transfers. |
| **Mt. Diablo buckwheat**<br>*Eriogonum truncatum* | -/-/ 1B.1 | Alameda, Contra Costa, and Solano Counties. | Chaparral, coastal scrub, valley and foothill grassland. Dry, exposed clay or sandy substrates 100 - 600m asl. | April - December | **None.** This species has been observed within the Buyer Service Area. No suitable habitat would be affected by Transfers. |
| **Mt. Diablo fairy-lantern**<br>*Calochortus pulchellus* | -/-/ 1B.2 | Alameda, Contra Costa, and Solano Counties. | Chaparral, cismontane woodland, riparian woodland, valley and foothill grassland on wooded and brushy slopes 200 - 800m asl. | April - June | **None.** Mt. Diablo fairy-lantern has been documented within the Buyer Service Area. No impacts to suitable habitat for this species are expected. |
| **Mt. Diablo jewel-flower**<br>*Streptanthus hispidus* | -/-/ 1B.3 | Contra Costa County. | Valley and foothill grassland, chaparral, talus or rocky outcrops 275 - 970m asl. | March - June | **None.** The Mt. Diablo jewel-flower has been documented in the Buyer Service Area. No impacts to suitable habitat area anticipated. |
| **Mt. Diablo manzanita**<br>*Arctostaphylos auriculata* | -/-/ 1B.3 | Contra Costa County. | Chaparral in canyons and on slopes. On sandstone 120 - 500m asl. | January - March | **None.** This species was previously observed within the Buyer Service Area according to CNDDB. No Transfers-related impacts to suitable habitat for Mt. Diablo phacelia are anticipated. |

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|---|---|---|---|---|---|
| **Mt. Diablo phacelia** *Phacelia phacelioides* | -/-/ 1B.2 | Contra Costa, San Benito, Santa Clara, and Stanislaus Counties. | Chaparral, cismontane woodland. Adjacent to trails, on rock outcrops and talus slopes, sometimes on serpentine 500 - 1370m asl. | April - May | **None.** Mt. Diablo phacelia has been documented within the Buyer Service Area. No impacts to suitable habitat for this species are expected. |
| **Mt. Hamilton coreopsis** *Leptosyne hamiltonii* | -/-/ 1B.2 | Alameda, Santa Clara, and Stanislaus Counties. | Cismontane woodland. On steep shale talus with open southwestern exposure 530 - 1300m asl. | March - May | **None.** CNDDB records of Mt. Hamilton coreopsis exist within the Buyer Service Area. Transfers would not affect suitable habitat for this species. |
| **Mt. Hamilton fountain thistle** *Cirsium fontinale* var. *campylon* | -/-/ 1B.2 | Alameda, Santa Clara, and Stanislaus Counties. | Cismontane woodland, chaparral, valley and foothill grassland. In seasonal and perennial drainages on serpentine soil 95 - 890m asl. | February - October | **None.** This species has been documented within the Buyers Service Area. No impacts to suitable habitat within the area of analysis are anticipated. |
| **Mt. Hamilton jewel-flower** *Streptanthus callistus* | -/-/ 1B.3 | Santa Clara County. | Chaparral, cismontane woodland. Open talus slopes on shale with grey pine and/or black oak 600 - 790m asl. | April - May | **None.** Mt. Hamilton jewel-flower has been documented within the Buyers Service Area by CNDDB. Transfers would not impact suitable habitat for this species. |
| **Mt. Hamilton lomatium** *Lomatium observatorium* | -/-/ 1B.2 | Santa Clara and Stanislaus Counties. | Cismontane woodland. Open to partially shaded openings in Pinus coulteri - Oak woodland. Sedimentary Franciscan rocks and volcanic soils 1219 - 1330m asl. | March - May | **None.** Mt. Hamilton lomatium has been documented within the Buyers Service Area by CNDDB. Transfers would not impact suitable habitat for this species. |
| **Munz's tidy-tips** *Layia munzii* | -/-/ 1B.2 | Fresno, Kern, and San Luis Obispo Counties. | Chenopod scrub, valley and foothill grassland. Hillsides in white-grey alkaline clay soils with grasses and chenopod scrub associates 45 - 760m asl. | March - April | **None.** This species has been observed within the Buyer Service Area. No suitable habitat would be affected by Transfers. |

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|---|---|---|---|---|---|
| **Norris' beard moss**<br>*Didymodon norrisii* | -/-/ 2.2 | Butte, Contra Costa, Colusa, Humboldt, Lake, Los Angeles, Madera, Monterey, Mariposa, Nevada, Plumas, San Benito, Santa Cruz, Shasta, Sierra, Sonoma, Tehama, Tulare, and Tuolumne Counties. | Cismontane woodland, lower montane coniferous forest. Moss from seasonally wet sheet drainages on exposed rock slabs or terraces that completely dry in summer. | -- | **None.** Records of Norris' beard moss exist for the Buyer Service Area. Transfers would not impact suitable habitat for this species. |
| **Northern California black walnut**<br>*Juglans hindsii* | -/-/1B | Native stands reported in Napa and Contra Costa Counties. | Riparian woodland. | April-May | **None.** Previously documented within the Buyer Service Area. Transfers would not impact suitable habitat for this species. |
| **Oregon meconella**<br>*Meconella oregana* | -/-/ 1B.1 | Occurs in California, Oregon and Washington. Within California occurs in Contra Costa and Santa Clara Counties. | Coastal prairie and coastal scrub in open, moist places 250 - 500m asl. | March - April | **None.** Oregon meconella has been observed within the Buyer Service Area. Transfers would not affect suitable habitat for this species. |
| **Oval-leaved viburnum**<br>*Viburnum ellipticum* | -/-/2.3 | Occurs in California, Oregon and Washington. Within California occurs in Contra Costa, El Dorado, Fresno, Glenn, Humboldt, Mendocino, Napa, Placer, Shasta, Sonoma and Tehama Counties. | Chaparral, cismontane woodland, and lower montane coniferous forest 215 - 1400m asl. | May - June | **None.** This species has been previously documented within the Buyer Service Area. Suitable habitat for oval-leaved viburnum is not expected to be affected by Transfers. |
| **Pallid manzanita**<br>*Arctostaphylos pallida* | T/E/1B.1 | Alameda and Contra Costa Counties. | Broadleafed upland forest, closed-cone coniferous forest, chaparral, cismontane woodland, coastal scrub. Grows on uplifted marine terraces on siliceous shale or thin chert at 185 - 465m asl. May require fire. | December - March | **None.** Pallid manzanita has been observed within the Buyer Service Area. No Transfers-related impacts to suitable habitat are anticipated. |

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|---|---|---|---|---|---|
| **Palmate-bracted bird's-beak**<br>*Cordylanthus palmatus* | E/E/1B.1 | Found in Glenn and Colusa Counties and within the Central Valley. | Alkali meadow, alkali scrub, valley and grasslands. | May-October | **None.** CNDDB records of this species exist for the Seller Service Area. Not likely to occur in rice fields; no suitable habitat is present (i.e. alkali areas). |
| **Panoche pepper-grass**<br>*Lepidium jaredii* ssp. *album* | -/-/ 1B.2 | Fresno, San Benito, and San Luis Obispo Counties. | Valley and foothill grassland. White or grey clay lenses on steep slopes. Incidental in alluvial fans and washes. Clay and gypsum-rich soils 65 - 910m asl. | February - June | **None.** Panoche pepper-grass has previously been documented within the Buyer Service Area. The proposed Transfers would not impact suitable habitat for this species. |
| **Peruvian dodder**<br>*Cuscuta obtusiflora* var. *glandulosa* | -/-/ 2.2 | Known from California, Baja California, Sonora and Texas. Within California records exist from Butte, Los Angeles, Merced, Sacramento, San Bernardino, Sonoma and Sutter Counties. | Marshes and swamps (freshwater). Freshwater marsh 15 - 280m asl. | July - October | **None.** CNDDB records of this species exist for the Seller Service Area. Peruvian dodder is unlikely to become established within rice fields. |
| **Pincushion navarretia**<br>*Navarretia myersii* ssp. *myersii* | -/-/1B.1 | Alamdor, Calaveras, Merced, Placer, and Sacramento Counties. | Vernal pools (often acidic). | May | **None.** Previously documented in the Seller Service Area. No vernal pools would be affected by Transfers. |
| **Pink creamsacs**<br>*Castilleja rubicundula* ssp. *rubicundula* | -/-/ 1B.2 | Butte, Contra Costa, Colusa, Glenn, Lake, Napa, Plumas, San Benito, Santa Clara, and Shasta Counties. | Chaparral, meadows and seeps, valley and foothill grassland. Openings in chaparral or grasslands. On serpentine 20 - 900m asl. | April - June | **None.** Pink creamsacs has been previously documented within the Buyer Service Area. No impacts to suitable habitat for this species are anticipated. |
| **Point Reyes bird's-beak**<br>*Chloropyron maritimum* ssp. *palustre* | -/-/ 1B.2 | California and Oregon. Within California it occurs in Alameda, Humboldt, Marin, Santa Clara, San Francisco, San Mateo, and Sonoma Counties. | Coastal salt marsh, usually in coastal salt marsh with Salicornia, Distichlis, Jaumea, Spartina, etc. 0 - 15m. | June - October | **None.** CNDDB records of this species exist for the Buyer Service Area. Suitable habitat for this species is not expected to be affected by Transfers. |

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|---|---|---|---|---|---|
| **Presidio clarkia**<br>*Clarkia franciscana* | E/E/1B.1 | Alameda and San Francisco Counties | Coastal scrub, valley and foothill grassland. Serpentine outcrops in grassland or scrub 20 - 335m. | May - July | **None.** Presidio clarkia has been previously observed within the Buyer Service Area. Suitable habitat exists in the area of analysis, but would not be affected by the proposed Transfers. |
| **Recurved larkspur**<br>*Delphinium recurvatum* | -/-/1B | Disbursed throughout the Sacramento and Central Valley. | Chenopod scrub, cismontane, valley and foothill grasslands (alkali). | March-June | **None.** According to the CNDDB this species has been previously recorded in the Buyer Service Area. Suitable habitat exists (i.e. alkali areas) in the area of analysis, but would not be affected by the proposed Transfers. |
| **Red Bluff dwarf rush**<br>*Juncus leiospermus* var. *leiospermus* | -/-/1B.1 | Butte, Placer, Shasta, and Tehama Counties. | Chaparral, valley and foothill grassland, cismontane woodlands, vernal pools. Vernally mesic sites. Sometimes on edges of vernal pools 30 - 1020m asl. The species has also been documented within intermittent drainages and in areas with pocket gopher and ground squirrel activity (Butte County Association of Governments 2011). | March - May | **Low.** Red Bluff dwarf rush has been previously documented within the Seller Service Area. Given that the species has some tolerance for disturbance, is a low potential for red bluff dwarf rush to establish within rice fields, which may represent marginal habitat. |
| **Red Hills soaproot**<br>*Chlorogalum grandiflorum* | -/-/1B.2 | Amador, Butte, Calaveras, El Dorado, Placer and Tuolumne Counties. | Cismontane woodland, chaparral, lower montane coniferous forest. Occurs frequently on serpentine or gabbro, but also on non-ultramafic substrates, often on historically disturbed sites. | May - June | **None.** CNDDB records of this species exist within the Seller Service Area. This species is not expected to occur within rice fields due to lack of suitable habitat (i.e., serpentine areas). |

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|---|---|---|---|---|---|
| **Red mountain catchfly** *Silene campanulata* ssp. *campanulata* | -/E/1B | Found in Colusa, Glenn, Mendocino, Shasta, Tehama, and Trinity Counties. | Chaparral and lower montane coniferous forest, usually sepentinite and rocky. | April-July | **None.** There is a CNDDB occurrences in the vicinity, within counties in the area of analysis. However, this species is not likely to occur in rice fields due to lack of suitable habitat. |
| **Robust spineflower** *Chorizanthe robusta* var. *robusta* | E/-/1B.1 | Alameda, Monterey, Marin, Santa Clara, Santa Cruz, San Francisco, and San Mateo Counties. | Cismontane woodland, coastal dunes, coastal scrub. Sandy terraces and bluffs or in loose sand 3 - 120m asl. | April - September | **None.** Robust spineflower has been documented within the Buyer Service Area. Transfers are not expected to affect suitable habitat for this species. |
| **Rock sanicle** *Sanicula saxatilis* | -/-/ 1B.2 | Contra Costa and Santa Clara Counties. | Broadleafed upland forest, chaparral, valley and foothill grassland. Bedrock outcrops and talus slopes in chaparral or oak woodland habitat 625 - 1215m asl. | April - May | **None.** CNDDB records of this species exist within the Buyer Service Area. Suitable habitat for rock sanicle is not expected to be affected by Transfers. |
| **Round-leaved filaree** *California macrophylla* | -/-/1B.1 | California, Baja California, Oregon. | Cismontane woodland, valley and foothill grassland. Clay soils 15 - 1200m asl. | March - May | **None.** Round-leaved filaree has been previously documented within both the Buyer and Seller Service Areas. No Transfers-related impacts to suitable habitat for the species are anticipated. |
| **Sacramento Orcutt grass** *Orcuttia viscida* | E/E/1B.1 | Valley grasslands and freshwater wetlands. | Vernal pools. | May-June | **None.** CNDDB records of this species exist for the Seller Service Area. Sacramento Orcutt grass is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |

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|---|---|---|---|---|---|
| **Saline clover**<br>*Trifolium hydrophilum* | -/-/ 1B.2 | California's Central coast and Bay Area. | Marshes and swamps, valley and foothill grassland, vernal pools. Mesic, alkaline sites 0 - 300m asl. | April - June | **Low.** Records of saline clover exist within both the Buyer and Seller Service Areas. Rice fields may represent marginally suitable habitat for this species. There is a low potential for impacts within the Seller Service Area (Colusa, Solano, and Yolo Counties). |
| **San Benito pentachaeta**<br>*Pentachaeta exilis* ssp. *aeolica* | -/-/ 1B.2 | Monterey, San Benito, and Santa Clara Counties. | Cismontane woodland, valley and foothill grassland. Grassy areas from 635 - 855m asl. | March - May | **None.** This species has previously been documented within the Buyer Service Area. No suitable habitat for this species would be impacted by the proposed Transfers. |
| **San Francisco Bay spineflower**<br>*Chorizanthe cuspidata* var. *cuspidata* | -/-/ 1B.2 | Alameda, Marin, San Francisco, San Mateo, and Sonoma Counties. | Coastal bluff scrub, coastal dunes, coastal prairie, coastal scrub. Sandy soil on terraces and slopes 5 - 550m asl. | April - August | **None.** San Francisco Bay spineflower has been observed within the Buyer Service Area. No impacts to suitable habitat for this species are anticipated in association with the proposed Transfers. |
| **San Francisco collinsia**<br>*Collinsia multicolor* | -/-/ 1B.2 | Monterey, Marin, Santa Clara, Santa Cruz, San Francisco, and San Mateo Counties. | Closed-cone coniferous forest, coastal scrub. On decomposed shale (mudstone) mixed with humus 30 - 250m asl. | March - May | **None.** This species has been documented within the Buyer Service Area. No impacts to suitable habitat are expected. |
| **San Francisco popcorn-flower**<br>*Plagiobothrys diffusus* | -/E/1B.1 | Alameda, Santa Cruz, San Francisco, and San Mateo Counties. | Valley and foothill grassland, coastal prairie. Historically known from grassy slopes with marine influence 60 - 485m asl. | March - June | **None.** San Francisco popcorn-flower has been observed within the Buyer Service Area. No impacts to suitable habitat for this species are anticipated in association with the proposed Transfers. |

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|---|---|---|---|---|---|
| **San Joaquin spearscale**<br>*Atriplex joaquiniana* | -/-/1B.2 | Western Central Valley and valleys of adjacent foothills. | Alkali grasslands, and alkali scrub. | April-September | **None.** Has been previously documented within both the Buyer and Seller Service Areas. Not likely to occur in rice fields, no suitable habitat present (i.e. alkali areas). |
| **San Joaquin woollythreads**<br>*Monolopia congdonii* | E/-/1B.2 | Fresno, Kings, Kern, Santa Barbara, San Benito, San Luis Obispo, and Tulare Counties. | Chenopod scrub and valley and foothill grassland. Alkaline or loamy plains, sandy soils 60 - 800m asl. | February - May | **None.** San Joaquin woollythreads was previously documented within the Buyer Service Area. No impacts to suitable habitat are anticipated. |
| **Sanford's arrowhead**<br>*Sagittaria sanfordii* | -/-/1B | Central Valley. | Freshwater marshes, shallow streams, and ditches. | May-August | **Moderate.** Sanford's arrowhead has been previously documented within the Seller Service Area. Not likely to establish in rice fields, but ditches represent suitable habitat. There is a moderate potential that this species would be affected by the proposed Transfers. |
| **Santa Clara red ribbons**<br>*Clarkia concinna ssp. automixa* | -/-/ 4.3 | Alameda and Santa Clara Counties. | Cismontane woodland, chaparral on slopes and near drainages 90-970m asl. | April - July | **None.** CNDDB records for this species exist for the Buyer Service Area. No suitable habitat for this species should be affected by Transfers. |
| **Santa Clara Valley dudleya**<br>*Dudleya abramsii* ssp. *setchellii* | E/-/ 1B.1 | Santa Clara County. | Valley and foothill grassland, cismontane woodland. On rocky serpentine outcrops and on rocks within grassland or woodland 80 - 335m asl. | April - October | **None.** Santa Clara Valley dudleya has been previously documented within the Buyer Service Area. Suitable habitat for this species would not be impacted by the proposed Transfers. |

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|---|---|---|---|---|---|
| **Santa Cruz tarplant,** *Holocarpha macradenia* | T/E/1B.1 | Alameda, Contra Costa, Monterey, Marin, Santa Cruz, and Solano Counties. | Coastal prairie, valley and foothill grassland. Light, sandy soil or sandy clay, often with non-natives 10 - 260masl. | June - October | **None.** Santa Cruz tarplant has been observed within the Buyer Service Area, according to CNDDB records. No impacts to suitable habitat are anticipated. |
| **Santa Cruz Mountains beardtongue** *Penstemon rattanii* var. *kleei* | -/-/ 1B.2 | Santa Clara and Santa Cruz Counties | Chaparral, lower montane coniferous forest. Sandy shale slopes, sometimes in the transition between forest and chaparral 400 - 1100m asl. | May - June | **None.** This species has been observed within the Buyer Service Area. No suitable habitat would be affected by Transfers. |
| **Santa Cruz Mountains pussypaws** *Calyptridium parryi* var. *hesseae* | -/-/ 1B.1 | Monterey, Santa Clara, Santa Cruz, San Luis Obispo, and Stanislaus Counties. | Chaparral, cismontane woodland, sandy or gravelly openings 305 - 1530m asl. | May - August | **None.** CNDDB records of Santa Cruz Mountains pussypaws exist for the Buyer Service Area. Suitable habitat for this species is not expected to be affected by Transfers. |
| **Santa Cruz tarplant,** *Holocarpha macradenia* | T/E/1B.1 | Alameda, Contra Costa, Monterey, Marin, Santa Cruz, and Solano Counties. | Coastal prairie, valley and foothill grassland. Light, sandy soil or sandy clay, often with non-natives 10 - 260masl. | June - October | **None.** Santa Cruz tarplant has been observed within the Buyer Service Area, according to CNDDB records. No impacts to suitable habitat are anticipated. |
| **Scadden Flat checkerbloom** *Sidalcea stipularis* | -/E/ 1B.1 | Nevada County. Known from two occurrences near Grass Valley. | Marshes and swamps. Typical habitat includes montane marshes fed by springs 700 - 740m asl. | July - August | **None.** This species has been previously documented within the Seller Service Area. It is not likely to establish in rice fields due to lack of suitable habitat (i.e. montane marsh). |
| **Sharsmith's harebell** *Campanula sharsmithiae* | -/-/ 1B.2 | Santa Clara and Stanislaus Counties. | Chaparral. Serpentine barrens 480 - 1820m asl. | April - June | **None.** Sharsmith's harebell has been observed within the Buyer Service Area. No impacts to suitable habitat for this species are expected. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Sharsmith's onion**<br>*Allium sharsmithiae* | -/-/ 1B.3 | Alameda, Santa Clara, and Stanislaus Counties. | Cismontane woodland. Rocky, serpentine slopes 400 - 1200m asl. | March - May | **None.** CNDDB records for this species occur within the Buyer Service Area. Suitable habitat for this species should not be impacted by the proposed Transfers. |
| **Sheldon's sedge**<br>*Carex sheldonii* | -/-/2.2 | Occurs in California, Idaho, Nevada, Oregon, Utah and Washington. Within California the species occurs in Lassen, Modoc, Placer, and Plumas Counties. | Lower montane coniferous forest, marshes and swamps, riparian scrub. Mesic sites along creeks and in wet meadows 1065 - 1755m asl. | May - August | **None.** Sheldon's sedge has been observed within the Seller Service Area. Although rice fields may provide the appropriate moisture conditions, this species occurs at very high elevations and is therefore not expected to be impacted by the proposed Transfers. |
| **Shining navarretia**<br>*Navarretia nigelliformis* ssp. *radians* | -/-/1B.2 | Alameda, Contra Costa, Fresno, Merced, Monterey, San Benito, San Joaquin, and San Luis Obispo Counties. | Cismontane woodland, valley and foothill grassland, and vernal pools 200 - 1000m asl. Known from grassland, and may not necessarily occur in vernal pools. | April - July | **None.** Previous CNDDB records of shining navarettia exist for the Seller Service Area. This species is unlikely to establish within rice fields due to lack of suitable habitat (i.e., vernal pools and native grassland). |
| **Sierra blue grass**<br>*Poa sierrae* | -/-/1B.3 | Butte, Madera, Nevada, Placer, Plumas, Shasta Counties. | Lower montane coniferous forest. Shady, moist, rocky slopes often in canyons 365 - 1160m asl. | April - June | **None.** This species has been documented within the Seller Service Area. This species is not likely to be impacted, given that it requires shaded rocky slope habitat not provided in rice fields. |
| **Showy golden madia**<br>*Madia radiata* | -/-/1B.1 | Contra Costa, Fresno, Kings, Kern, Monterey, Santa Barbara, San Benito, Santa Clara, San Joaquin, San Luis Obispo, and Stanislaus Counties. | Valley and foothill grassland, cismontane woodland, chenopod scrub. Mostly on adobe clay in grassland or among shrubs 25 - 1125m asl. | March - May | **None.** Showy golden madia has been observed within the Buyer Service Area. No project impacts to suitable habitat for this species are anticipated. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Slender Orcutt grass**<br>*Orcuttia tenuis* | T/E/1B.1 | Northern Sacramento Valley, Pit River Valley; isolated populations in Lake and Sacramento Counties. | Vernal pools. | May-October | **None.** The CNDDB contains records of slender Orcutt grass in the Seller Service Area. However, this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |
| **Slender-leaved pondweed**<br>*Stuckenia filiformis* | -/-/ 2.2 | Occurs in California, Arizona, Nevada, Oregon, and Washington. | Marshes and swamps. Shallow, clear water of lakes and drainage channels 15 - 2310m asl. | May - July | **None.** Slender-leaved pondweed has been previously documented within the Buyer Service Area. It is not expected to occur within rice fields in the Seller Service Area given the lack of suitable natural lake and stream habitat. |
| **Slender silver moss**<br>*Anomobryum julaceum* | -/-/ 2.2 | California and Oregon. Within California it occurs in Butte, Contra Costa, Humboldt, Los Angeles, Mariposa, Santa Barbara, Santa Cruz, Shasta, and Sonoma Counties. | Broadleafed upland forest, lower montane coniferous forest, north coast coniferous forest. Grows on damp rocks and soil in acidic substrates and on roadcuts 100 - 1000m asl. | -- | **None.** CNDDB records of slender silver moss exist for the Buyer Service Area. Suitable habitat for this species is not expected to be affected by Transfers. |
| **Smooth lessingia**<br>*Lessingia micradenia var. glabrata* | -/-/ 1B.2 | Santa Clara County. | Chaparral. Serpentine often on roadsides 120 - 485m asl. | July - November | **None.** This species has been previously documented within the Buyer Service Area. No impacts to chaparral or serpentine areas are anticipated. |
| **Soft bird's beak**<br>*Cordylanthus mollis* ssp. *mollis* | E/R/1B.2 | Located in Contra Costa, Marin, Napa, Sacramento, Solano, and Sonoma Counties. | Coastal salt marshes and swamps. | July-November | **None.** CNDDB occurrences exist for the Buyer Service Area, however this species is not likely to be affect by Transfers due to lack of suitable habitat (i.e. coastal salt marshes). |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Stinkbells**<br>*Fritillaria agrestis* | -/-/ 4.2 | Occurs in Central and Northern California, including Alameda, Contra Costa, Fresno, Kern, Mendocino, Merced, Monterey, Mariposa, Placer, Sacramento, Santa Barbara, San Benito, Santa Clara, Santa Cruz, San Luis Obispo, San Mateo, Stanislaus, Tuolumne, Ventura, and Yuba Counties. | Cismontane woodland, chaparral, valley and foothill grassland. Sometimes on serpentine, mostly in non-native grassland or in grassy openings in clay soil 95 - 890m asl. | March - June | **None.** This species has been documented within both the Buyer and the Seller Service Areas. No impacts to suitable habitat for stinkbells are anticipated. |
| **Succulent owl's clover**<br>*Castilleja campestris* ssp. *succulenta* | T/E/1B.2 | Fresno, Madera, Merced, Mariposa, San Joaquin, and Stanislaus Counties. | Vernal pools. | April-May | **None.** Succulent owl's clover has been documented in the Seller Service Area, however this species is not likely to occur in rice fields due to lack of suitable habitat (i.e. vernal pools). |
| **Suisun Marsh aster**<br>*Symphyotrichum lentum* | -/-/ 1B.2 | Contra Costa, Napa, Sacramento, San Joaquin, Solano, and Yolo Counties. | Saline and freshwater marshes and swamps. Most often seen along sloughs with Phragmites, Scirpus, blackberry, Typha, etc. at 0-3m asl. | May - November | **None.** This species has been previously documented within both the Buyer and Seller Service Areas. This species is not expected to occur within rice fields given its sensitivity to habitat alteration and agricultural amendments. Environmental commitments would require that downstream flows are maintained, such that no impacts are anticipated in the natural habitats for the species. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Talus fritillary**<br>*Fritillaria falcata* | -/-/ 1B.2 | Alameda, Monterey, San Benito, Santa Clara, and Stanislaus Counties. | Chaparral, cismontane woodland, lower montane coniferous forest. On shale, granite, or serpentine talus 300 - 1525m asl. | March - May | **None.** Talus fritillary has been observed within the Buyer Service Area. Suitable habitat for this species is not expected to be affected. |
| **Temblor buckwheat**<br>*Eriogonum temblorense* | -/-/ 1B.2 | Fresno, Kern, Monterey, and San Luis Obispo Counties. | Valley and foothill grassland. Barren clay or sandstone substrates 300 - 1000m asl. | April - September | **None.** Records of temblor buckwheat exist within the Buyer Service Area. Transfers are not expected to impact any suitable habitat for this species. |
| **Tiburon buckwheat**<br>*Eriogonum luteolum var. caninum* | -/-/ 1B.2 | Alameda, Contra Costa, Marin, Sonoma Counties. | Chaparral, valley and foothill grassland, cismontane woodland, coastal prairie. Serpentine soils on sandy to gravelly sites 0 - 700m asl. | May - September | **None.** Has been observed within the Buyer Service Area. No impacts to suitable habitat for Tiburon buckwheat are expected. |
| **Tiburon paintbrush**<br>*Castilleja affinis* ssp. *neglecta* | E/T/ 1B.2 | Marin, Napa, and Santa Clara Counties. | Valley and foothill grassland. Rocky serpentine sites 75 - 400m asl. | April - June | **None.** CNDDB records of Tiburon paintbrush exist within the Buyer Service Area. Transfers are not expected to impact suitable habitat for this species. |
| **Tracy's eriastrum**<br>*Eriastrum tracyi* | -/R/ 1B.2 | Colusa, Fresno, Glenn, Kern, Santa Clara, Shasta, Stanislaus, Tehama, Trinity, and Tulare Counties. | Chaparral, cismontane woodland. Gravelly shale or clay, often in open areas 315 - 760m asl. | June - July | **None.** Previously documented within the Buyer Service Area. No impacts to suitable habitat for this species are expected. |
| **Vernal pool smallscale**<br>*Atriplex persistens* | -/-/ 1B.2 | Colusa, Glenn, Madera, Merced, Solano, Stanislaus, and Tulare Counties. | Vernal pools. Alkaline vernal pools 10 - 115m asl. | June - October | **None.** Vernal pool smallscale has been documented within the Seller Service Area. This species is not likely to establish within rice fields given the lack of vernal pool and alkaline habitat. |

| **Common Name** *Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Western leatherwood** *Dirca occidentalis* | -/-/ 1B.2 | Alameda, Contra Costa, Marin, Santa Clara, San Mateo, and Sonoma Counties. | Broadleafed upland forest, chaparral, closed-cone coniferous forest, cismontane woodland, north coast coniferous forest, riparian forest, riparian woodland. On mesic sites on brushy slopes 30-550m asl within mixed evergreen and foothill woodland communities. | January - April | **None.** CNDDB records of this species exist within the Buyer Service Area. Suitable habitat for western leatherwood is not expected to be affected by Transfers. |
| **White-flowered rein orchid** *Piperia candida* | -/-/ 1B.2 | California, Oregon, Washington. Within California the species occurs in Del Norte, Humboldt, Mendocino, Santa Clara, Santa Cruz, Siskiyou, San Mateo, Sonoma, and Trinity Counties. | North coast coniferous forest, lower montane coniferous forest, broad leafed upland forest. Coast ranges from Santa Cruz County North on serpentine. Forest duff, mossy banks, rock outcrops and muskeg 0 - 1200m asl. | March - September | **None.** White-flowered rein orchid has been documented within the Buyer Service Area. However, no impacts to suitable habitat for this species are anticipated in the Buyer Service Area. |
| **Woodland woollythreads** *Monolopia gracilens* | -/-/ 1B.2 | Alameda, Contra Costa, Monterey, Santa Clara, Santa Cruz, San Luis Obispo, and San Mateo Counties. | Chaparral, valley and foothill grassland (serpentine), cismontane woodland, broad leafed upland forests, north coast coniferous forest. Grassy sites in openings, sandy to rocky soils. Often seen on serpentine after burns but may have only a weak affinity to serpentine. | February - July | **None.** Has been observed within the Buyer Service Area. No impacts to suitable habitat for woodland woolly threads are anticipated. |
| **Woolly rose-mallow** *Hibiscus lasiocarpos* var. *occidentalis* | -/-/ 1B.2 | Butte, Contra Costa, Colusa, Glenn, Sacramento, San Joaquin, Solano, Sutter, and Yolo Counties. | Marshes and swamps (freshwater). Moist, freshwater-soaked river banks and low peat islands in sloughs. Known from the Delta watershed 0 - 150m asl. | June - September | **None.** Previously observed in the Buyer Service Area. Not likely to establish in rice fields given the lack of suitable habitat (marsh and swamp). This species is sensitive to habitat disturbance and agricultural amendments. |

| **Common Name**<br>*Scientific name* | **Special Status* (F/S/RPR)** | **Distribution** | **Habitat Association** | **Blooming Period** | **Potential Impact** |
|---|---|---|---|---|---|
| **Wright's trichocoronis**<br>*Trichocoronis wrightii* var. *wrightii* | -/-/ 2.1 | Colusa, Merced, Riverside, San Joaquin, and Sutter Counties. | Marshes and swamps, riparian forest, meadows and seeps, vernal pools. Mud flats of vernal lakes, drying river beds and alkali meadows 5 - 435m asl. | May - September | **Low.** According to the CNDDB, this species has previously been recorded in the Seller Service Area. Rice fields are not expected to support this species given the lack of suitable natural habitats. |

RPR=California Rare Plant Rank
1B= Rare, threatened, or endangered in California and elsewhere
2= Plants Rare, Threatened, or Endangered in California, But More Common Elsewhere
3= Plants about which we need more information - A review list
*Status explanations:
F=Federal
E= listed as endangered under the federal Endangered Species Act
T= listed as threatened under the federal Endangered Species Act
S=State
E=Endangered
T=Threatened
R=Rare
SSC=Species of Special Concern

Wildlife and plant species addressed in the area of analysis have been selected through the following process. First, all species identified in database records searches went through an evaluation to identify what are considered "special-status species" in relationship to the federal ESA and CESA compliance. For the purpose of this assessment, "special-status species" are those species that meet one or more of the following criteria:

- Species that are listed or proposed for listing as threatened or endangered under ESA (50 Code of Federal Regulations [CFR] 17.11 [listed animals]; 50 CFR 17.12 [listed plants]; and various notices in the Federal Register [FR]).
- Species that are candidates for possible future listing as threatened or endangered under ESA (75 FR 69222, November 10, 2010).
- Species that are listed or proposed for listing by the State of California as threatened or endangered under CESA (14 California Code of Regulations [CCR] 670.5).
- Species that meet the definitions of rare or endangered under the California Environmental Quality Act (CEQA) (State CEQA Guidelines Section 15380).
- Plants listed as rare under the CNPPA (CDFW Commission 1900 et seq.).
- Plants listed by California Native Plant Society (CNPS) as plants about which more information is needed to determine their status and plants of limited distribution, which may be included as special-status species on the basis of local significance or recent biological information.
- Animals listed as California Species of Special Concern (SSC) to the CDFW (Shuford and Gardali 2008 [birds]; Williams 1986 [mammals]; and Jennings and Hayes 1994 [amphibians and reptiles]).
- Animals that are fully protected in California (CDFW Commission 3511 [birds], 4700 [mammals], 5050 [amphibians and reptiles], and 5515 [fish]).
- Birds of Conservation Concern (USWFS 2008).

The selection process resulted in an initial list of 257 special-status plant and wildlife species. Tables N-1 and N-2 provide information on all 257 special-status species known from, or with potential to occur in the area of analysis, including common and scientific name, listing status (Federal, State, Global Rank, and/or State Rank), suitable habitat characteristics, distribution in California, and potential for occurrence in the area of analysis.

Not all of these species have the potential to be affected by long-term water transfers. Many of the 257 species are not expected to occur in the natural communities and agricultural habitats that would be affected by the action alternatives (e.g., riverine, riparian, natural and managed wetlands, rice fields, and irrigation/drainage channels). Consequently, the action alternatives have the potential to affect only a limited number of these special-status species.

For each plant and wildlife species that could be affected by the Proposed Action in Table N-3, the likelihood that water transfers would affect the species is assigned a category in the last column and the rationale for that categorization is provided. Those species in Tables N-1 and N-2 which are known to occur in the area of analysis, but would not be affected by the action alternatives are not addressed further in this analysis. Based on these considerations, the initial list of species potentially present was reduced to 14 species that could be affected. These 14 species are listed in Table N-3 along with HCP/NCCPs that are adopted or in preparation which cover the species and may have additional requirements for species conservation within their plan areas. Special-status plants and terrestrial wildlife species potentially affected by the action alternatives are discussed below. Potentially affected special-status fish species are discussed separately in Section 3.7 of this Final EIS/EIR.

## Table N-3.
## Potentially Affected Special-Status Plant and Wildlife Species in the Area of Analysis

| | | | | Conservation Plan Coverage[2] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Status** | **Species** | **Status[1]** | **BRCP** | **BDCP** | **ECCC HCP/NCCP** | **NB HCP** | **PCCP** | **SJMSCP** | **SCV HCP/NCCP** | **SMSHCP** | **SSHCP** | **YNHP** | **YS NCCP/HCP** |
| **Plants** | California Rare Plant Rank | Ahart's dwarf rush | RPR 1B.2 | X | | | | X | | | | X | | X |
| | | Sanford's arrowhead | RPR 1B.2 | | | | | | X | | | | | |
| | | Red Bluff dwarf rush | RPR 1B.1 | X | | | | X | X | | | | | |
| | | Saline clover | RPR 1B.2 | | | | | | | | | | | |
| **Wildlife** | State or Federally Listed | Giant garter snake | FT, ST | X | X | X | X | X | X | | X | X | X | X |
| | | San Joaquin kit fox | FE, ST | | X | X | | | X | X | | | | |
| | | Greater sandhill crane | ST, FP | X | X | | | | X | | | X | | X |
| | Species of Special Concern | Black tern | SSC/WL | | | | | | | | | | | |
| | | Long-billed curlew | SSC | | | | | | X | | | | | |
| | | Pacific pond turtle | SSC | | X | X | X | | X | X | | X | X | X |
| | | Purple martin | SSC | | | | | | | | | | X | |

| | Status | Species | Status[1] | Conservation Plan Coverage[2] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | BRCP | BDCP | ECCC HCP/NCCP | NB HCP | PCCP | SJMSCP | SCV HCP/NCCP | SMSHCP | SSHCP | YNHP | YS NCCP/HCP |
| | | Tricolored blackbird | ST | X | X | X | X | X | X | X | X | X | X | X |
| | | White-faced ibis | WL | | | | X | | X | | | | | |
| | | Yellow-headed blackbird | SSC | | | | | | | | | | | |

[1] Status:

FE-federally listed endangered

FP-fully protected under California Fish and Game Code

FT-federally listed threatened

RPR 1B.1-California Rare Plant Rank 1B.1 = Plants rare, threatened, or endangered in California and elsewhere. Seriously threatened in California (over 80 percent of occurrences threatened / high degree and immediacy of threat)

RPR 1B.2-California Rare Plant Rank 1B.1 = Plants rare, threatened, or endangered in California and elsewhere. Fairly threatened in California (20 to 80 percent occurrences threatened / moderate degree and immediacy of threat)

ST-state-listed threatened

SSC-California Species of Special Concern

WL- species that were previously designated as SSC but no longer merit SSC status or which do not meet SSC criteria but for which there is concern and a need for additional information to clarify status.

[2] Conservation plan

BDCP – Bay-Delta Conservation Plan (under development)

BRCP – Butte Regional Conservation Plan (under development)

ECCCHCP/NCCP – East Contra Costa County HCP/NCCP (adopted)

NBHCP – Natomas Basin HCP (adopted)

PCCP – Placer County Conservation Plan (under development)

SCVHCP/NCCP – Santa Clara Valley HCP/NCCP (adopted)

SJMSCP – San Joaquin County Multi-Species Habitat Conservation and Open Space Plan (adopted)

SMSHCP-Solano Multispecies HCP (under development)

SSHCP – South Sacramento HCP (under development)

YNHP – Yolo Natural Heritage Program (under development)

YSNCCP/HCP – Yuba-Sutter NCCP/HCP (under development)

# N.1 Special-Status Plants

## N.1.1 Ahart's Dwarf Rush

Ahart's dwarf rush (*Juncus leiospermus* var. *ahartii*) is a California Rare Plant Rank (RPR) 1B.2 species known from Butte, Calaveras, Placer, Sacramento, Tehama, and Yuba counties, and previous observations exist within the Seller Service Area. This species has generally been documented at mesic locations within valley and foothill grassland between 30 and 229 meters above mean sea level (amsl). It may also occur in disturbed areas including agricultural fields and locations with gopher digging activity. Ahart's dwarf rush typically blooms between March and May. Development is the major threat to this species.

## N.1.2 Sanford's Arrowhead

Sanford's arrowhead (*Sagittaria sanfordii*) is a California RPR 1B.2 perennial rhizomatous herb found in the Central Valley in freshwater marsh, shallow stream areas, and ditches between zero and 650 meters amsl. Previous observations exist within the Seller Service Area. Sanford's arrowhead typically blooms between May and August.

Threats to Sanford's arrowhead include grazing, development, recreational activities, non-native plants, road widening, and alteration of channels.

## N.1.3 Red Bluff Dwarf Rush

Red Bluff dwarf rush (*Juncus leiospermus* var. *leiospermus*) is a California RPR 1B.1 species that occurs within Butte, Placer, Shasta, and Tehama counties. Red Bluff dwarf rush is known from vernally mesic sites in chaparral, valley and foothill grassland, cismontane woodlands, and vernal pools from 30 to 1,020 meters amsl. It may also be found in intermittent drainages and areas of pocket gopher and ground squirrel activity (Butte County Association of Governments 2011). The typical bloom period for Red Bluff dwarf rush is March through May. Suitable habitat for this species occurs within the area of analysis and occurrences have been documented within the Seller Service Area.

Some of the recognized threats to Red Bluff dwarf rush include: development, grazing, vehicles, industrial forestry, and agricultural activities.

## N.1.4 Saline Clover

Saline clover (*Trifolium hydrophilum*) is a California RPR 1B.2 species known from California's central coast and Bay Area. Previous observations exist within both the Buyer and Seller Service Areas. This species has generally been documented in marshes and swamps, valley and foothill grassland, and vernal pool habitats from zero to 300 meters amsl. It is often found in mesic or alkaline areas. Saline clover blooms from April through June.

The status of many saline clover populations is not known. Development, trampling, road construction, and vehicles are considered some of the major threats to the species.

# N.2 Special-Status Wildlife

## N.2.1 Giant Garter Snake

Giant garter snake (*Thamnophis gigas*) is listed as threatened under both the ESA and CESA (58 FR 54053). A Revised Draft Recovery Plan for giant garter snake was completed in 2015, but no critical habitat has been designated for this species (U.S. Fish and Wildlife Service 2015). One of the largest garter snakes, the giant garter snake reaches up to 64 inches in length, with females generally slightly longer and heavier than males (Hansen 1980).

Giant garter snake historically occupied wetlands throughout the Sacramento and San Joaquin Valleys, as far north as Chico, and as far south as Buena Vista Lake, near Bakersfield (Hansen and Brode 1980). The current known distribution of giant garter snakes is patchy, extending from near Chico, Butte County, south to Mendota Wildlife Area, Fresno County. Giant garter snakes are not known from the northern portion of the San Joaquin Valley north to the eastern fringe of the Sacramento-San Joaquin River Delta, where the floodplain of the San Joaquin River is limited to a relatively narrow trough (Hansen and Brode 1980, Federal Register 58:54053–-54066). Numerous observations of giant garter snake have been documented within the Sacramento Valley portion of the Seller Service Area. Records also exist within the Buyer Service Area, including near Mendota, in the Central Valley (CNDDB 2018; Halstead et al. 2014).

Giant garter snakes typically breed in March and April and live young are born from late July to early September (Halstead et. al. 2015). The giant garter snake inhabits marshes, sloughs, ponds, small lakes, low gradient streams, agricultural wetlands (including irrigation canals and rice fields), and adjacent uplands. Essential habitat components consist of 1) freshwater aquatic habitat with protective emergent vegetation cover where snakes can forage; 2) upland habitat near the aquatic habitat that can be used for thermoregulation and summer shelter (i.e., burrows), and 3) upland refugia outside flood waters that can serve as winter hibernacula (U.S. Fish and Wildlife Service 2015).

Ideal giant garter snake aquatic habitat exhibits the following characteristics.

- Water present from March through November.
- Slow moving or static water flow with mud substrate.
- Presence of emergent and bankside vegetation that provides cover from predators and may serve in thermoregulation.
- Absence of a continuous canopy of riparian vegetation.
- Available prey in the form of small amphibians and small fish.
- Thermoregulation (basking) sites with supportive vegetation such as folded tule clumps immediately adjacent to escape cover.
- Absence of large predatory fish.
- Absence of recurrent flooding, or, where flooding is probable, the presence of upland refugia.

Another key requirement of the giant garter snake includes maintenance of connectivity between habitats. Giant garter snakes rely on canals and ditches as movement corridors. These corridors provide important habitat, and are used during daily movement within a home range.

Giant garter snake typically forage and shelter within cattail, bulrush, or other emergent herbaceous wetland vegetation, using grassy banks and openings at the water's edge for basking. Rice fields in particular may be important nursery and feeding habitat, providing prey that are absent from other permanent aquatic areas (USFWS 1999b). Wintering habitat consists of higher elevation upland areas with vegetation, burrows or other underground refugia (Hansen 1988). Studies of marked snakes indicated that individuals typically move about 0.25 to 0.5 miles per day. Individuals have been documented to move five to eight miles over the course of a few days. Giant garter snake home range size is highly variable, with an average size of about 0.1 square miles (USFWS 2010). During the winter months, when the snakes are inactive, small mammal burrows and other soil or rock crevices may be used for hibernation, and also provide refuge from hot conditions during the snake's active season (Hansen and Brode 1993; USFWS 1999b). Giant garter snake have been documented using burrows as much as 165 feet from marsh edges to shelter from heat during the active season, and up to 820 feet away during the winter (Wylie et al. 2000).

#### *N.2.1.1 Use of Rice Lands*

The following information on use of rice lands by giant garter snake was obtained from a Biological Assessment report (U.S. Bureau of Reclamation [Reclamation] 2019) prepared for the Proposed Action as part Reclamation's Section 7 consultation with U.S. Fish and Wildlife Service.

Recent studies have been and are currently being conducted to gather information on the distribution and occurrence of giant garter snake in rice lands. Studies conducted by CDFW and USGS have documented giant garter snake in portions of the rice-producing regions of the Sacramento Valley, particularly the Colusa Basin. USGS has conducted trapping surveys of giant garter snake at the Sacramento National Wildlife Refuge Complex, and giant garter snake were observed at each of the national wildlife refuges in the region (Colusa, Delevan, and Sacramento). It is likely that giant garter snake occur outside of refuge lands in the adjacent rice production areas.

Recent work by USGS has utilized landscape-level information on habitat attributes such as canopy cover, distance to rice fields, and canal density, to model the current likely locations of suitable giant garter snake habitat in the Sacramento Valley. This work resulted in a habitat suitability dataset for the Sacramento Valley. Based on survey data collected from 1996 to 2005, the habitat suitability dataset predicts that 83 percent of giant garter snake occurrences will be in the top 50 percent of suitable habitat (i.e., rice production within historic marsh wetland areas) (Halstead et al. 2010). Another landscape-level analysis completed by USGS looked at whether historic or contemporary conditions were better predictors of giant garter snake occurrence in areas of rice agriculture. The conclusion from this research is that proximity to historic habitat, such as historic areas of tule marsh, is the most important variable for predicting occurrence of giant garter snake in the Sacramento Valley (Halstead et al. 2014). This information was used to generate maps of giant garter snake priority habitat for participating water agency lands within the Sacramento Valley. The goal of the mapping effort was to identify areas of "priority habitat"

where environmental commitments could be focused. These maps were used in the 2014 water transfer consultation to ensure that adequate water was available for "priority suitable habitat with a high likelihood of giant garter snake occurrence". Subsequently, Reclamation has assigned those environmental commitments (maintaining adequate water in drains and canals) to all rice-lands participating in this program through crop idling/shifting. This all-inclusive approach is reasonable partially because the location of all giant garter snake within the action area is not known. The assumption is that there is potential for giant garter snake in all areas participating in idling/shifting transfers. The Priority Habitat Mapping by USGS is not scheduled for annual updating, but may be updated when sufficient data is accumulated to provide a relevant updates.

More recent research involving occupancy of giant garter snake did not support the hypothesis that historic tule marsh is the most important variable for predicting occupancy (Hansen et al. 2017). The results of this later study suggest, "canal density, the proportion of adjacent rice agriculture and wetlands, and underlying soils appear to be stronger drivers" for giant garter snake occupancy.

Regardless of the importance of historic tule marsh or underlying soils on current giant garter snake occupancy, the loss of tule marsh habitat has resulted in rice cultivation lands becoming important giant garter snake habitat. This is particularly true of the associated canals and their banks, which are used for both spring and summer active behavior and winter hibernation. USGS research involving radio-telemetry of female giant garter snake showed that "litter, emergent vegetation, terrestrial vegetation, and submerged vegetation microhabitats were positively selected, and rock and rice were avoided" (Halstead 2016). However, the discussion of that research paper also pointed out that "The response of individual giant gartersnakes to rice was highly variable, with some individuals remaining in canals for the entire active season, others selecting rice and venturing into it, and still others remaining in restored wetlands where no rice was available to them."

A study published in 2017 looked at the response of giant garter snake to water availability in the Sacramento Valley at both the site and individual levels. While the study determined that rice cultivation is important to giant garter snake, it showed that the giant garter snake were strongly associated with the water conveyance canals and made "little use of rice fields themselves" (Reyes 2017). The study also showed that maintaining canals without neighboring rice cultivation led to a decrease in giant garter snake survival rates.

Giant garter snake seasonal activity associated with rice cultivation occurs in the following progression:

- **Spring**: Rice is planted and the fields are flooded with several inches of water. Rice fields that contain prey species such as small fish or frogs may attract giant garter snake. However, the lack of emergent vegetative cover in the rice fields may preclude foraging during this period.

- **Summer:** While the rice grows, giant garter snake continue to use related water infrastructure, drains, canals, and to a lesser extent, rice fields as long as their prey and vegetative cover is present in sufficient densities. As the rice crop matures and provides

emergent vegetative cover (starting in late June), giant garter snake are more likely to utilize the fields for foraging.

- **Late Summer/Fall**: Once rice is mature (starting in late August)) the water is drained from the rice fields and giant garter snake likely reduce foraging activities in the fields. Rice is harvested at this time and female giant garter snake have just borne young and need food to regain their body weight. In August and September, the snakes can get a good supply of food from the rice lands because prey animals are concentrated in the rice drains. The dry-down of the rice fields in fall is thought to be important because prey, which have been proliferating, are concentrated in the drains and remaining pockets of standing water in the fields where snakes can gorge prior to the period of winter inactivity.

- **Winter:** giant garter snake is dormant in the winter while rice fields are either fallow or being prepared for planting in the spring.

Valcarcel (2011) studied giant garter snake spatial ecology in agricultural and constructed wetlands. He found that home ranges in agricultural habitat were 80 percent smaller and had less variation among individuals than home ranges in constructed wetlands. Snakes in agricultural habitat had greater and more uniform home range overlap. In both agricultural and constructed wetlands, vegetation patch edges were used more often than interior locations, and temperature can greatly influence movement. The research recommended further investigation of giant garter snake dispersal movements and habitat connectivity in agricultural areas.

### N.2.2 San Joaquin Kit Fox

San Joaquin kit fox is federally-listed as endangered under the ESA (USFWS 1967) and state-listed as threatened under CESA (Swick 1971). No critical habitat has yet been designated for the species.

San Joaquin kit foxes occur in some areas of suitable habitat on the floor of the San Joaquin Valley and in the surrounding foothills of the Coast Ranges, Sierra Nevada, and Tehachapi Mountains from Kern County north to Contra Costa, Alameda, and San Joaquin Counties (USFWS 1998). Since 1998, the population structure has become more fragmented, with some resident satellite populations having been locally extirpated, and frequented by dispersing kit foxes rather than resident animals (USFWS 2010:15). The largest extant populations of kit fox are in Kern County (Elk Hills and Buena Vista Valley) and San Luis Obispo County in the Carrizo Plain Natural Area (USFWS 1998). Natural habitats for San Joaquin kit fox include alkali sink, alkali flat, and grasslands. San Joaquin kit foxes may use agricultural lands such as row crops, orchards, and vineyards to a limited extent but kit foxes are unable to occupy farmland on a long-term basis (USFWS 2010:19–21.) San Joaquin kit foxes usually prefer areas with loose-textured soils suitable for den excavation (Orloff et al. 1986:62) but are found on virtually every soil type (USFWS 1998:129). Where soils make digging difficult, kit foxes may enlarge or modify burrows built by other animals, particularly those of California ground squirrels (Orloff et al. 1986:63; USFWS 1998:127). Structures such as culverts, abandoned pipelines, and well casings may also be used as den sites (USFWS 1998:127).

San Joaquin kit fox are active throughout the year and are generally active during twilight. The kit fox's home range may vary from less than 2.6 square kilometers ($km^2$) to 31 $km^2$ (Morrell 1972; Zoellick et al. 2002, Spiegel and Bradbury 1992; White and Ralls 1993). The breeding season begins during September and October when adult females begin to clean and enlarge natal or pupping dens. Mating and conception occur between late December and March, and litters of two to six pups are born between late February and late March (USFWS 1998:126).

Growth of agricultural and urban areas is cited as the primarily threat to San Joaquin kitfox. Land conversion displaces populations, may reduce preferred prey abundance, prohibits movement throughout the landscape, and may also result in direct or indirect mortality of kit foxes (Constable et al. 2009; USFWS 1998). Intensive grazing, use of pesticides and rodenticides, and predation by coyote and red fox are other notable stressors on San Joaquin kit fox populations (Bell et al. 1994; USFWS 1998).

### N.2.3 Greater Sandhill Crane

The Central Valley population of greater sandhill crane (*Grus canadensis tabida)* is a state-listed threatened and fully protected species. This species uses a variety of habitats including non-tidal fresh emergent wetland, natural seasonal wetland, and managed seasonal wetland. They will also utilize upland habitats such as grassland and upland crop areas. As a result of the loss of a large proportion of wetlands in the Sacramento Valley, greater sandhill cranes are increasingly associated with managed seasonal wetland environments and seasonally flooded agriculture, particularly rice fields.

Formerly a common breeder in California, the species now breeds only in Siskiyou, Modoc, Lassen, Sierra Valley, Plumas and Sierra counties (Zeiner et al. 1988); during the summer, the birds are found near wet meadows, shallow lacustrine and fresh emergent wetland habitats. Greater sandhill crane is known to winter in the Sacramento and San Joaquin valleys, within the Butte Sink (from Chico in the north to the Sutter Buttes in the south and from Sacramento River in the west to Highway 99 in the east), where birds forage in annual and perennial grassland habitats, moist croplands with rice and corn stubble, and emergent wetlands. Cranes migrate to the Central Valley between September and November and depart between March and May (Reclamation and DWR 2004); however, the California breeding population winters chiefly in the Central Valley (Zeiner et al. 1988). Sandhill cranes mate for life and have high site fidelity; the pair will return to the same territory each year (USFWS 1987).

Food, cover, and nesting requirements for greater sandhill cranes are closely associated with water in the form of some type of wetland. The loss and degradation to riverine and wetland ecosystems is an important threat to sandhill crane populations. For the migratory populations, this is of greatest concern in foraging and wintering areas (USGS 2006). Additional threats include development pressures and human disturbance when nesting.

### N.2.4 Black Tern

The black tern (*Chlidonias niger*) is designated as a California SCS. Within California, black terns typically occur as migrants and summer residents between mid-April and mid-October (Shuford and Gardali 2008) where they breed in flooded rice fields and freshwater marshes, including lakes and ponds with marsh edges (Shuford et al. 2001). In the Central Valley, black terns nest on small dirt mound-islands in rice fields (Shuford et al. 2001) and are known to build

nests on masses of dead floating vegetation, or on mounds within marsh habitat (Shuford and Gardali 2008). The species may also nest on dikes or levees (Reclamation and DWR 2004). The remainder of the year, the terns migrate to bays, rivers, and pelagic waters (Reclamation and DWR 2004).

The black tern was once a common visitor to emergent wetlands of the Central Valley, but its numbers have declined due to habitat losses, especially the widespread loss of freshwater marshes. In California, the terns have been known to breed in the Central Valley, Klamath Basin, and the Modoc Plateau (Shuford et al. 2001). Due to lack of suitable freshwater habitat in most NWRs and State Wildlife Areas during the summer, black tern breeding sites in the Sacramento Valley are primarily flooded rice fields (Technology Associates 2009a). In 2001, Shuford et al. reported that rice fields supported 90 percent of the Central Valley breeding population. Surveys in the late 1990s found breeding black terns to be widespread in Sacramento Valley rice fields, with the largest concentration in the northern Colusa Basin. This species only has two known regular breeding locations in the San Joaquin Valley, in rice fields in Merced and Fresno counties (Shuford and Gardali 2008).

Black terns are considered to be an area-dependent species with specific breeding and foraging requirements. Because black terns have a limited distribution and are dependent upon flooded rice fields for breeding, conversion of rice fields to other crops, or to dry land rice, pose a threat to the migrant population (Technology Associates 2009a). Additional threats to the species include water management of rice fields (i.e. rapid lowering of water exposes nests to predators) and effects from exposure to pesticides (Technology Associates 2009a).

### N.2.5 Pacific Pond Turtle

The Pacific pond turtle (*Actinemys marmorata*) is the only native box turtle widely distributed in the western United States, occurring from Baja California north into the State of Washington. Historically, the turtle once inhabited the vast permanent and seasonal wetlands of the Central Valley. Pacific pond turtle is considered a SSC by CDFW and its status is currently under review by USFWS.

Pacific pond turtle is associated with nontidal fresh emergent wetland, managed seasonal wetland, valley/foothill riparian, and lacustrine habitats. They may also utilize upland habitats including grassland and scrub (Holland 1994). Its preferred habitat is slow moving or quiet water, with emergent vegetation and undercuts for refuge. Protected, grassy uplands with a clay/silt soil are the preferred nesting sites. Irrigation ditches, drains, and rice fields provide suitable habitat for Pacific pond turtle foraging, with basking areas on adjacent levees. The turtles are active during the spring, summer, and fall when rice preparation, growing, and harvesting are performed, respectively.

The draining of wetlands for agriculture and urban development has greatly reduced this species' habitat. Other causes of population decline include increased predation and collecting by humans. Poor reproductive success due to predation and nest destruction also hamper the turtle's recovery. Reduced vegetative cover, such as in heavily maintained ditches, may increase predation on females and juveniles moving between aquatic habitats and nest sites between May and October (Holland 1988).

The CNDDB reports several occurrences spread throughout the area of analysis in Sacramento, San Joaquin, and Contra Costa counties.

### N.2.6 Purple Martin

Purple martin (*Progne subis*) is a passerine bird species and is considered by the CDFW to be a SSC. Purple martin occurs in eastern North America, west to the Pacific Coast and south into Central Mexico. In the arid west, its distribution is concentrated in the southern Rocky Mountains and the Sonoran Desert (Shuford and Gardali 2008). In California, purple martins are summer residents, typically observed between mid-March and mid-August (Shuford and Gardali 2008). They have been documented in forest and woodland areas, generally at lower elevations, and the most robust populations are known from conifer forests on the north coast and the foothills of the Sierra Nevada Mountains. Only a small breeding population occurs in the Central Valley.

Purple martins prefer breeding areas with numerous nesting cavities and locally sparse canopy cover. They require access to open foraging areas that support their insect prey, particularly wetlands or other water bodies. Purple martins may nest as single pairs or in larger groups.

Non-native European starlings (*Sturnus vulgaris*) compete with purple martins for nest sites. Additional threats include loss of suitable nesting sites due to habitat conversion by human activity or events such as stand-replacing fires (Shuford and Gardali 2008).

### N.2.7 Long-Billed Curlew

The long-billed curlew (*Numenius americanus*) is designated as a CDFW Watch List species and a Bird of Conservation Concern by the USFWS (USFWS 2008). The long-billed curlew is a migratory bird that breeds east of the Cascade Mountains, including northeastern California, through the western Great Plains (Zeiner et al. 1988). It winters from Central and Imperial Valleys, coastal California to southwestern United States. and is found as a winter migrant in the San Joaquin Valley.

Long-billed curlews are found in grasslands, meadows, pastures, and fallow agricultural fields, as well as tidal flats, beaches, and salt marshes in winter. The most highly preferred habitat is natural marshes, grassland, irrigated pasture, and alfalfa fields (San Joaquin County Multi-Species Habitat Conservation and Open Space Plan 2000) and preferred winter habitat includes large coastal estuaries, upland herbaceous areas, and croplands (Zeiner et al. 1988). A small number of nonbreeders remain in coastal habitat in summer and a larger number of birds remain in some years in the Central Valley (Zeiner et al. 1988). In California, long-billed curlew nest on elevated interior grasslands and wet meadows, usually adjacent to bodies of water, such as lakes or marshes (Zeiner et al. 1988).

The conversion of natural lands to agriculture has greatly diminished available forage for wintering birds (Zeiner et al. 1988); wintering habitat in California wetlands has declined by 90 percent (Dugger and Dugger 2002). Continuing threats to long-billed curlews include habitat loss owing both to development and projected effects of climate change and effects of pesticide spraying indirectly reducing the birds' prey items (Dugger and Dugger 2002). The species has previously been proposed as a candidate for Federal Endangered status.

### N.2.8 Tricolored Blackbird

The tricolored blackbird (*Agelaius tricolor*) is a medium-sized passerine bird, which is very similar in appearance to red-winged blackbird (*Agelaius phoeniceus*). The species is listed as threatened under CESA and designated as a Bird of Conservation Concern by the USFWS (USFWS 2008). The species forms the largest colonies of any North American passerine bird, often with tens of thousands of breeding pairs (Beedy and Hamilton 1999).

Nearly all tricolored blackbird populations occur within California. While no major changes in their overall geographic distribution have been noted, large gaps in the occupied range now exist due to loss of habitat (e.g., Kings, San Joaquin, Riverside, and San Bernardino counties) and populations have significantly declined (Kyle and Kelsey 2011). Most individuals are year-round residents in the Central Valley, although some birds overwinter elsewhere, including in the Sacramento-San Joaquin Delta (Beedy 2008).

This species typically breeds in areas with access to open water and protected nesting sites, often including flooded, thorny, or spiny vegetation. Historically, tricolored blackbirds nested in freshwater marsh habitat in vegetation including tules, cattails, willows, thistles or nettles. Nests may also be concentrated in grain fields, giant reed (*Arundo donax*), and riparian scrubland and forest areas (DeHaven et al. 1975; Kyle and Kelsey 2011). Birds may forage as much as eight miles from nest sites (Beedy and Hamilton 1999) in areas that support insect prey. Pasturelands, alfalfa and rice crops, dairies, grassland, and shrubland habitats may be used in lieu of natural flooded habitat (Beedy and Hamilton 1999).

Tricolored blackbird colonies are sensitive to habitat loss, predation, and human activities. When water is withdrawn from marshes, nests become more susceptible to predation, such as by coyotes (*Canis latrans*) (Technology Associates 2009b). Chemical application in agricultural areas may reduce survivorship and disturbance associated with urbanization, including noise, pet and human presence, may result in nest abandonment (Beedy and Hamilton 1999).

### N.2.9 White-Faced Ibis

White-faced ibis (*Plegadis chihi*) is considered a Species of Concern by USFWS and an SCC by CDFW. Historically, the ibis was a locally common summer resident in California and its breeding distribution was centered in the San Joaquin Valley. Currently, the species occurs in California as an uncommon, localized breeder and summer resident. It is a mobile species and shifts in range usually coincide with changing water levels and water quality. The ibis is found in shallow, emergent wetlands with high quality fresh and brackish water. Muddy grounds of wet meadows, irrigated or flooded pastures, flooded pond edges and shallow lacustrine water, and wet cropland such as rice fields are suitable foraging habitat. Ibises typically prefer large emergent wetlands with islands of dense emergent vegetation for nesting (CDFG 2008).

White-faced ibis is a colonial breeder and builds shallow nests in thick emergent vegetation such as tule and cattail, in shrubs, or in low trees (Ryder and Manry 1994). It breeds in scattered locations in the San Joaquin Valley and has established breeding colonies in the Sacramento Valley. Significant breeding colonies have been reported in the Mendota Wildlife Area and the Colusa NWR (Natomas Basin HCP 2003). The species winters primarily in the San Joaquin and Imperial Valleys with a concentrated wintering population near Los Banos in Merced County (Zeiner et al. 1990).

Populations of white-faced ibis have declined in California and stopped breeding regularly as a result of loss or deterioration of extensive marshes in the Central Valley, which are required for nesting. Elsewhere in its range, pesticides have caused decline in numbers (Zenier 1988).

### N.2.10 Yellow-Headed Blackbird

The yellow-headed blackbird (*Xanthocephalus xanthocephalus*) is a small to medium-sized passerine which is a California SSC. This species winters in the western United States; in California it has been documented east of the Cascade Range and Sierra Nevada Mountains, within the Imperial, Colorado River, and Central Valleys, as well as localized areas of the Coast Range west of the Central Valley (Twedt *et al*. 1991). It is fairly common in winter in the Imperial Valley, but its distribution is concentrated mainly in the western portion of the valley (CDFG 2008).

Yellow-headed blackbirds forage along emergent wetland and moist, open areas near croplands and grasslands, in addition to muddy shores of lacustrine habitat (CDFG 2008). They mainly feed on seeds and cultivated grains, although aquatic insects may make up a large part of their diet during the breeding season (Twedt et al. 1991; Twedt and Crawford 1995). Rice fields near freshwater marshes often support breeding colonies (Twedt and Crawford 1995).

In California, yellow-headed blackbirds are found year-round, but breed and winter in different locations and habitat. Water levels are a very important factor in reproduction success. This species breeds in fresh emergent wetland with dense vegetation (e.g. cattails and tules) and deep water, generally along lake and pond borders (Picman et al. 1993). They only breed where large insects are abundant and nesting is timed with maximum emergence of aquatic insect prey (Zeiner et al. 1990).

Throughout its range, the primary threat to the yellow-headed blackbird is the conversion of wetlands to croplands and urban land uses. The species' population has declined in California as a result of habitat loss and competitive exclusion from great-tailed grackles (*Quiscalus mexicanus*), as well as other mammalian and avian predators. Agricultural pesticides and herbicides have also negatively affected the species (Technology Associates 2009b).

### N.2.11 Other Migratory Birds

Managed wetlands and flooded agriculture within the Seller's Service Area provide critical nesting and wintering habitat for millions of migratory birds, particularly waterfowl that migrate to the Sacramento Valley. These open water habitats and associated vegetation provide food, cover, and resting sites for migrating birds. The Sacramento Valley is considered the most important wintering site for migratory birds on the Pacific Flyway, supporting nearly 50 percent of wintering shorebirds and over 60 percent of wintering waterfowl using the Pacific Flyway. Flooded agriculture within the Sacramento Valley accounts for approximately 57 percent of food resources available to waterfowl (Petrie and Petrick 2010). Although these species are not considered special-status wildlife species, they are protected under the Migratory Bird Treaty Act.

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# Appendix O

# Evaluation and Average Monthly Flows Using the Groundwater Model for Smaller Streams

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# Appendix O
# Tables Summarizing the Screening Evaluation and Average Monthly Flows using the Groundwater Model for Smaller Streams

**Table O-1.**
**Screening Evaluation Results for Smaller Streams in the Sacramento River Watershed for Detailed Vegetation and Wildlife Impact Analysis for the Proposed Action**

| Waterway | >1 cfs reduction? | >10% reduction? | Data Source |
|---|---|---|---|
| Deer Creek (Tehama County) | N | - | N/A |
| Antelope Creek | N | - | N/A |
| Paynes Creek | N | - | N/A |
| Seven Mile Creek | N | - | N/A |
| Elder Creek | N | - | N/A |
| Mill Creek (Tehama County) | N | - | N/A |
| Thomes Creek | N | - | N/A |
| Mill Creek (tributary to Thomes Creek) | N | - | N/A |
| Stony Creek | Y | Y | USGS Gage 11388000; Water Years 1976-2003 |
| Butte Creek | Y | N | USGS Gage #11390000; Water Years 1976-2003 |
| Cache Creek | Y | Y | USGS Gage #11452500; Water Years 1975-2013 |
| Eastside/Cross Canal | Y | U | N/A |
| Auburn Ravine | N | - | N/A |
| Coon Creek | Y | Y | Bergfeld personal communication 2014 |
| Dry Creek (tributary to Bear River) | Y | U | N/A |
| Honcut Creek | N | - | N/A |
| South Fork Honcut Creek | Y | U | N/A |
| North Fork Honcut Creek | Y | U | N/A |
| Colusa Basin Drain | Y | N | DWR Gage # WDL A02976; Water Years 1976-2003 |
| Lower Sycamore Slough | Y | U | N/A |
| Upper Sycamore Slough | N | - | N/A |
| Wilkins Slough Canal | Y | U | N/A |
| Sand Creek | Y | U | N/A |
| Cortina Creek | Y | U | N/A |
| Lurline Creek | Y | U | N/A |

| Waterway | >1 cfs reduction? | >10% reduction? | Data Source |
|---|---|---|---|
| Stone Corral Creek | N | Y | USGS Gage #11390672; Water Years 1976-2003 |
| Funks Creek | N | - | N/A |
| Freshwater Creek | N | - | N/A |
| Putah Creek | Y | N | USGS Gage # 11454000; Water Years 1976-2003 |
| Big Chico Creek | N | - | N/A |
| Little Chico Creek | Y | Y | DWR Gage # WDL A04280; Water Years 1976-1996 |
| Salt Creek | Y | U | N/A |
| Willow Creek (nr Williams) | Y | U | N/A |
| South Fork Willow Creek | N | Y | USGS Gage #11390655; Water Years 1976-2003 |
| French Creek | N | - | N/A |
| Spring Valley Creek | N | - | N/A |
| Walker Creek (Willow Creek tributary) | N | - | N/A |
| North Fork Walker Creek | N | - | N/A |
| Wilson Creek | N | - | N/A |

Y = Yes; N = No; U = Unknown
Note: Darkened rows indicate that a detailed effects analysis was not conducted because both criteria were not met.

**Table O-2.**
**Average Monthly Flow in Cache Creek Under the No Action/No Project Using Historical Data and the Proposed Action using the Groundwater Model and Reduction in Flow due to the Proposed Action[1]**

| Month | No Action/ No Project[1] | Proposed Action | Reduction | Percent Reduction |
|---|---|---|---|---|
| | Flow (cfs) | | | |
| Jan | 1,255.2 | 1,251.2 | 4.1 | 0.3 |
| Feb | 1,625.1 | 1,621.8 | 3.4 | 0.2 |
| Mar | 1,706.0 | 1,702.6 | 3.4 | 0.2 |
| Apr | 801.8 | 800.0 | 1.8 | 0.2 |
| May | 157.2 | 155.6 | 1.6 | 1.0 |
| Jun | 34.4 | 33.1 | 1.3 | 3.9 |
| Jul | 18.4 | 17.4 | 1.0 | 5.6 |
| Aug | 16.8 | 15.8 | 1.1 | 6.3 |
| Sep | 16.0 | 14.9 | 1.0 | 6.5 |
| Oct | 16.8 | 15.8 | 1.0 | 5.7 |
| Nov | 72.5 | 71.3 | 1.2 | 1.7 |
| Dec | 444.8 | 442.7 | 2.1 | 0.5 |

[1] USGS data, streamflow gage for Cache Creek near Yolo, gage #11452500 (1975-2013). Groundwater model data (1976-2003).

**Table O-3.**
**Average Monthly Flow by Water Year Type in Cache Creek Under the No Action/No Project Using Historical Data and the Proposed Action using the Groundwater Model and Reduction in Flow due to the Proposed Action[1]**

| Month | WYT | No Action/ No Project[1] | Proposed Action | Reduction | Percent Reduction |
|---|---|---|---|---|---|
| | | | Flows (cfs) | | |
| Jan | W | 2,677.3 | 2,673.7 | 3.8 | 0.1 |
| | AN | 1,604.0 | 1,595.3 | 8.7 | 0.5 |
| | BN | 634.7 | 630.4 | 4.3 | 0.7 |
| | D | 312.5 | 310.1 | 2.4 | 0.8 |
| | C | 231.5 | 228.7 | 2.8 | 1.2 |
| Feb | W | 3,713.8 | 3,711.6 | 2.3 | 0.1 |
| | AN | 1,945.8 | 1,941.6 | 4.1 | 0.2 |
| | BN | 1,014.2 | 1,009.7 | 4.5 | 0.4 |
| | D | 193.1 | 191.1 | 2.0 | 1.0 |
| | C | 168.2 | 162.9 | 5.3 | 3.2 |
| Mar | W | 4,159.3 | 4,157.3 | 2.1 | 0.0 |
| | AN | 1,758.1 | 1,754.7 | 3.5 | 0.2 |
| | BN | 805.1 | 802.7 | 2.4 | 0.3 |
| | D | 225.5 | 223.5 | 2.0 | 0.9 |
| | C | 103.1 | 96.6 | 6.5 | 6.3 |
| Apr | W | 2,170.1 | 2,168.2 | 1.9 | 0.1 |
| | AN | 589.7 | 586.5 | 3.2 | 0.5 |
| | BN | 337.0 | 334.9 | 2.1 | 0.6 |
| | D | 28.2 | 26.4 | 1.7 | 6.2 |
| | C | 11.0 | 10.4 | 0.7 | 6.1 |
| May | W | 367.2 | 365.3 | 1.9 | 0.5 |
| | AN | 219.3 | 216.5 | 2.8 | 1.3 |
| | BN | 60.9 | 60.1 | 0.8 | 1.3 |
| | D | 15.1 | 13.8 | 1.6 | 10.3 |
| | C | 3.8 | 3.2 | 0.4 | 11.5 |
| Jun | W | 86.6 | 84.8 | 1.8 | 2.1 |
| | AN | 33.4 | 30.9 | 2.5 | 7.4 |
| | BN | 6.5 | 5.3 | 1.2 | 18.9 |
| | D | 7.9 | 6.8 | 1.1 | 13.5 |
| | C | 0.6 | 0.5 | 0.2 | 27.9 |
| Jul | W | 43.0 | 41.2 | 1.8 | 4.1 |
| | AN | 18.1 | 16.9 | 1.2 | 6.4 |
| | BN | 7.6 | 6.4 | 1.2 | 15.8 |
| | D | 6.4 | 5.5 | 0.9 | 13.5 |
| | C | 0.6 | 0.4 | 0.1 | 21.5 |
| Aug | W | 41.1 | 39.4 | 1.7 | 4.1 |
| | AN | 13.8 | 12.6 | 1.2 | 8.4 |
| | BN | 3.2 | 2.8 | 0.4 | 13.0 |
| | D | 7.1 | 5.8 | 1.3 | 18.2 |
| | C | 0.5 | 0.4 | 0.1 | 18.0 |

| Month | WYT | No Action/ No Project[1] | Proposed Action | Reduction | Percent Reduction |
|---|---|---|---|---|---|
| | | | Flows (cfs) | | |
| Sep | W | 37.6 | 35.9 | 1.7 | 4.6 |
| | AN | 16.2 | 14.6 | 1.7 | 10.2 |
| | BN | 1.3 | 1.3 | 0.0 | 0.0 |
| | D | 6.9 | 6.2 | 0.7 | 10.6 |
| | C | 0.9 | 0.8 | 0.1 | 13.4 |
| Oct | W | 29.9 | 28.4 | 1.5 | 5.0 |
| | AN | 16.5 | 15.9 | 0.5 | 3.3 |
| | BN | 2.0 | 2.0 | 0.0 | 0.0 |
| | D | 17.5 | 16.8 | 0.7 | 4.1 |
| | C | 4.0 | 3.1 | 0.9 | 22.8 |
| Nov | W | 197.1 | 195.1 | 2.0 | 1.0 |
| | AN | 11.0 | 10.6 | 0.4 | 3.8 |
| | BN | 7.3 | 7.3 | 0.0 | 0.0 |
| | D | 39.2 | 37.5 | 1.7 | 4.5 |
| | C | 2.0 | 1.4 | 0.6 | 30.5 |
| Dec | W | 963.4 | 961.6 | 1.8 | 0.2 |
| | AN | 399.6 | 396.8 | 2.8 | 0.7 |
| | BN | 170.7 | 170.7 | 0.0 | 0.0 |
| | D | 276.9 | 274.1 | 2.7 | 1.0 |
| | C | 26.8 | 25.1 | 1.8 | 6.7 |

[1] USGS data, stream gage Cache Creek near Yolo, gage #11452500 (1975-2013). Groundwater model data (1976-2003).

**Table O-4.**
**Average Monthly Flow in Stony Creek Under the No Action/No Project Using Historical Data and the Proposed Action using the Groundwater Model and Reduction in Flow due to the Proposed Action**

| Month | No Action/ No Project[1] | Proposed Action | Reduction | Percent Reduction |
|---|---|---|---|---|
| | | Flow (cfs) | | |
| Jan | 1403.0 | 1401.9 | 1.1 | 0.1 |
| Feb | 1556.6 | 1555.6 | 1.0 | 0.1 |
| Mar | 891.2 | 890.2 | 0.9 | 0.1 |
| Apr | 168.5 | 167.6 | 0.9 | 0.5 |
| May | 207.1 | 206.5 | 0.7 | 0.3 |
| Jun | 74.5 | 73.8 | 0.7 | 0.9 |
| Jul | 31.0 | 30.3 | 0.6 | 2.0 |
| Aug | 40.9 | 40.3 | 0.6 | 1.5 |
| Sep | 40.5 | 40.0 | 0.5 | 1.2 |
| Oct | 58.8 | 57.2 | 1.6 | 2.7 |
| Nov | 112.8 | 111.7 | 1.1 | 1.0 |
| Dec | 562.4 | 561.4 | 1.0 | 0.2 |

[1] USGS data, streamflow gage for Stony Creek below Black Butte Dam, gage #11388000 (1976-2003). Groundwater model data (1976-2003).

**Table O-5.**
**Average Monthly Flow by Water Year Type in Stony Creek Under the No Action/No Project Using Historical Data and the Proposed Action using the Groundwater Model and Reduction in Flow due to the Proposed Action[1]**

| Month | WYT | No Action/ No Project[1] | Proposed Action | Reduction | Percent Reduction |
|---|---|---|---|---|---|
| | | | Flows (cfs) | | |
| Jan | W | 2662.6 | 2661.9 | 0.7 | 0.0 |
| | AN | 1841.4 | 1839.9 | 1.6 | -0.1 |
| | BN | 53.8 | 53.1 | 0.6 | -1.2 |
| | D | 439.9 | 438.9 | 1.0 | -0.2 |
| | C | 488.7 | 487.1 | 1.6 | -0.3 |
| Feb | W | 3660.6 | 3659.9 | 0.7 | 0.0 |
| | AN | 1905.4 | 1904.5 | 0.9 | 0.0 |
| | BN | 105.0 | 104.3 | 0.6 | 0.6 |
| | D | 104.6 | 103.7 | 0.9 | 0.9 |
| | C | 54.2 | 52.8 | 1.5 | 2.7 |
| Mar | W | 2176.3 | 2175.6 | 0.7 | 0.0 |
| | AN | 698.9 | 698.1 | 0.8 | 0.1 |
| | BN | 158.0 | 157.4 | 0.6 | 0.4 |
| | D | 228.6 | 227.8 | 0.9 | 0.4 |
| | C | 48.9 | 47.4 | 1.4 | 2.9 |
| Apr | W | 335.7 | 335.1 | 0.6 | 0.2 |
| | AN | 173.0 | 172.3 | 0.8 | 0.5 |
| | BN | 84.7 | 84.1 | 0.6 | 0.7 |
| | D | 66.7 | 65.8 | 0.9 | 1.4 |
| | C | 49.6 | 48.3 | 1.4 | 2.8 |
| May | W | 449.9 | 449.3 | 0.6 | 0.1 |
| | AN | 201.7 | 201.2 | 0.5 | 0.3 |
| | BN | 55.1 | 54.5 | 0.5 | 1.0 |
| | D | 101.7 | 100.8 | 1.0 | 0.9 |
| | C | 10.8 | 10.2 | 0.6 | 5.6 |
| Jun | W | 177.7 | 177.1 | 0.6 | 0.3 |
| | AN | 47.2 | 46.7 | 0.5 | 1.1 |
| | BN | 30.0 | 29.5 | 0.5 | 1.7 |
| | D | 24.4 | 23.3 | 1.1 | 4.3 |
| | C | 10.5 | 9.9 | 0.5 | 5.0 |
| Jul | W | 47.9 | 47.4 | 0.6 | 1.2 |
| | AN | 46.1 | 45.6 | 0.5 | 1.1 |
| | BN | 26.5 | 26.0 | 0.5 | 1.9 |
| | D | 17.0 | 16.2 | 0.8 | 5.0 |
| | C | 10.9 | 10.3 | 0.5 | 4.9 |
| Aug | W | 80.0 | 79.5 | 0.6 | 0.7 |
| | AN | 47.6 | 47.1 | 0.5 | 1.1 |
| | BN | 23.4 | 22.9 | 0.5 | 2.0 |
| | D | 15.3 | 14.3 | 1.0 | 6.2 |
| | C | 10.2 | 9.6 | 0.5 | 5.4 |

| Month | WYT | No Action/ No Project[1] | Proposed Action | Reduction | Percent Reduction |
|---|---|---|---|---|---|
| | | | Flows (cfs) | | |
| Sep | W | 64.7 | 64.2 | 0.5 | 0.8 |
| | AN | 66.5 | 66.0 | 0.6 | 0.8 |
| | BN | 13.0 | 12.5 | 0.5 | 3.5 |
| | D | 16.8 | 16.0 | 0.8 | 5.0 |
| | C | 14.9 | 14.8 | 0.1 | 0.9 |
| Oct | W | 108.2 | 107.4 | 0.7 | 0.7 |
| | AN | 44.2 | 43.1 | 1.1 | 2.6 |
| | BN | 27.1 | 26.4 | 0.7 | 2.7 |
| | D | 32.2 | 30.8 | 1.4 | 4.5 |
| | C | 33.0 | 29.7 | 3.3 | 10.0 |
| Nov | W | 255.8 | 255.1 | 0.7 | 0.3 |
| | AN | 35.3 | 34.5 | 0.8 | 2.2 |
| | BN | 36.7 | 36.0 | 0.7 | 1.9 |
| | D | 54.1 | 53.0 | 1.1 | 2.1 |
| | C | 45.6 | 43.5 | 2.0 | 4.5 |
| Dec | W | 1234.8 | 1234.1 | 0.7 | 0.1 |
| | AN | 367.6 | 366.9 | 0.6 | 0.2 |
| | BN | 53.8 | 52.9 | 0.7 | 1.2 |
| | D | 363.0 | 362.0 | 1.0 | 0.3 |
| | C | 80.7 | 78.9 | 1.8 | 2.2 |

[1] USGS data, streamflow gage for Stony Creek below Black Butte Dam, gage #11388000 (1976-2003). Groundwater model data (1976-2003).

# Appendix P

# Methods for Assessing Impacts on Natural Communities and Special-Status Plants and Wildlife

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# Appendix P
# Methods for Assessing Impacts on Natural Communities and Special-Status Plants and Wildlife

## P.1 Natural Community Impacts Assessment

The natural community impacts assessment included an analysis of impacts on wetlands and upland habitat types. Natural communities that qualify as wetlands are tidal perennial aquatic, saline emergent wetland, tidal freshwater emergent wetland, non-tidal fresh emergent wetland, natural seasonal wetland, managed seasonal wetland, natural seasonal wetland, valley/foothill riparian habitat, and montane riparian habitat. Natural upland communities include grassland, inland dune scrub, upland scrub, and upland cropland habitat.

The impacts of water transfer actions on natural communities were assessed qualitatively based on possible changes in the distribution and extent of the natural communities affected, either through conversion to other habitat types or through change in quality relative to existing conditions. This assessment was conducted by assessing the types of natural communities that would potentially occur in areas where various water transfer activities, as described above, would occur. The type, frequency, magnitude and duration of these transfer activities, as described in the preceding section, were assessed relative to the needs of those natural communities. This approach was used to assess whether these activities would be likely to fragment existing natural communities, disrupt important wildlife management areas, or reduce habitat patch size.

## P.2 Species Impacts Assessment

The species impacts analysis includes an assessment of the direct and indirect impacts of implementing the long-term water transfer actions on terrestrial species. The assessment evaluated permanent and temporary impacts on terrestrial natural resources, including special-status species, and is based on impacts on natural communities that the species use within the area of analysis, the species' geographic distribution, and records for these species in the area of analysis maintained in the California Natural Diversity Database (CNDDB), and from other sources. This analysis included consideration of the way in which the habitat is used by different species, e.g., breeding, foraging, or dispersal habitat. It is important to note that although wildlife species are associated with certain natural communities, it does not necessarily indicate that wildlife species are restricted to those areas. The analysis indicates that habitat areas have a higher probability of species occurrence compared with areas identified as non-habitat. The

analysis does not incorporate microhabitat conditions and other site-specific variables that may further restrict a species use within a natural community.

### P.2.1 Plant Species

For plant species, species-habitat associations were defined (Table N-2, Appendix N) and the extent of potential permanent and/or temporary impacts on individual special-status species was based upon the impacts on their associated natural community types. Plants are often associated with specific microhabitats within the natural community and generally have localized occurrences in the region and in their suitable habitat. The analysis does not analyze the impacts of long-term water transfers at the microhabitat level; any loss or alteration of a natural community associated with a plant species is assumed to be a loss of suitable habitat for the species.

Impacts to plant species were assessed qualitatively, based on predicted changes to land use or water availability that could affect species distribution. Direct and indirect impacts of implementing transfers could include the alteration of species composition, establishment of invasive species, and changes to natural communities that result in removal, conversion, or fragmentation of the community.

### P.2.2 Wildlife Species

For wildlife species, species-habitat associations were developed and defined (Table N-1, Appendix N) based on literature and review of species databases, including CNDDB and California Wildlife Habitat Relationship (CWHR). Wildlife species and natural communities' relationships are generally not as specific as for plant species. Wildlife species generally occur in several habitat types and move among them. Thus, where necessary, the analysis evaluates the impacts to wildlife species both on a natural community and species level. Hydrologic impacts on wildlife species were assessed qualitatively based on extrapolation of groundwater and surface water modeling results to the species habitat requirements.

Direct and indirect impacts on wildlife communities may include habitat degradation or removal, displacement of wildlife, project-related impacts on adjacent habitat (e.g., changes in hydrology in adjacent areas), and habitat fragmentation leading to disruption of breeding, dispersal, and/or foraging behaviors.

## P.3 Impact Mechanisms Specific to Transfer Type

Impact mechanisms associated with groundwater substitution transfers, cropland idling/ crop shifting transfers, reservoir transfers, and rivers/creeks transfers that could affect natural communities and habitat for special-status plants and wildlife are described below.

### P.3.1 Groundwater Substitution Transfers

As a part of the Full Range of Transfers Alternative (Proposed Action), there would be an increased use of groundwater to irrigate crops instead of diversion of water from rivers, creeks, and other streams. This would entail increased groundwater pumping compared to existing

conditions to substitute water usually obtained from surface water supplies, which could result in a reduction in levels of groundwater in the vicinity of pumps.

Modeled changes in groundwater elevations over time were used to assess the potential impacts of groundwater depletion on stream flows in small tributaries and associated natural communities. Appendix D includes more information about SACFEM2013, which was used to model groundwater substitution-related changes to groundwater and surface water. The groundwater modeling results indicate that shallow groundwater is typically deeper than 15 feet in most locations under existing conditions, and often substantially deeper. This is substantially below the rooting depth of typical vegetation associated with upland communities (e.g., grassland and scrubland habitats). Some tree species, such as valley oak, can have root depths in excess of 20 feet and upward of 80 feet, and rely on groundwater at such a depth during months of low rainfall. However, these species have further adapted to California's Mediterranean climate of wet winters and hot, dry summers by diversifying their rooting structure to take advantage of multiple sources of water. Valley oak trees, for example, typically lose their long taproot by the time they are 40 years old, having developed a complex root system that often extends nearly twice as far as the tree's dripline within the first several meters of the ground surface (Bolsinger 1988).

Riparian habitats are structurally and compositionally diverse, providing a variety of food resources and shelter not found in adjacent upland habitat (Palmer and Bennett 2006, Kirkpatrick et al. 2007). Depth of groundwater has been shown to be an important driver of riparian tree species presence, abundance, and health (Merritt et al. 2010). Merritt et al. showed that riparian tree species are more common in areas with shallow groundwater (less than 4.5 feet below surface level). The maintenance of riparian forests that support complex habitat requires perennial streamflow to maintain elevated groundwater tables during the growing season (Stromberg et al. 2007; Merritt and Poff 2010). Because of the interaction of surface flows and groundwater flows in riparian systems, including associated wetlands, enables faster recharge of groundwater, these systems are less likely to be impacted by groundwater drawdown as a result of the Action Alternatives.

The frequency of occurrence of riparian forest cover vegetation decreases with the lowering of groundwater levels (Merritt et al. 2010) until the vegetation transitions into communities dominated by upland species less reliant on groundwater levels. In wetland and riparian habitats, groundwater could be much shallower than 15 feet below ground surface, ranging from eight feet to just below the ground surface (Faunt, ed. 2009).

In a few locations in the North Delta, groundwater elevations under existing conditions are less than 15 feet below ground surface and natural communities reliant on groundwater are more likely to be impacted.

The impact of groundwater substitution on natural communities is based on impacts to upland habitats, and those dependent on stream flows. The impact assessment method for stream flow dependent species is discussed in Section 3.8.2.1.4 of the Environmental Impact Statement/ Environmental Impact Report (EIS/EIR). This impact was evaluated based on the magnitude and frequency of groundwater depletion relative to existing conditions models.

The potential impacts of groundwater substitution on natural communities in upland areas was considered potentially significant if it resulted in a consistent, sustained depletion of water levels that were accessible to overlying communities (groundwater depth under existing conditions was 15 feet or less). A sustained depletion would be considered to have occurred if the groundwater basin did not recharge from one year to the next.

In addition to changing groundwater levels, groundwater substitution transfers could affect stream flows. As groundwater storage refills during and after a transfer, it could result in reduced availability of surface water in nearby streams and wetlands.

## P.3.2 Cropland Idling/Crop Shifting Transfers

Cropland idling/crop shifting would make water available for transfer that would have been used for agricultural irrigation without the transfer. Cropland idling/crop shifting transfers would occur in the Sacramento River watershed area of analysis. The irrigation season for this area generally lasts from April through September. Rice has been the crop idled most frequently in previous transfer programs. For crop shifting transfers, water is made available when farmers shift from growing higher water use crop to a lower water use crop. Cropland idling/crop shifting would potentially affect some wildlife species that depend on cropland for foraging and/or depend on habitat associated with cropland and managed agricultural lands, including surrounding supply and return water canals. Crop shifting would potentially affect habitat value for various wildlife species. These farming practices may also have an effect on downstream habitat dependent upon agricultural flow returns.

Cropland idling/shifting transfers would be done in accordance with the environmental commitments described in Section 2.3.2.4 of the EIS/EIR.

Croplands (except cotton) generally provide forage, resting, and nesting habitat for a variety of wildlife. Many species rely on agro-ecosystems to meet their lifecycle requirements. Vegetable crops (e.g., tomatoes, onions, melons, and sugar beets), grain crops (e.g., corn, rice, etc.), and alfalfa generally provide forage for wildlife both pre- and post-harvest. The value of a crop to wildlife as habitat and for forage varies greatly between crops (from corn and wheat—highly beneficial to wildlife; cotton—limited to no benefits to wildlife) and species to species. Seasonally flooded agriculture, specifically rice fields, and its associated uplands, drainage ditches, irrigation canals, and dikes, provide potentially suitable habitat for many species including giant garter snake, Pacific pond turtle, and a variety of water birds including, but not limited to egrets, herons, ducks, and geese. Upland crop habitat, such as wheat and corn, provide potentially suitable foraging habitat for many species, including migratory birds and San Joaquin kit fox.

Waste products (grain, fruits, or foliage) remaining in fields after harvest also serve as a food resource for wildlife species, including many special-status species associated with upland cropland (see Section 3.8.2.3.3 of the EIS/EIR). A reduction in the availability of waste products as forage to wildlife could result in significant effects to those species dependent upon waste grain for a large portion of their forage, primarily birds and rodents (primary consumers). These species may also provide a prey base for predators, such as hawks or foxes, and a reduction in the numbers primary consumers could affect predator condition and abundance.

Rice fields in particular provide important foraging habitat for many wildlife species found within the Seller Service Area; not only do the wildlife forage on post-harvest waste grain, but they will also forage on small fish, amphibians, small mammals, and invertebrates that live in the flooded fields. Invertebrates, such as crayfish, can be found on canal banks and berms that separate the rice patties. Shallow water also attracts aquatic insects and other invertebrates, which can provide a source of prey for many wildlife species, such as long-billed curlew. Rice fields also provide resting, nesting, and breeding habitat similar to natural wetlands.

Associated with seasonally flooded agriculture idling is the potential loss of water within adjacent agricultural irrigation and return ditches, when crops are idled/shifted. Agricultural canals and ditches can contain wetland vegetation such as cattails, which provide cover for animals, and these canals and ditches provide forage, resting, nesting habitat and movement corridors for a variety of species (e.g., Pacific pond turtle, giant garter snake, tricolored blackbird, waterfowl, and wading birds), and could serve as migration corridors for various species of wildlife. The potential reduction in flows resulting from idling or shifting of seasonally irrigated crops could reduce habitat for those species that rely on habitat dependent agricultural return flows, with potentially significant impacts on to those species.

Cropland idling would result in fallow fields, which do not provide the same type of habitat as farmed fields, nor the forage base for animals, but which do provide habitat for early successional plants and the species that depend upon them, as well as providing areas that are relatively undisturbed, providing space for nests and burrows. Studies show that fallow fields and inactive farmland may provide suitable foraging, nesting, and/or dispersal habitat for many species of birds (Woodbridge 1998; California Rice Commission 2011).

Cropland idling/shifting has the potential to contribute to fragmentation and isolation of suitable wildlife habitat. Habitat fragmentation can have a significant negative impact to wildlife, by preventing species from moving or dispersing between areas. In the case of animals, different areas may be used for different life history needs, such as trees for nesting and grain fields for foraging, which may or may not overlap in time. The ability to move between different types of habitat or from one area of habitat to another area of similar habitat, on a seasonal or daily basis, is critical to the species success.

Cropland idling/shifting under long-term water transfer would occur in addition to standard farming practices, which include rotation of crops and fallowing of fields in response to market conditions and water availability, and to maintain soils and reduce problems with pests and disease. Because crop rotation and idling are standard practices, species that reside in agricultural areas adjust to these types of activities.

The distribution of these water year types within the action period is unknown. Additionally, the exact locations of cropland idling/shifting actions would not be known until the spring of each year, when water acquisition decisions are made.

The effects of cropland idling/shifting are evaluated on a qualitative analysis based on the proportional of the total acreage idled/shifted, the frequency with which cropland idling/shifting is expected to occur, the value of that cropland to special-status species, and the degree of habitat

fragmentation that would likely occur. This evaluation includes consideration of the environmental commitments which are intended to avoid or minimize the potential impacts of this activity.

The effects of idling/shifting of upland crops (those crops that do not require seasonal inundation) are evaluated based on the representative crops of corn, alfalfa and tomatoes, although other upland crops could also be idled. The effects of idling/shifting seasonally flooded crops is represented by rice, which has historically been the crop most idled, but may also include other field crops that require seasonal flooding for at least one week as a management practice, or those which are flooded seasonally to enhance habitat values for a specific wildlife species (e.g., waterfowl).

For purposes of analyzing effects of cropland idling on the availability of habitat for assemblages of wildlife that are wide-ranging throughout the Sacramento Valley (i.e., migratory birds), reductions in crop production (in acres) were compared against baseline acreages for each crop type. Baseline crop acreages consisted of averages over a 5 year period (2008 – 2012) that included wet, below normal, dry, and critically dry water years.

### P.3.3 Reservoirs

Water would be made available for transfers from Camp Far West, Collins, Folsom, Hell Hole, French Meadows, and McClure reservoirs. These reservoirs would continue to operate in accordance with their existing regulatory requirements and other commitments. Water transfers from these reservoirs would result in decreasing their storage and associated elevation and surface area, during the period when transfers would be made (July through September), and the ongoing reduction in storage until the reservoirs are refilled. Shasta, Oroville, New Bullards Bar, and Folsom reservoirs would not provide water for transfer, but their release patterns may be affected, in that the project may modify flows at compliance points in the mainstem rivers downstream of these reservoirs or in the Delta. Additionally, they could store water made available early in the season (April through June) before capacity is available to move the water through the Delta. Transfers could result in more or less water being released from these reservoirs at different times of year. All reservoirs would continue to function under their existing operating requirements, including reservoir drawdown to targeted storage levels, and in meeting downstream flow, temperature, and other water quality requirements.

Reservoirs are distinct from lakes and ponds in that they are artificial environments designed for use for water supply, flood control, and/or hydroelectric power production, although not all reservoirs serve all of these functions. These reservoirs are generally filled during periods of high runoff during the winter and spring, and emptied during the drier times of year to provide water for human and environmental needs. Depending on hydrologic conditions and downstream water needs, these reservoirs may not reach either their maximum storage elevation or be drawn down to their lowest allowed operating elevation (minimum pool) every year. A large proportion of the reservoirs' volume is filled and drained each year, however, resulting in large changes in water surface elevation of tens to over a hundred feet between the spring and fall of a single year. Because the reservoir does not provide a reliable supply of water near their maximum elevations, natural communities around reservoirs typically consist of upland vegetation types that are not dependent on the reservoir for water. Species and natural communities requiring more substantial

amounts of water may become established along riparian corridors tributary to the reservoirs or in areas along the margins of the reservoirs where water is retained when the reservoir water levels decline. Within the high water line of the reservoir, the annual cycle of inundation and desiccation prevents permanent vegetation from becoming established. This area may support ruderal species that can establish quickly when this habitat becomes available. This area is unlikely to support substantive cover or other habitat features suitable for wildlife immediately adjacent to the water. Wildlife that utilize reservoir habitats would typically use the nearshore areas on both the aquatic and terrestrial side of the water line. Open water areas are used infrequently and do not provide primary habitat.

The impacts of changes in reservoir storage in the Seller Service Area were evaluated based on the results of the transfer operations model which predicted changes in storage volume, elevation, and surface area on a monthly timestep. Substantial, systematic or prolonged changes in reservoir levels as a result of long-term water transfer storage and releases, particularly those that occur outside of the normal range of operation for that reservoir, could impact vegetation and wildlife species associated at or near water surface and within the drawdown zone, where water may be held longer or released sooner than it would have been under existing conditions. Changes in reservoir operations would also affect downstream riverine habitat, the effects of which are considered in the section below for Rivers and Creeks.

These effects were evaluated against the existing conditions during the corresponding time period, considering the change in elevation and the value of the existing habitat to natural communities and special–status species associated with the reservoir.

### P.3.4 Rivers and Creeks

As discussed in the preceding sections, water transfers would affect flows in the rivers and creeks within the Seller Service Area adjacent to and downstream of the areas where these activities would occur. There are no anticipated changes in conditions in the rivers and creeks in the Buyer Service Area. Changes in stream flows in the Seller Service Area could potentially affect natural communities, such as riverine, riparian, seasonal wetland, and managed wetland natural communities, which are reliant on groundwater for all or part of their water supply. These changes could propagate downstream and affect areas downstream of the location where pumping occurs, which may extend to the Sacramento River and Delta. To meet regulatory requirements, some minor modifications in the operation of the Central Valley Project (CVP) and State Water Project (SWP) may be required, which may affect storage and flow releases in some reservoirs within the area of analysis.

Groundwater substitution transfers were modeled using the SACFEM2013 groundwater model to assess potential changes to groundwater and surface water. Groundwater substitution pumping was simulated as an additional pumping stress on the system, above the baseline pumping volume. The annual volume of transfers was determined by comparing the supply in the seller service area to the demand in the buyer service area. The availability of supplies in the seller service area was determined based on data provided by the potential sellers. The demand was estimated using demand data provided by East Bay Municipal Utility District (MUD) and Contra Costa Water District (WD) as well as the available capacity at the Delta export pumps to convey transfers. The available export capacity was determined from CalSim II model results. The

CalSim II model currently only simulates conditions through Water Year (WY) 2003. The available capacity for south of delta exports was typically more limiting than the south of delta water supply demand. Because CalSim II results are only available through 2003, the SACFEM2013 model simulation was truncated at the end of WY 2003.

The analysis of supply and demand resulted in the potential to export groundwater substitution pumping transfers through the Delta during 12 of the years from 1970 through 2003 (33 years, SACFEM2013 simulation period). Each of the 12 annual transfer volumes was included in a single model simulation. Including each of the 12 years of transfer pumping in one simulation rather than 12 individual simulations allows for the potential compounding effects from pumping from prior years. Appendix D includes more information about the use of SACFEM2013 in this analysis.

The results of the SACFEM2013 analysis estimated streamflow depletion from groundwater substitution throughout the Sacramento Valley. These estimates were included in Transfer Operations Model simulations of the Action Alternatives. The Transfer Operations Model results are the basis for the determination of potential effects to fish and their habitats. Appendix C includes more details about the transfer operations model.

The analysis of potential impacts to stream flow in the Seller Service Area focused on the frequency and magnitude of changes in mean monthly flow rates by water year types (wet, above normal, below normal, dry, and critical), as compared to existing conditions, based on the modeling results. As discussed there, not every water body could be evaluated in the groundwater model; therefore, smaller water bodies adjacent to those modeled are assumed to respond in a similar way, with similar changes in flow magnitude and timing. Potential impacts to biological resources in these adjacent water bodies would be similar to those of the modeled streams.

For the Proposed Action and No Cropland Modifications Alternative, a screening analysis was conducted for smaller waterways for which groundwater modeling data were available to eliminate the need for biological analyses for streams in which substantial reductions in stream flow did not occur. If the flow reduction caused by implementing the transfer action would be less than one cubic feet per second (cfs) and less than ten percent change in mean flow by water year type, then no further analysis was required, because the effect was considered too small to have a substantial effect on terrestrial species.

The ten percent threshold was used to determine measurable flow changes based on several major legally certified environmental documents in the Central Valley (Trinity River Mainstem Fishery Restoration Record of Decision, December 19, 2000; San Joaquin River Agreement Record of Decision in March 1999; Freeport Regional Water Project Record of Decision, January 4, 2005; Lower Yuba Accord Final EIR/EIS). In these documents, there is consensus that differences in modeled flows of less than ten percent would be within the noise of the model outputs and beyond the ability to measure actual changes.

The one cfs minimum flow threshold was applied to each month during the entire modeled period, such that, if a change of greater than one cfs occurred in any one month during the modeled period, the waterway would be examined further for biological effects.

Combined, these two thresholds were used as an initial screening evaluation to determine whether further analyses were warranted to assess biological significant impacts because these two thresholds may not always translate into a significant biological effect on plant and wildlife species. Therefore, these further biological analyses included consideration of other physical and biological factors in addition to absolute and relative flow changes, including presence and timing of life stages of species, size of the waterway, timing of flow changes, and water year type.

Historical stream flow information from the United States Geologic Survey (USGS) or the California Data Exchange Center (CDEC) for these streams were gathered where available and used as the measure of baseline flow. For locations for which historical flow data were limited or unavailable, a quantitative analysis was not possible; thus a qualitative discussion of potential impacts is included for these locations. No impacts would occur to groundwater in the No Action/No Project and No Groundwater Substitution alternatives and, therefore, this screening analysis did not apply.

For rivers and their major tributaries, including the Sacramento, American, Feather, Yuba, Bear, San Joaquin, and Merced rivers, transfer operations model outputs were used to assess impacts to surface water flows.

The evaluation of potential impacts to natural communities and special-status vegetation and wildlife considered the magnitude and frequency of streamflow depletion in small streams, both as depicted by the groundwater model. These changes are evaluated for small streams, as CVP and SWP operations could not be altered to offset any changes in these streams. The impacts of groundwater substitution on the larger rivers and CVP and SWP reservoirs are carried from the groundwater model to the transfer operations model, but this model also incorporates other changes in hydrology associated with cropland idling/shifting, reservoir releases, and water conservation, so the combined effect of all these activities are evaluated concurrently for these water bodies.

The impact analysis assumes that an action alternative would have an adverse effect on vegetation and associated wildlife within each river system if it resulted in: a substantially reduced source water for natural communities (e.g., loss of seasonal inundation of adjacent floodplain); flow changes impacting/affecting wildlife movement, foraging pattern, breeding, or predation risks; flow changes altering vegetation communities (e.g., increased in stream flow causing erosion of stream banks resulting in the loss of shaded riverine habitat); flow changes impacting/affecting vegetation recruitment or establishment, or changes in the timing of flows such that natural geomorphic processes do not occur.

### P.3.5 Sacramento-San Joaquin Delta

The changes described above for rivers and streams would be also apply downstream into the Delta. Additionally, exports would vary in timing and magnitude with implementation of water

transfers. These changes were modeled using the Transfers Operations Model. To assess the potential impacts of these changes on vegetation and wildlife resources in the Delta, the difference in Delta outflow and the location of X2, defined as the distance (in kilometers) up the axis of the estuary to the daily averaged near-bottom 2-practical salinity units (psu) isohaline (Jassby et al. 1995), were considered. Changes in these parameters were used to qualitatively assess the impacts of long-term water transfers on natural communities and special-status species. Modeled changes in Delta outflow or X2 relative to existing conditions were considered substantial and required further analysis if they were greater than ten percent.

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