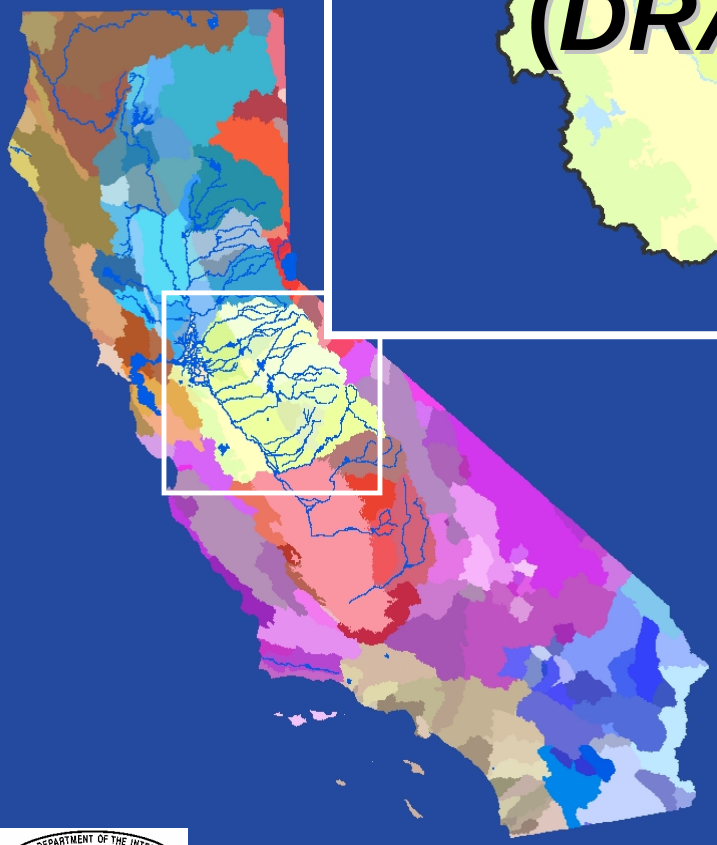
RECLAMATION

Managing Water in the West

CALSIM II San Joaquin River Model (*DRAFT*)



U.S. Department of the Interior
Bureau of Reclamation
Mid Pacific Region
Sacramento, CA

April 2005

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations/Acronyms

AF	Acre-Feet
AF/year	Acre-Feet per Year
AFRP	Anadromous Fish Restoration Program
Agreement	Oakdale ID/South San Joaquin ID Operational Agreement with Reclamation
Benchmark	September 30, 2002 CALSIM II Benchmark Model
Calaveras County WD	Calaveras County Water District
cfs	Cubic Feet per Second
Chowchilla WD	Chowchilla Water District
COE	United States Army Corps of Engineers
CU Model	Consumptive Use Model
CUAW	Consumptive Use of Applied Water
CVGSM	Central Valley Groundwater - Surface Water Simulation Model
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
D-1422	State Water Resources Control Board Water Rights Decision 1422
D-1641	State Water Resources Control Board Water Rights Decision 1641
DAU	Detailed Analysis Unit
DFG	California Department of Fish and Game
DMC	Delta-Mendota Canal
DPLA	Division of Planning and Local Assistance
DWR	California Department of Water Resources
EC	Electrical Conductivity
El Nido ID	El Nido Irrigation District
ET	Evapotranspiration
ETAW	Evapotranspiration of Applied Water
Exchange Contractors	San Joaquin River Exchange Contractors Water Authority
FERC	Federal Energy Regulatory Commission
FWS	United States Fish and Wildlife Service
GIS	Geographic Information System
gpcd	Gallons per Capita per Day
IE	Irrigation Efficiency
Interior	United States Department of the Interior

IPO	New Melones Interim Plan of Operations
M&I	Municipal and Industrial
Madera ID	Madera Irrigation District
MAF	Million Acre-Feet
Merced ID	Merced Irrigation District
Merced NWR	Merced National Wildlife Refuge
Modesto ID	Modesto Irrigation District
MS Excel	Microsoft Excel
NRL	Non-Recoverable Loss
Oakdale ID	Oakdale Irrigation District
PG&E	Pacific Gas and Electric Company
PWSS	Public Water System Statistics
Reclamation	United States Bureau of Reclamation
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
South San Joaquin ID	South San Joaquin Irrigation District
Stevinson WD	Stevinson Water District
Stockton East WD	Stockton East Water District
SWP	California State Water Project
SWRCB	State Water Resources Control Board
TAF	Thousand Acre-Feet
TDS	Total Dissolved Solids
Turlock ID	Turlock Irrigation District
USAN	Upper San Joaquin River Basin Model
VAMP	Vernalis Adaptive Management Plan
WQ Module ver 1.00	San Joaquin River Water Quality Module Version 1.00
WSI	Water Supply Index

1. Purpose of Document

This document has been prepared to support the joint California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) water resources planning model, CALSIM II. The purpose is to record the San Joaquin River Basin implementation of CALSIM II as of April 2005. This document describes model methodology, logic, assumptions, data input and output.

The objective of this document is to provide model development and reference material of water demands, hydrology, and operation protocol in the San Joaquin River Basin. It is anticipated that this document be used by managers and technical specialists within DWR and Reclamation, and external agencies to understand the San Joaquin River Basin CALSIM II simulation.

This document and accompanied results do not reflect a benchmark release of the CALSIM II model. The logic and results presented within this document are preliminary and are subject to change. Questions or comments regarding benchmark status and current modifications to the model should be directed to DWR or Reclamation.

2. Introduction

CALSIM II is a computer model that simulates much of the water resources systems and their operations in California's Central Valley and Sacramento-San Joaquin Delta region. The focus of CALSIM II representation is primarily on the Central Valley Project and State Water Project systems (CVP-SWP). The model was developed jointly by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation). Its purpose is to provide quantitative hydrologic information related to scenario-based CVP-SWP operations and assumptions related to climate, water demands, and regulatory environment. As the official planning model of both agencies, CALSIM II is used extensively to support a variety of studies describing comparative effects of alternative scenarios varying by infrastructure, operational rules, regulations, water demands, and/or climate.

CALSIM II is a significant upgrade relative to its predecessor models, PROSIM and DWRSIM, particularly in the representation of project operations in the Sacramento River Basin, its tributaries, and the Delta, and operations that meet provisions of the Central Valley Improvement Act (CVPIA) and CALFED ROD. Nevertheless, DWR and Reclamation continue to invest in CALSIM II enhancements. Two motivations drive this investment: (a) response to perceived

gaps between CALSIM II capabilities and ongoing planning questions, and (b) anticipation of future planning questions that will need to be served by CALSIM II with functionality beyond the current model. Both of these factors motivated redevelopment of CALSIM II's hydrology representation on the Eastside San Joaquin River Basin.

The original representation of the San Joaquin River Basin within CALSIM II was based on the SANJASM and STANMOD models, using simplifying assumptions that allow the basin a fairly static role in planning studies focused on impacts to other areas of the CVP/SWP system. Correlations were employed to define some hydrologic factors, and demands were implemented as monthly distributions of fixed contract amounts. These assumptions precluded dynamic interaction with new and evolving river system operations decision processes, or of projected land use change effects on San Joaquin Basin operations. In anticipation of studies specifically focused on San Joaquin Basin operations, an updated depiction of the Basin was clearly needed and has now been developed and incorporated into CALSIM II. This effort combined a thorough review of existing model attributes with the development of new information and data to produce a contemporary representation of the hydrology and operations of the San Joaquin Basin.

San Joaquin River hydrology is significantly affected by the operations of several major east side irrigation districts. The model revisions described in this document are underpinned by a new, land-use based, depiction of east side water demands. With this approach, variable acreage and associated land use combine with consumptive use data to define demand for water. Including seasonal and year-to-year variation of weather dependent demands has become critical to the needs of today's planning studies. As acreage and land use assumptions change, the model is able to dynamically portray demand-driven operations in the Basin. It must be noted that throughout this effort, the assistance and cooperation of the irrigation districts was invaluable in defining an appropriate characterization of their operations.

The area of analysis (see Figure 2-1) is the portion of the San Joaquin Basin that is bounded by the Calaveras River to the north, the upper San Joaquin River (Friant) to the south, the Sierra Nevada Mountains to the east, and the Delta-Mendota Canal and San Luis Service area that is hydraulically connected to the San Joaquin River to the west.

The interaction between groundwater and surface water is not included in this version of CALSIM II. The hydrology and operations included in this version represent the surface water component of the San Joaquin River Basin. Groundwater is loosely linked through the inference that demands not met with surface supplies are met with groundwater. Also, the development of water balances for surface water operations includes assumptions for deep percolation of surface supplies to the groundwater aquifer and the interaction of groundwater

within the accretions/depletions of the streams. Additional linkages within CALSIM II between surface water and groundwater are anticipated in future refinements. The demand areas on which the water balances are developed are depicted in Figure 2-1. The schematic representation of the San Joaquin River Basin in CALSIM II is depicted in Figure 1-2.

The refinement of east side operations, hydrology, and demands has been accomplished over several years through multiple efforts. The Bureau of Reclamation Reservoir System Analysis Branch (MP710) initiated the development effort in 2002 through a contract with MBK Engineers. The effort was further enhanced with a subsequent contract, again with MBK Engineers in 2003. The framework for modeling the San Joaquin Basin in CALSIM II was completed and validated after completion of the second contract; however, there were still some remaining tasks to be accomplished prior to being used in planning studies. These tasks included developing projected level land use for both the current (2005) and future (2030) levels of development, integrating the D-1641 stand alone representation of the San Joaquin Basin with a full five-step (D-1485, D-1641, B2, JPOD, EWA) CALSIM II model. Integration of the San Joaquin Model into a full CALSIM II OCAP study was completed in late 2004 through Reclamation's effort in developing the San Joaquin River Eastside Integrated Resources Management Plan (IRMP). Land use projections are approaching completion, also through the IRMP.

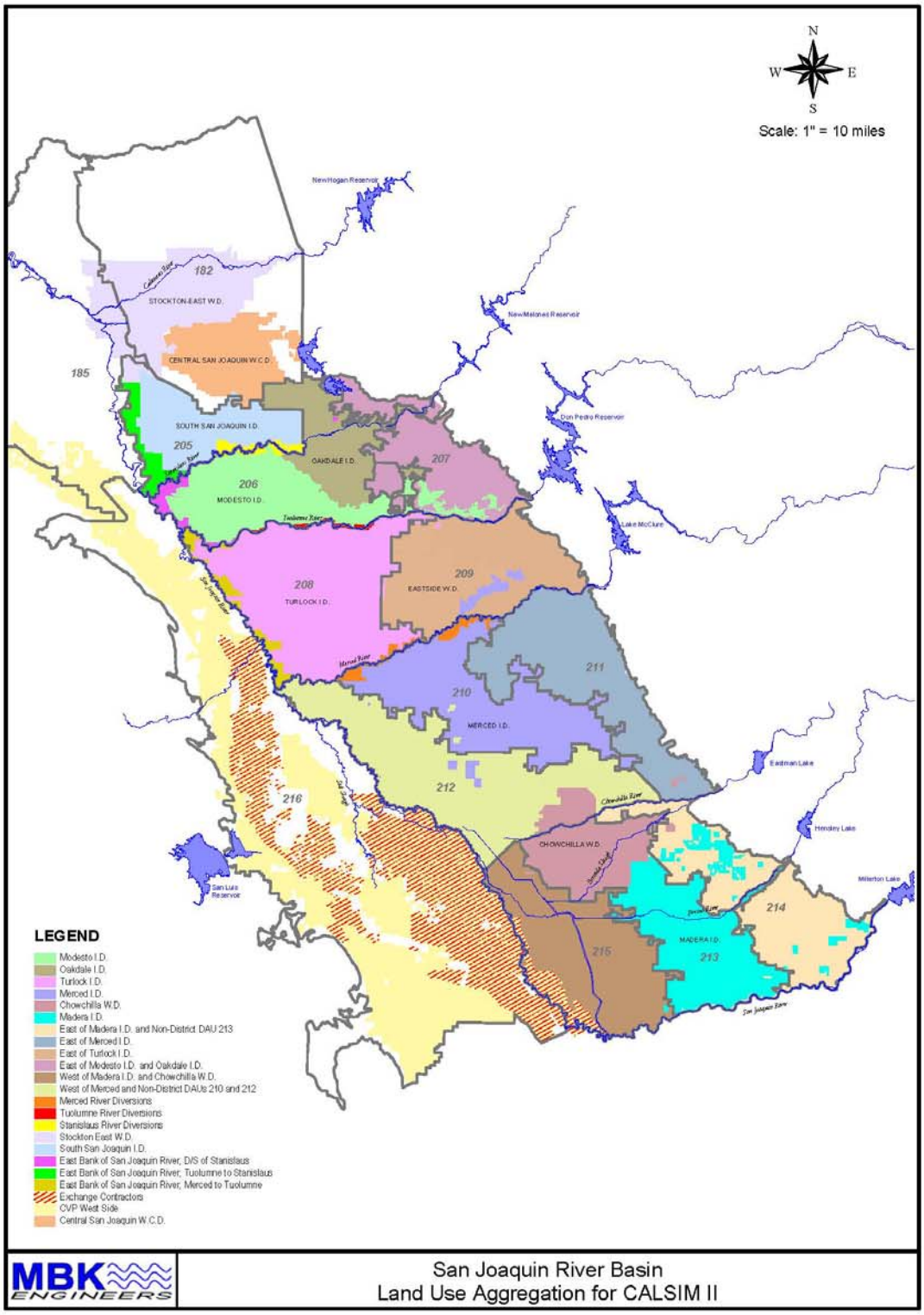


Figure 2-1: CALSIM II Representation of the San Joaquin River Basin and Demand Areas

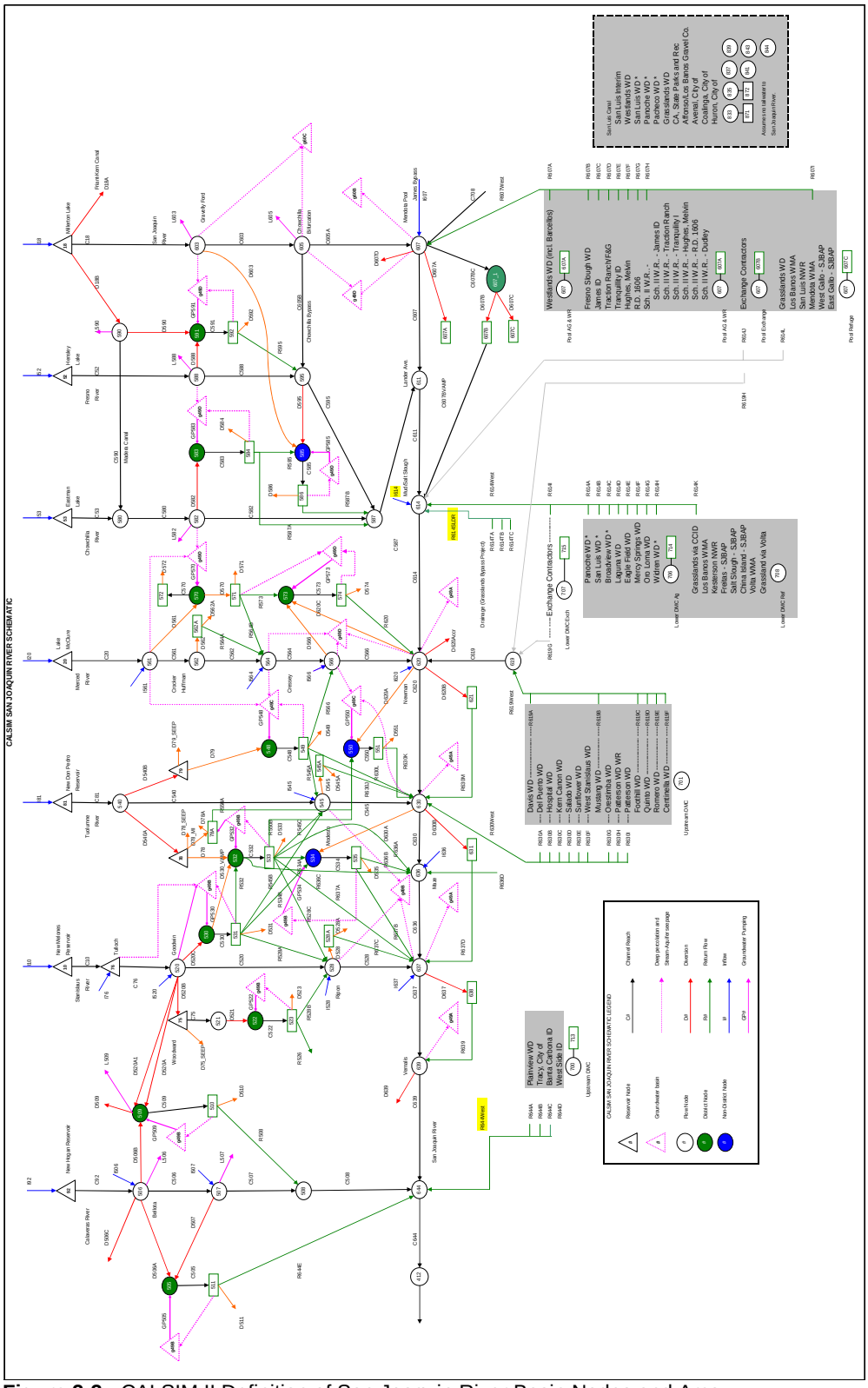


Figure 2-2: CALSIM II Definition of San Joaquin River Basin Nodes and Arcs

3. Water Demands

There are three types of water demands identified in CALSIM II: agricultural, municipal and industrial (M&I), and refuge. Each of these demands has its own characteristics in terms of demand pattern, its sources of supply, and its affect on other aspects of a hydrologic balance.

East Side Demands

Agricultural Demands

Simply put, land-use based agricultural demands are developed by assuming an irrigated acreage and estimating how much water is required to irrigate that land's associated crops.

Land-use based demands are developed by first estimating the consumptive use of applied water (CUAW), often referred to as the evapotranspiration of applied water (ETAW), or the amount of irrigation directly required by crops. The CUAW represents the amount of applied water realized as evapotranspiration (ET); it does not include water that is lost or returned to the water system.

The CUAW is determined based on irrigated acreage using the California Department of Water Resources (DWR) consumptive use model (CU model). Irrigated acreage for all east side demand areas within the area of analysis was developed using the Geographic Information System (GIS) coverage from the 1995 DWR land use survey. Land use is aggregated to 13 crop types, based on crops with similar water use, and input to the CU model to estimate the CUAW.

Demand Areas

As depicted in Figure 2-1, the east side of the San Joaquin Basin was divided into 21 demand areas. Demand areas are the fundamental unit of analysis for the basin. A water budget is performed on each area to determine diversion requirements, water sources, losses, and return flows. With the exception of the demand area representing non-district lands on the east bank of the San Joaquin River north of the Stanislaus River confluence, a representation of each of the east side areas has been implemented in CALSIM II. Currently, the area on the east bank San Joaquin River north of the Stanislaus River has a simplified operation that acts as a surrogate until it is integrated in CALSIM II consistently with the other areas.

Land Use

CALSIM II demands are traditionally based on a projected level land use, such as projecting land use that might occur for the time horizon of year 2005 or 2030.

Projected levels of land use for the San Joaquin River Basin were not available for the CALSIM II improvements. Historical land use data was used in place of projected land use to perform water budgets and develop CALSIM II simulations for model validation. GIS was used to determine land use for each demand area in the San Joaquin Basin. GIS land use coverage was also used to distribute regional land use estimates to CALSIM II demand areas, based on relative land use within CALSIM II demand areas. A map containing CALSIM II demand areas and land use is illustrated in Figure 3-1.

Land use data development (for use as an input into CALSIM II) consisted of five basic steps:

- Assembling data
- Developing new CALSIM II demand areas
- Rectifying overlapping water districts
- Combining GIS data
- Generating a summary table

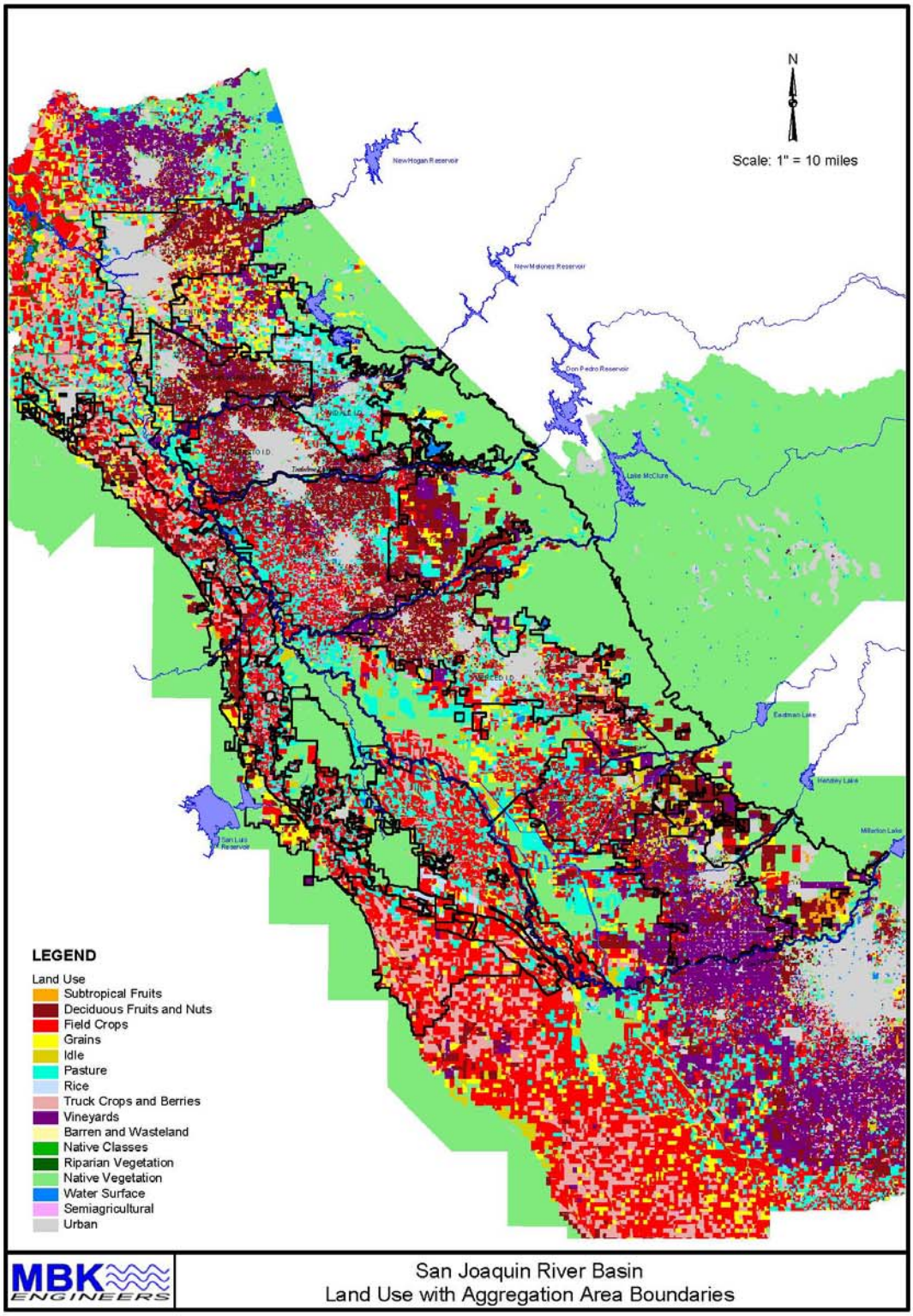


Figure 3-1: CALSIM II Demand Area Land Use

Assembly of Data

DWR provided county delineated GIS land use files. These individual counties were merged into one "shapefile", which represents the following vintage of survey for land use data within each county.

County	Survey Year
Fresno	1994
Madera	1995
Merced	1995
San Joaquin	1988
Stanislaus	1996
Tuolumne	1997
Mariposa	1998

The crop types identified in the DWR land use surveys did not correspond to CU model input requirements and therefore had to be categorized based on similar crop characteristics. For example, the DWR files included total acreage for kiwi crops within a given county. Kiwi fruit is not identified as a CU model input but can be categorized as "citrus/olive" which is a CU model crop type. The categorization of each crop type identified in the DWR land use data is shown in Appendix C.

The DWR land use files also included a water source attribute that describes whether the water source is surface, ground, mixed, or unknown. This attribute was used to identify sources of water on the east side.

Several other GIS shapefiles were merged into the land use shapefile for demand area delineation purposes. These shapefiles defined DWR planning area (e.g., Detailed Analysis Units) and water district boundaries.

Development of CALSIM II Demand Areas

New CALSIM II demand areas were developed on the basis of subdividing areas of unique water demands. Demand area boundaries were defined according to three categories: water districts, non-district lands, and non-district riparian water users. Water district demand areas were delineated based on actual water district boundaries. In many cases, these boundaries coincided with detailed analysis unit (DAU) boundaries. Non-district lands were delineated according to DAU boundaries, except where district boundaries overlapped the DAUs. Non-district riparian water user boundaries were defined as the residual area between water district boundaries and a corresponding river reach.

Rectification of Overlapping Water Districts

After assembling the district boundaries, it became apparent that overlaps existed. To avoid double-counting land use data, the overlapping areas were reconciled in terms of water source. For each overlapping area, based on judgment, the district

that supplies water to the area was chosen to be associated with the area. The overlaps were then eliminated using GIS software tools.

Union of GIS Data

In order to query land use in terms of any combination of the data layers, all the layers needed to be combined in a spatial 'union', described by the following diagram.

The files that were united are: DWR planning areas (e.g., DAUs), water districts, CALSIM II demand areas, and land use. The resulting shapefile was then cropped to the extent of the CALSIM II demand areas.

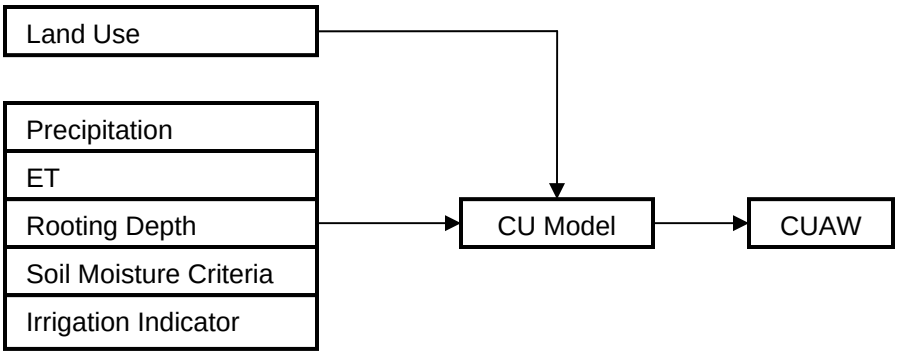
Generation of Summary Table

The final step in creating tabular data (for Microsoft Excel) was to generate a summary table. The table needed to show the total acreage of each unique land use type for each unique combination of data layers. ArcView is only capable of summarizing data based on one attribute; therefore, it was necessary to concatenate all of the desired fields into one field, and then summarize the total acreage based on that attribute.

A table was then generated showing the total acreage for each unique value of this concatenation of attributes. The data in this table can be used to determine land use for combinations of specific regions of any (or all) of the input layers. Land use for each CALSIM II demand area in the San Joaquin River Basin is displayed in Appendix C.

Consumptive Use

The CUAW represents the amount of applied water realized as ET; it does not include water that is lost or returned to the water system. The CUAW for an area is based on irrigated acreage using the DWR CU model. Irrigated acreage for any particular area is developed using the GIS coverage as described previously in this section. Land use is aggregated to 13 crop types based on crops with similar water use. The DWR CU model incorporates monthly precipitation, ET rates, soil moisture criteria, rooting depth, irrigation indicators, and other factors along with land use to estimate the CUAW on a monthly basis. The interaction of the land use and environmental data within the CU model is depicted below.



The CU model does not currently consider temperature or other meteorological data in its determination of CUAW. The ET data in the current CU model is based on 1976 evaporation values. It consists of crop ET during growing months and evaporative demand during non-growing months. Inaccurate ET assumptions could influence results of the water budgets and consequently, water district operations. For example, above normal temperatures would likely cause CUAW values to be higher than those reported by the CU model. A refinement of the CU model and its results could be incorporated into CALSIM II at a later time.

Monthly CUAW values for each demand area, calculated based on historical land use from GIS coverage, are located in Appendix A.

District Area Agricultural Demands

As previously described, each east side demand area can have a unique circumstance that translates demands for CUAW to a diversion requirement. Generically, CUAW is combined with conveyance losses (if any), operational spills and tailwater (return flow), non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The diversion requirement is the volume of water supplied from surface or groundwater, regardless of source. Complicating this conceptual diversion model are district system operations which may include canal regulating storage that seasonally increases or decreases diversion requirements. Each district included in CALSIM II is somewhat unique in the factors leading to the determination of diversion requirements.

Deep Percolation of Applied Water

Applied water returns to the stream network, percolates to groundwater or is used consumptively as ET. In CALSIM II, deep percolation of applied water is specified in a lookup table as a fixed percentage of the applied water less the surface runoff. These percentages are based on average percolation rates that are output from the historical run of the Central Valley Groundwater - Surface Water Simulation Model (CVGSM), water district budgets, and judgment. Within the current water balances of several of the east side areas, deep percolation was not specifically identified but inherently incorporated within a larger factor applied to CUAW. The consistency of deep percolation assumptions will require validation

(at the time of integration) of the San Joaquin Valley groundwater component of CALSIM II.

Conveyance Losses

Conveyance losses are generally associated with district conveyance and distribution facilities. These losses are comprised of canal leakage, seepage and evaporation. Separately determined, when significant, are losses from district regulating storage. CALSIM II identifies the disposition of these losses as either to the atmosphere or the stream network including groundwater.

Non-Recoverable Losses

DWR employs a method to identify a proportion of applied irrigation water that is not used in crop ET, does not return to the surface or groundwater system, but is depleted or lost. This may happen through:

- Evaporation from canals, laterals and farm reservoirs
- Percolation to a saline aquifer
- Disposal of sub-surface drainage using evaporation ponds
- Surface runoff to a saline sink or the ocean

Return Flow and Operational Spills

For many districts in the San Joaquin River Basin, return flow (operational spills) should not be simulated as a fraction of CUAW or diversion. Operational spills are more a function of the operation of district canals and laterals, and are dependent upon the state of water availability within a year. During dryer years when water supply is limited, districts are more vigilant in controlling their systems and attempt to minimize operational spill. Several of the modeled districts have operational spills depicted as an assumed constant volume year-to-year, varying by year-type. Return flows typically associated with farmer-level tailwater that escape out of the district boundary are currently accounted for (if accounted for) within the factor used to adjust CUAW to a diversion requirement.

Description of Demands by District

For the major irrigation districts on the east side of the San Joaquin Valley separate protocols were developed to determine water demands and diversion requirements.

Madera Irrigation District

Methodology The factors leading to determining the water demands and diversion requirements of the Madera Irrigation District (Madera ID) were developed by preparing a water budget for the district. Water demands were developed using land use data, estimated CUAW, historical records from Madera ID, estimates of district losses, estimates of deep percolation, and guidance from Madera ID personnel. Madera ID records on stream diversions, Madera Canal deliveries, and flows leaving the district were readily available and useful in developing a water budget.

Water Budget The water budget for Madera ID was performed on a monthly basis from 1980 to 1998. All water entering and leaving Madera ID was accounted for in the water budget. The CUAW was combined with district losses, district spills, non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The diversion requirement is the volume of water that must be diverted into the district, regardless of source, and is depicted in the following graphic.

CUAW
Deep Percolation of Applied Water
Conveyance Loss (Seepage)
Spills
Non Recoverable Loss

= Diversion Requirement

The district's diversion requirement is satisfied by Fresno River diversions, Madera Canal deliveries, and pumping from private wells located in the district (depicted below).

Fresno River Diversions
Groundwater Pumping
Madera Canal Delivery

= Diversion Requirement

The water budget balanced water entering the district with water leaving the district. Water leaves the district to either the atmosphere, surface flow, or into the ground. The balance of water leaving the district with water entering the district is illustrated as follows.

CUAW
Deep Percolation of Applied Water
District Losses (Seepage)
Spills
Non Recoverable Loss

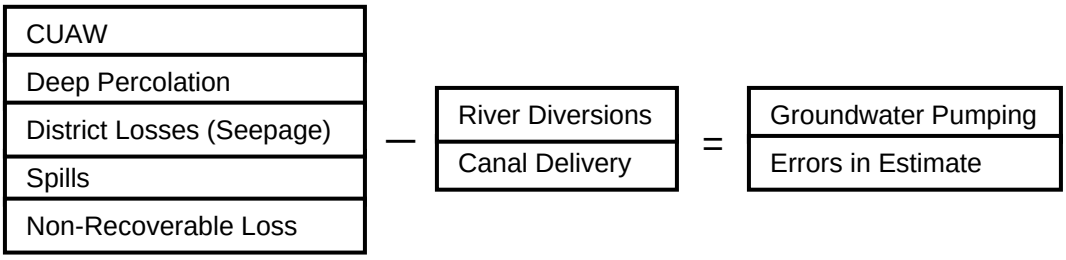
=

River Diversions
Groundwater Pumping
Madera Canal Delivery

Flows leaving the district are very small. These flows are either diverted by downstream users or enter the groundwater aquifer through seepage shortly after it leaves the district boundary. Non-recoverable loss is assumed to be 10 percent of CUAW, a standard used by DWR and the Bureau of Reclamation (Reclamation).

The annual distribution system loss in Madera ID is assumed to be 30 percent of the surface diversion in dry years[1] and 40 percent in normal years[2]. This estimate is based on experience of Madera ID operators and data gathered by the district.

Deep percolation of applied water and groundwater pumping from private wells are two water budget components that are not measured and are difficult to estimate. However, when combined they provide a closure term for balancing the water budget. An assumption was made regarding the amount of applied water that percolates into the groundwater aquifer. Deep percolation of applied water is assumed to be 25 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and discussions with district personnel.
By assuming that deep percolation is 25 percent of CUAW and distribution system losses are 30 percent in dry years and 40 percent in normal years, the only component of the water budget that has not been determined is groundwater pumping from privately owned wells. Groundwater pumping from privately owned wells is thus determined by subtracting river diversions and Madera Canal deliveries from the diversion requirement. All errors in the estimation procedure are manifest in the private groundwater pumping estimates. Consequently, the results can provide guidance when developing private pumping estimates, but will not yield exact pumping values. The calculation procedure is illustrated below.



Results of Water Budget and Model Input Based on Madera ID water budget results, inputs for CALSIM II have been developed. The CUAW developed from the DWR CU model are directly input into CALSIM II. The non-recoverable loss of 10 percent of CUAW is also a direct data parameter input to the model. District losses are set to 30 percent of surface water diversions in dry years and 40 percent in normal years. Deep percolation of applied water is set at 25 percent of CUAW.

Groundwater pumping from private wells within the district is input as a minimum monthly amount that will be pumped every year regardless of supply, and a maximum monthly volume that can be pumped in dryer years. These groundwater pumping parameters are described in Table 3-1.

[1] Except as noted, within the text of this document a “dry” year refers to both dry and critically dry hydrologic conditions as defined by the San Joaquin River Basin 60-20-20 index.
[2] Except as noted, within the text of this document a “normal” year refers to wet, above normal, and below normal hydrologic conditions as defined by the San Joaquin River Basin 60-20-20 index.

Table 3-1: Groundwater Pumping Parameters (acre-feet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	0	0	0	0	0	0	0	20,000	30,000	30,000	25,000	3,000
Maximum	8,000	1,000	0	0	1,000	20,000	45,000	66,000	55,000	50,000	50,000	30,000

Based on a review of historical flows leaving the district, there is a distinct difference between dry year and normal year operations. During wetter years, much of the return flow is either precipitation runoff or saturated soils drainage. Within CALSIM II, the flows leaving the district are depicted by the values shown in Table 3-2.

Table 3-2: Flow Exiting District (acre-feet)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Critical[3]	500	180	0	0	0	950	920	1,100	940	840	880	790	7,100
Non-Critical	240	70	0	0	0	0	0	180	190	210	230	40	1,160

Chowchilla Water District

Methodology The water demands and diversions of Chowchilla Water District (Chowchilla WD) were determined by preparing a water budget for the district using available data and judgment. Water demands were developed using land use data, estimated CUAW, historical stream flow records, estimates of district losses, and estimates of deep percolation.

The operation of Eastman Lake is determined by the diversion requirement developed from the water budget and water supplied by the Friant system. Both the pattern and quantity of water supplied from Friant may influence the operation of Eastman Lake. Operational rules for Eastman Lake were developed to best use the water supplies from both water supply sources.

Water Budget The water budget for Chowchilla WD was performed on a monthly basis from 1980 to 1998. All water entering and leaving Chowchilla WD was accounted for in the water budget. The factors included surface diversions, spills, ET, non-recoverable loss, and deep percolation. The same water budget model used for Madera ID applied to Chowchilla WD. The CUAW was combined with district losses, district spills, non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The district's diversion requirement is satisfied by Chowchilla River diversions (including Ash and Berenda Sloughs), Madera Canal deliveries, and pumping from private wells located in the district.

The process of performing a water budget involves balancing water entering the district with water leaving the district. Water leaves the district to either the atmosphere, surface flow, or into the ground. The only information available to

[3] Except as noted, within the text of this document a "critical" year refers to the critically dry hydrologic condition as defined by the San Joaquin River 60-20-20 index.

perform the water budget for Chowchilla WD is CUAW (based on DWR land use data), flow below Buchanan Dam, and Madera Canal deliveries. All other data are estimated.

Flow leaving the district was assumed to be very small and is either diverted by downstream users or enters the groundwater aquifer through seepage shortly after it leaves the district boundary. The non-recoverable loss is assumed to be 10 percent of CUAW. The annual distribution system losses in Chowchilla WD are assumed to be 35 percent of surface diversion. This value is based on judgment and characteristics of water districts in the area.

Deep percolation of applied water is assumed to be 25 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and values assumed for districts in the area. By assuming that deep percolation is 25 percent of CUAW and distribution system losses are 35 percent, the remaining component of the water budget that has not been determined is groundwater pumping from privately owned wells. This component is estimated by subtracting river diversions and Madera Canal deliveries from the diversion requirement. Identical to the Madera ID procedure, all errors in the estimation procedure are manifest in the private groundwater pumping estimates. Therefore, the results for this parameter can provide guidance when developing private pumping estimates, but will not yield exact pumping values.

Results of Water Budget and Model Input Based on results of the Chowchilla WD water budget, inputs for CALSIM II have been developed. The CUAW developed from the DWR CU model is directly input into CALSIM II. Non-recoverable loss of 10 percent is also directly input into the model. District losses are set to 35 percent of surface diversion, and deep percolation of applied water is 25 percent of CUAW.

Groundwater pumping from private wells within the district is input as a minimum monthly amount that will be pumped every year, regardless of supply, and a maximum monthly volume that can be pumped in dryer years. These values are shown in Table 3-3.

Table 3-3: Groundwater Pumping Parameters (acre-feet)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	500	0	0	0	0	0	1,500	12,000	20,000	20,000	20,000	5,000
Maximum	7,000	500	0	0	1,000	35,000	35,000	35,000	45,000	45,000	45,000	20,000

There are no data available regarding flows leaving Chowchilla WD; they are assumed to be very small. For modeling purposes, and without any available data, the flows leaving the district are set equal to Madera ID spills. The actual spill parameters used in CALSIM II can be seen in Table 3-2 above.

Merced Irrigation District

Methodology The Merced Irrigation District (Merced ID) is primarily located south of the Merced River, but does include about 5,000 acres of irrigated land north of the Merced River. For the purposes of modeling the Merced ID system in CALSIM II, lands north of the Merced River are combined with lands south of the river to represent one diversion for the district.

The water demands and operation of Merced ID were determined by preparing a water budget for the district. Water demands are developed using land use data, estimated CUAW, historical records from Merced ID, estimates of district losses, estimates of deep percolation, and guidance from Merced ID personnel. The Merced ID maintains detailed records of district operations. Records of stream diversions, flows leaving the district, district pumping, and district losses were useful in developing a water budget.

Water Budget The water budget for Merced ID was performed on a monthly basis from 1980 to 1998. Water entering and leaving Merced ID was accounted for in the water budget. The factors included surface water diversions, spills, ET, non-recoverable loss, deep percolation, and water deliveries within Merced ID and its sphere-of-influence.

The CUAW was combined with district losses, district spills, non-recoverable loss, and deep percolation of applied water to estimate diversion requirements. The district's diversion requirement is satisfied by Merced River diversions, pumping from district wells, and pumping from private wells located in the district. Water leaves the district to either the atmosphere, surface flow, or into the groundwater aquifer.

Merced ID has more than 750 miles of canals that convey water to the district's customers. The annual canal loss was provided by the district and the non-recoverable loss was assumed to be 10 percent of CUAW. Merced ID maintains records of flows leaving the district.

Deep percolation of applied water and groundwater pumping from private wells are unknown components of the water budget. An assumption was made regarding the amount of applied water that percolates into the groundwater aquifer. Deep percolation of applied water is assumed to be 30 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and the influence the assumptions has upon private pumping estimates.

By assuming that deep percolation is 30 percent of CUAW, groundwater pumping from privately owned wells is the closure term of the water budget and is determined by subtracting historical river diversions and district pumping from the diversion requirement. All errors in the estimation procedure are manifest within the estimation of private groundwater pumping. Therefore, the result can provide guidance when developing private pumping estimates; however, it will not yield exact pumping values.

Results of Water Budget and Model Input Based on results of the Merced ID water budget, inputs for CALSIM II have been developed. CUAW (developed from the DWR CU model) is directly input into CALSIM II. A non-recoverable loss of 10 percent of CUAW is also directly input into the model. District losses are assumed to be 150,000 acre-feet (AF) per year, distributed on the pattern of monthly CUAW. Pumping from district owned wells is set at about 9,000 AF per year and is also distributed on the monthly pattern of CUAW. District pumping was based on annual pumping from 1993 through 1998. Although district pumping has been greater in the past, many changes within the district have occurred and pumping from district owned wells should not be allowed to increase above the assumed value.

Deep percolation of applied water is set at 30 percent of CUAW. Groundwater pumping from private wells is assumed to be a minimum of 45,000 AF per year, distributed on the CUAW monthly pattern, and bounded by a maximum of 250,000 AF per year, also distributed on the CUAW monthly pattern. District delivery to areas outside the district boundary are set as 40,000 AF per year (not including Stevinson Water District or Merced National Wildlife Refuge), subject to reductions based on water availability. Spills or flows leaving the district are a function of requirements for downstream water districts, excess runoff from small tributaries, and normal district operations. Additionally, some spills which are independent of requirements for downstream water districts are returned to the Merced River at Cressey. These returns are determined by water year type and month, and only occur when there is an irrigation demand (see Table 3-4 below).

Table 3-4: Flow Exiting District (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Critical	200	0	0	0	0	100	400	400	350	400	400	400	2,650
Non-Critical	1,500	300	0	100	130	600	1,100	1,200	1,750	1,550	1,900	1,700	11,830

Merced ID spills are discussed in further detail in Section 7, page 97.

Turlock Irrigation District

Methodology The methodology used to determine the diversion requirement for Turlock Irrigation District (Turlock ID) differs from the previously described methodologies. Deep percolation within the district is variable and dependent upon the availability of water from the district. The availability of system operation data and estimates of groundwater pumping allows the development of a monthly varying factor that relates CUAW to canal deliveries and thus, diversions. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate district system operation parameters and determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-

recoverable losses, district and private groundwater pumping, system losses, operational spills, diversions, and regulating reservoir operation as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. The resulting volume is then reduced by an estimate for groundwater pumping by the growers, and becomes the canal delivery of the district. Other parameters (district operational spills and canal losses) are added to this estimate to determine diversions from Turlock Lake. The diversion from La Grange Reservoir for the district is determined by taking into consideration the diversion for canal deliveries and the seasonal operation and losses of Turlock Lake. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Through the development of a balance for Turlock Lake, net evaporation and seepage losses for the regulating reservoir and the canal between Turlock Lake and La Grange Dam are estimated.

Table 3-5: Turlock Lake and Upper System Net Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	5,265	4,884	4,733	5,438	6,293	7,270	8,352	9,524	9,952	10,505	11,000	9,141

Current operational spills from the district's canals have also been estimated and differentiated by year-type, based on recent historical records. Canal losses are estimated to be 800 AF per month.

Table 3-6: Operational Canal Spills (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	2,000	2,000	2,000	2,000	2,000	2,000	2,500	2,500	3,000	3,000	3,000	2,500
Non-Critical	9,000	2,000	2,000	2,000	2,000	2,500	7,500	8,500	8,500	8,500	8,000	8,000

Groundwater and drainage pumping used by the district as a supply within its canal system (at a minimum) are shown below. Also shown are values assumed to be the maximum pumping by the district for supply purposes. The values are estimated from recent historical records.

Table 3-7: District Groundwater Parameters (AF)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	8,000	0	0	0	0	1,500	6,500	8,500	10,000	12,000	11,000	10,000
Maximum	8,000	0	0	0	0	6,000	10,000	15,000	17,000	17,000	15,000	12,000

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with district personnel and a review of the groundwater management plan for the area.

Table 3-8: Non-District Groundwater Parameters (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	4,382	0	0	0	0	4,719	8,090	13,483	16,854	18,876	16,180	7,416

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters, then were adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-9: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	35	35	35	35	35	35	60	65	75	65	60	60

For the month of March, the canal turnout delivery factor varies between 35 and 50 percent, depending upon the level of CUAW during the month.

Modesto Irrigation District

Methodology The methodology used to determine the diversion requirement for Modesto Irrigation District (Modesto ID) is consistent with the methodology used for Turlock ID. Deep percolation within the district is variable and dependent upon the availability of water from the district. The availability of system operation data and estimates of groundwater pumping allows the development of a monthly varying factor that relates CUAW to canal deliveries and thus, diversions. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate district system operation parameters and determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-recoverable losses, district and private groundwater pumping, system losses, operational spills, diversions, and regulating reservoir operation as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. The resulting volume is then reduced by an estimate for groundwater pumping by the growers, and then becomes the canal delivery of the district. Other parameters (district operational spills, intercepted flows useable for

supply, and canal losses) are added to this estimate to determine diversions from Modesto Lake. The diversion from La Grange Reservoir for the district is determined by taking into consideration the diversion for canal deliveries and the seasonal operation and losses of Modesto Lake. Also considered was the diversion from Modesto Lake for the Modesto Water Treatment Plant. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Through the development of a balance for Modesto Lake, net evaporation and seepage losses for the regulating reservoir and in the canal between Modesto Lake and La Grange Dam are estimated.

Table 3-10: Modesto Lake and Upper System Net Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	4,300	3,500	3,300	3,600	3,700	3,900	4,300	5,100	5,400	6,000	6,000	5,400

Current operational spills from the district's canals have also been estimated and differentiated by year-type, based on recent historical records. Canal losses are estimated to be 100 AF per month.

Table 3-11: Operation Canal Spills (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,500	3,500	4,500	4,000
Non-Critical	7,000	2,000	2,000	2,000	2,000	3,000	6,500	8,000	7,000	7,000	7,500	7,000

Groundwater and drainage pumping used by the district as a supply within its canal system (at a minimum) are shown in Table 3-12. Also shown are values assumed to be the maximum pumping by the district for supply purposes. The values are estimated from recent historical records.

Table 3-12: District Groundwater Parameters (AF)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	2,000	0	0	0	0	1,000	2,500	2,500	2,500	3,000	3,000	2,000
Maximum	8,000	0	0	0	0	6,000	2,500	6,000	6,000	7,000	7,000	2,000

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with the district and review of the groundwater management plan for the area.

Table 3-13: Non-District Groundwater Parameters (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	974	0	0	0	0	1,049	1,798	2,996	3,745	4,195	3,596	1,648

The district currently provides water to the Modesto Water Treatment Plant. The diversion from Modesto Lake is shown in Table 3-14.

Table 3-14: Diversion to Modesto Water Treatment Plant (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	2,916	2,855	2,925	2,767	2,425	2,776	2,742	2,994	3,004	3,124	3,095	3,003

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters, then were adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-15: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	35	35	35	35	35	35	60	75	80	80	70	70

For the month of March, the canal turnout delivery factor varies between 35 and 60 percent, depending upon the level of CUAW during the month.

Oakdale Irrigation District (South of Stanislaus River)

Methodology The methodology used to determine the diversion requirement for Oakdale Irrigation District (Oakdale ID) is consistent with the methodology used for Turlock ID and Modesto ID. The district is physically located both north and south of the Stanislaus River, diverting water to the South Main Canal and jointly with the South San Joaquin Irrigation District (South San Joaquin ID) from the Joint Main Canal. CALSIM II depicts the district separately north and south of the river. A monthly varying factor is developed that relates CUAW to canal deliveries and thus, diversions. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate district system operation parameters and determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-recoverable losses, district and private groundwater pumping, system losses, operational spills, and diversions as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. This value is then reduced by an estimate for groundwater pumping by the growers, and becomes the canal delivery of the district.

Other parameters (district operational spills and canal losses) are added to this estimate to determine diversions from Goodwin Dam. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Current operational spills from the district's canals have been estimated and differentiated by year-type. Canal losses are estimated to be 2,000 AF per month.

Table 3-16: Operation Canal Spills (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	2,110	1,400	1,400	1,400	1,400	2,110	2,110	2,800	2,510	2,510	3,200	2,800
Non-Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,510	3,510	4,510	4,000

Groundwater and drainage pumping used by the district as a supply within its canal system (at a minimum) are shown below. Also shown are values assumed to be the maximum pumping by the district for supply purposes. The values are estimated from recent historical records.

Table 3-17: District Groundwater Parameters (AF)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Minimum	487	0	0	0	0	524	899	1,498	1,873	2,097	1,798	824
Maximum	2,000	0	0	0	0	1,000	2,500	6,000	6,000	7,000	7,000	2,000

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with district personnel and a review of the groundwater management plan for the area.

Table 3-18: Non-District Groundwater Parameters (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	747	0	0	0	0	724	1,018	1,471	1,697	1,765	1,493	1,086

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters. These values were then adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-19: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	60	60	35	35	35	60	60	60	75	70	65	60

South San Joaquin Irrigation District and Oakdale Irrigation District (North of Stanislaus River)

Methodology The methodology used to determine the diversion requirement for the South San Joaquin ID and Oakdale ID North demand area is consistent with

the methodology used for the Turlock ID and Modesto ID demand areas. The combined operation of South San Joaquin ID (located entirely north of the Stanislaus River) and Oakdale ID (located both north and south of the river) is depicted by CALSIM II. Although diversions to Oakdale ID physically occur prior to Woodward Reservoir, CALSIM II has the combined diversions of the two districts routed through Woodward Reservoir. This modeling convenience does not violate the depiction of diversions from Goodwin Dam. A monthly varying factor that relates CUAW to canal deliveries and thus, diversions, is developed for the combined demands. The factor is refined by iteratively comparing calculated diversion requirements with observed diversions.

Water Budget A water budget model was used to estimate the combined districts' system operation parameters and to determine the canal turnout delivery factor. Recent monthly records for the period 1990 through 2001 served as the basis of the analysis. The water balance used records or estimates of CUAW, non-recoverable losses, district and private groundwater pumping, system losses, operational spills, diversions, and regulating reservoir operation as known parameters.

The water budget procedure sequentially builds the diversion requirements, beginning with the estimate for CUAW. The CUAW is adjusted upward by a factor reflecting unrecoverable losses. The turnout delivery factor is then applied to the adjusted CUAW and is reflective of a ratio between the adjusted CUAW and canal-side deliveries. The resulting volume is then reduced by an estimate for groundwater pumping by the growers, and becomes the canal delivery of the districts. Other parameters (district operational spills, intercepted flows useable for supply, and canal losses) are added to this estimate to determine diversions from Woodward Reservoir and above. The diversion from Woodward Reservoir and above (for the districts) is determined by taking into consideration the diversion for canal deliveries and the seasonal operation and losses of Woodward Reservoir. The canal turnout factor is refined by comparison of historical diversions and calculated diversions.

Results of Water Budget and Model Input Various parameters were developed for the water budget. Through the development of a balance for Woodward Reservoir, net evaporation and seepage losses for the regulating reservoir and in the canal between Woodward Reservoir and Goodwin Dam are estimated.

Table 3-20: Woodward Reservoir and Upper System Net Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	4,052	3,658	3,501	3,437	3,492	4,320	5,587	6,212	7,000	7,000	7,000	6,513

Current operational spills from the combined districts' canals have also been estimated, differentiated by year-type, based on recent historical records. Canal losses are estimated to be 2,000 AF per month.

Table 3-21: Operation Canal Spills – Combined (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,500	3,500	4,500	4,000
Non-Critical	3,000	2,000	2,000	2,000	2,000	3,000	3,000	4,000	3,500	3,500	4,500	4,000

Groundwater and drainage pumping used by the districts as a supply within their canal systems (at a minimum) are shown in Table 3-22.

Table 3-22: District Groundwater Parameters – Combined (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	487	0	0	0	0	524	899	1,498	1,873	2,097	1,798	824

An estimate for non-district pumping (at a minimum) to satisfy applied water requirements was made based on conversations with each district's personnel.

Table 3-23: Non-District Groundwater Parameters – Combined (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	3,136	0	0	0	0	3,041	4,276	6,176	7,127	7,412	6,271	4,561

A canal turnout delivery factor is used to account for all other applied water requirements in excess of CUAW and the non-recoverable losses. These monthly values were initially estimated based on performing a water balance between estimated and recorded parameters and then were adjusted to provide a reasonable comparison between simulated and recorded diversions.

Table 3-24: Canal Turnout Delivery Factor (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	35	35	35	35	35	40	70	75	80	80	70	70

Central San Joaquin Water Conservation District

Methodology The Central San Joaquin WCD methodology of determining agricultural demands varies from the methodologies used for the other districts on the east side. Central San Joaquin WCD has a relatively small effect on reservoir operations and the surface water network, and therefore a more simplified approach of developing the district's demands was used.

Demands Development and Model Input The Central San Joaquin WCD diversion requirement was developed based on crop consumptive use. Estimates of the district's CUAW were determined using the CU model and loss factors were added to the estimates to account for deep percolation and non-recoverable losses. Per DWR guidelines, non-recoverable losses were assumed to be 10 percent of CUAW while deep percolation was assumed to be 30 percent of CUAW. Flows that leave district boundaries and become available for reuse are assumed to be negligible.

Stockton East Water District

Methodology A water budget for Stockton East Water District (Stockton East WD) was performed on a monthly basis for the period when data was available. Water entering and leaving Stockton East WD was accounted for in the water budget. The parameters included surface diversions, spills, ET, non-recoverable loss, deep percolation, and urban diversions.

Water Budget The water budget was developed by first estimating CUAW. The CUAW was combined with district losses, district spills, non-recoverable loss, deep percolation of applied water, and urban demands to estimate the diversion requirement of the district, regardless of source. The district diversion requirement is satisfied by Calaveras River diversions, pumping from private wells located in the district, urban groundwater pumping, and diversions (imports) from the Stanislaus River at Goodwin Dam (depicted below).

Calaveras River Diversions
Stanislaus River Diversions
Agriculture Groundwater Pumping
Urban Groundwater Pumping

=

Diversion Requirement

The process of performing the water budget involved balancing water entering the district with water leaving the district. Water leaves the district to either the atmosphere, surface flow, or into the groundwater aquifer. Mathematically balancing the water leaving and entering the district is illustrated below.

CUAW
Deep Percolation of Applied Water
District Losses (Seepage)
Spills
Non-Recoverable Loss
Urban Demands

=

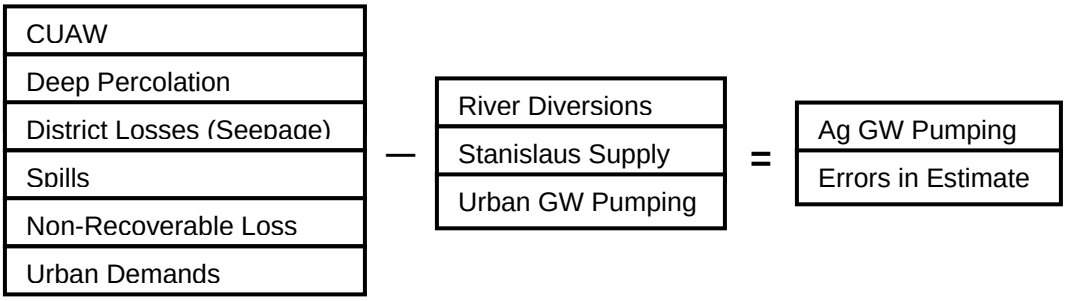
Calaveras River Diversions
Stanislaus River Diversions
Agriculture Groundwater Pumping
Urban Groundwater Pumping

Non-recoverable loss was assumed to be 10 percent of CUAW. District spills are very minor and are estimated to be approximately 10 cubic feet per second (cfs) during the irrigation season (based on conversations with district personnel). District losses occur throughout the distribution system.

The deep percolation of applied water and groundwater pumping from wells are unknown components of the water budget. One factor was selected as an assumption and the other was solved as the closure term. An assumption was made regarding the amount of applied water that percolates into the groundwater

aquifer. Deep percolation of applied water was assumed to be 25 percent of CUAW, based on groundwater modeling performed by DWR, judgment, and the resulting calculated pumping estimates.

By assuming that deep percolation was 25 percent of CUAW, the remaining component of the water budget was groundwater pumping from wells and use of other minor unaccounted stream flow. Pumping was estimated by subtracting historical river diversions from the other diversion requirement factors. All errors in the estimations are manifest within the groundwater pumping estimates; therefore, the result can provide guidance when developing private pumping estimates but will not yield exact pumping values. The estimation procedure is illustrated below.



Results of Water Budget and Model Input Based on operating rules provided by the Stockton East WD and results of the water budget, inputs for CALSIM II have been developed. The CUAW developed from the DWR CU model are directly input into CALSIM II. A non-recoverable loss of 10 percent of CUAW is also a direct input to the model.

Agricultural demands within the Stockton East WD boundaries are greater than surface water supply in every year; therefore, the amount of groundwater pumping is calculated as the total diversion requirement, minus available surface water. The average annual groundwater pumping is about 75,000 AF and ranges from about 60,000 AF in wetter years to about 110,000 AF in dry years.

Urban demands are treated as a constant 40,000 AF diversion volume each year, based on input from Stockton East WD. Urban groundwater pumping is used to satisfy urban demands of 40,000 AF and varies depending on availability of surface water defined by CALSIM II.

Non-District Demand Area Agricultural Demands

Those water demand areas not identified as districted areas are referred to as “non-district” areas. These areas do not normally cause or affect direct changes to the major water supply facilities located in the San Joaquin Valley. Their sources of supply may be incidental runoff from district areas, groundwater pumping, or pumping from a stream. All non-district demands are defined in CALSIM II using the following parameters:

- CUAW (time series from the DWR CU model)
- Non-recoverable loss (10 percent)
- Deep percolation of applied water (30 percent of CUAW)
- Irrigation efficiency (75 percent for surface deliveries, no assumption for groundwater)

For non-district areas, irrigation efficiency is used to calculate return flows. Irrigation efficiency is assumed to be 75 percent for surface water delivery, but there is no assumption for groundwater delivery (i.e., there are no return flows associated with groundwater pumping). These assumptions are consistent for all non-district areas.

There are 12 non-district agricultural demand areas within the east side area. A description of each non-district area and the accompanying operations for meeting the areas' demands are found in Section 7.

Municipal Demands

Historically, urban demands have only made up a small percentage of the total water demand in the east side of the San Joaquin Basin, and much of that demand has been met through groundwater pumping. Urban demands have, therefore, had a relatively small surface water diversion requirement in comparison to agriculture.

With the exception of the Stockton East WD, the CALSIM II Benchmark essentially ignored east side urban water demands because of their insignificance on surface water diversions. However, the DWR Division of Planning and Local Assistance (DPLA) land use projections show large urban growth within the San Joaquin Valley during the next 20 years. Some predictions show that most of this urban development will take place on agricultural lands and will thus change the land's use. Land use conversion will have a considerable impact on both groundwater and surface water demands. The anticipation of land use changes requires a more refined assessment and depiction of urban water use in CALSIM II.

Development Methodology

Typically, urban water use values are analyzed and published in units of gallons per capita per day (gpcd). To estimate municipal water demands, one simply applies these factors to an estimate of population for a geographic area and multiplies that value by the number of days in the analysis period. This method was selected for calculating San Joaquin Valley urban demands due to the availability of data. The DPLA collects and analyzes water use information from water purveyors for updating Bulletins 160 (California Water Plan) and 166 (Urban Water Use in California). The data is then stored in the Public Water System Statistics (PWSS) database. From these surveys, DPLA has determined

daily per capita water use for much of California. Additionally, DPLA has completed population forecasts that extend more than 20 years.

It is difficult to estimate what the average water consumption will be decades from now. Some predictions indicate that new technology and conservation techniques will considerably reduce future urban water demand. The 1998 update of Bulletin 160 assumes that if water conservation activities take place, urban demands in the San Joaquin Valley will be reduced up to 12 percent by the year 2020, with respect to 1995 demands. Table 3-25 contains population and per capita water use information provided by DPLA. The table also includes the resulting annual water use in AF for each DAU on the east side of the Basin.

Table 3-25: DPLA Population and Water Demand Information

DAU	Population		Annual Water Use (gpcd)		Annual Water Use (AF)	
	Existing	2030	Existing	2030	Existing	2030
205	99,075	176,100	225	198	24,972	39,060
206	280,955	517,300	278	245	87,495	141,766
206	2,065	2,500	280	246	648	690
208	174,900	320,075	304	268	59,562	95,920
209	1,945	2,350	326	287	710	755
210	141,750	243,600	348	306	55,259	83,568
211	1,530	1,800	317	279	543	562
212	4,275	5,020	303	267	1,451	1,499
213	63,325	139,400	295	260	20,927	40,539
214	37,875	81,100	320	282	13,577	25,853
215	1,245	1,450	261	230	364	373

Note: 2030 values assume a 12% reduction from existing demand, based on the 1995 to 2020 reduction in demand.

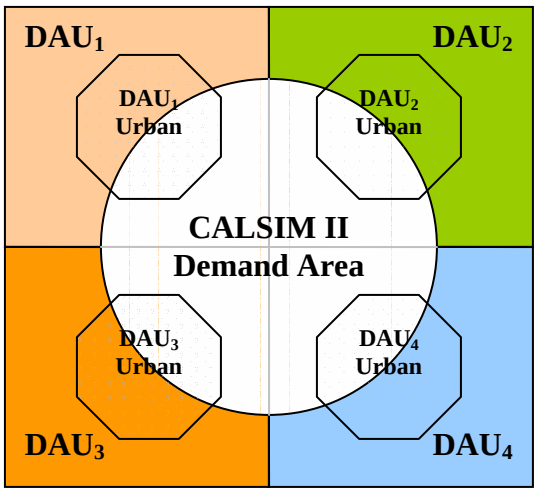
Data Limitations and Solutions

There are at least two significant limitations of the DPLA data with regard to implementation and use in CALSIM II. The biggest limitation is that per capita water use values and population projections are published according to DAU, whereas the new CALSIM II east side representation incorporates new planning areas (introduced in Sections 1 and 3 as CALSIM II demand areas) which are inconsistent with DAU boundaries. A second limitation to the DPLA data is that the daily per capita water use is based on annual averages rather than monthly or daily averages. For example, a California city with an average annual water use of 300 gpcd may actually use 400 gpcd during the summer months and 200 gpcd during the winter months. Since CALSIM II is a monthly model, the DPLA annual data must be disaggregated to a monthly time step.

Because DAU boundaries do not coincide with the new demand areas, a method was developed to estimate total annual water use in each demand area using the DAU per capita water use values. This method relies on GIS technology and land use surveys to determine the percentage of the total DAU urban land use that is

located within the overlapping portion of a corresponding demand area. Multiplying this percentage by the total DAU population gives an estimation of the number of residents in that section of the DAU. This assumes that the number of people per acre of urban-classified land is consistent throughout the entire DAU.

The DPLA per capita water use value for the given DAU can then be multiplied by the population estimate, returning an annual water requirement for a section of the corresponding demand area. Because each demand area may coincide with multiple DAUs, this procedure must be applied to all sections overlapping a different DAU. The total urban water demand for the demand area is the sum of each section's water requirement. Figure 3-2 illustrates the methodology for determining annual urban water requirements for the new demand areas.



DAU_1
Area = 1000 acres
Residents = 500
Urban Per Capita Water Use
(Average Annual) = 250 gpcd
Area Overlapping the Demand Area
= 200 acres
DAU_1 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping the Demand Area
= 60 acres

DAU_2
Area = 1000 acres
Residents = 1000
Urban Per Capita Water Use
(Average Annual) = 300 gpcd
Area Overlapping the Demand Area
= 200 acres
DAU_2 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping Sub-Basin = 60 acres

DAU_3
Area = 1000 acres
Residents = 300
Urban Per Capita Water Use
(Average Annual) = 275 gpcd
Area Overlapping the Demand Area
= 200 acres
DAU_3 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping the Demand Area
= 60 acres

DAU_4
Area = 1000 acres
Residents = 700
Urban Per Capita Water Use
(Average Annual) = 290 gpcd
Area Overlapping the Demand Area
= 200 acres
DAU_4 Urban Classified Land Use
Total Urban Area = 150 acres
Area Overlapping the Demand Area
= 60 acres

Demand Area
Area = 1000 acres
Urban Area = (60 + 60 + 60 + 60)
= 240 acres
Average Annual Urban Water Use =
{[(60 ac / 150 ac) * 500 * 250 gpcd] +
[(60 ac / 150 ac) * 1000 * 300 gpcd] +
[(60 ac / 150 ac) * 300 * 275 gpcd] +
[(60 ac / 150 ac) * 700 * 290 gpcd]} *
Conversion Factor

= 318 acre-feet annually

Figure 3-2: Defining Urban Water Requirements in CALSIM II Demand Areas

The resulting annual urban water demand for each CALSIM II demand area is shown in Table 3-26.

Table 3-26: Annual Urban Water Demand (AF)

CALSIM II Demand Area	Urban Water Demand
Chowchilla Water District	4,792
East bank of San Joaquin River, Downstream of Stanislaus	5,221
East bank of San Joaquin River, Merced to Tuolumne	345

CALSIM II Demand Area	Urban Water Demand
East bank of San Joaquin River, Tuolumne to Stanislaus	5
East of Madera Irrigation District and Non-District DAU 213	13,473
East of Merced Irrigation District	540
East of Modesto Irrigation District and Oakdale Irrigation District	887
East of Turlock Irrigation District	663
Madera Irrigation District	16,254
Merced Irrigation District	54,734
Merced River Diversions	1,056
Modesto Irrigation District	64,823
Oakdale Irrigation District North	3,743
Oakdale Irrigation District South	15,841
South San Joaquin Irrigation District	17,338
Stanislaus River Diversions	2,053
Tuolumne River Diversions	2,212
Turlock Irrigation District	57,834
West of Madera Irrigation District and Chowchilla Water District	262
West of Merced Irrigation District and Non-District Areas in DAU 210 and 212	1,450

Since CALSIM II is a monthly model, annual municipal water requirements are disaggregated to a monthly time step before inclusion in the model. The PWSS database provided by DPLA includes population estimates and monthly municipal and industrial delivery volumes for water purveyor service areas. With this information, it was possible to determine the annual delivery volume for a given purveyor (and corresponding service area) and the monthly percent of total annual delivery. The resulting monthly delivery pattern is used for distributing the demand areas' derived annual urban demands over each month of the year.

The monthly delivery patterns derived from PWSS data are representative of a single service area and not an entire demand area or DAU. However, since data is not available at an aggregate level, distribution patterns associated with individual service areas were used as surrogates for the entire demand areas. The representative service area was selected based on proximity, population served, and reasonableness of the data (i.e., follows basic trends of increased water use during the drier months and vise versa). Table 3-27 shows the monthly distribution of annual deliveries applied to each area.

Table 3-27: Monthly Distribution of Annual M&I Deliveries Based on Representative Purveyor

Demand Area	Service Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Chowchilla WD	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%

Demand Area	Service Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
East bank of SJR, Downstream of Stanislaus	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%
East bank of SJR, Merced to Tuolumne	City of Turlock, 1997	10%	8%	6%	6%	5%	7%	8%	9%	10%	10%	11%	10%
East bank of SJR, Tuolumne to Stanislaus	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
East of Madera ID, Non-District	City of Fresno, 2000	8%	6%	5%	5%	4%	6%	8%	10%	12%	13%	13%	10%
East of Merced ID	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
East of Modesto ID and Oakdale ID	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
East of Turlock ID	City of Turlock, 1997	10%	8%	6%	6%	5%	7%	8%	9%	10%	10%	11%	10%
Madera ID	City of Fresno, 2000	8%	6%	5%	5%	4%	6%	8%	10%	12%	13%	13%	10%
Merced ID	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
Merced River Riparian Diversions	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
Modesto ID	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
Oakdale ID (North)	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
Oakdale ID (South)	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
South San Joaquin ID	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%
Stanislaus River Riparian Diversions	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%
Tuolumne River Riparian Diversions	City of Oakdale, 2001	8%	6%	4%	4%	5%	5%	8%	9%	14%	13%	14%	10%
Turlock ID	City of Turlock, 1997	10%	8%	6%	6%	5%	7%	8%	9%	10%	10%	11%	10%
West of Madera ID and Chowchilla WD	City of Fresno, 2000	8%	6%	5%	5%	4%	6%	8%	10%	12%	13%	13%	10%
West of Merced ID	City of Merced, 1997	8%	5%	5%	4%	4%	6%	7%	10%	11%	14%	14%	12%
Stockton East WD	City of Stockton, 2001	10%	7%	6%	6%	5%	6%	6%	8%	11%	12%	12%	11%

It is not necessary to ensure that each monthly pattern is exactly representative of the demand area. First, almost all urban water diversion requirements in CALSIM II (at the current level of development) are met through groundwater pumping, and CALSIM II assumes that none of the urban uses are returned as surface flows. Second, urban water use (also at the current level of development) is a small percentage of total water use in the Basin. Therefore, the CALSIM II results will not be sensitive to small changes in the monthly percentages.

As San Joaquin Valley municipal water use becomes a greater percentage of the total water use, errors associated with the derived monthly delivery patterns will

have a more significant effect on surface water operations. With future land use and population projections showing significant urbanization, it would seem less reasonable to apply one service area's monthly delivery pattern to an entire demand area at a future level of demand. However, the errors associated with this procedure will likely be less than the errors associated with projecting per capita water use 20 years into the future. Without better data available, it was assumed that a single service area's current monthly delivery pattern is representative of a corresponding demand area's future monthly water delivery pattern.

Implementation in CALSIM II

Under the current demand level for the San Joaquin Basin CALSIM II modeling, most of the urban water demands are met through groundwater pumping. For urban uses satisfied through groundwater sources, it is assumed that 100 percent of the demand will be met each year and that there are no return flows to the system. Only the major surface water M&I diversions are represented in CALSIM II and consist of Stockton East WD's delivery to City of Stockton (up to 40 TAF[4] annually, see also Section 3, page 40 and Section 7, page 117), Modesto ID's delivery to City of Modesto (up to 34.6 TAF[5] annually, see also Section 3, page 34 and Section 7, page 104), and South San Joaquin ID's South County Project delivery (up to 25 TAF[6] annually, see also Section 7, page 111). As the revised CALSIM II San Joaquin representation is developed for a future level of development, new assumptions will have to be made as to which urban water users will be served by surface water and how return flows will be accounted.

Refuge Demands

With the exception of the Merced National Wildlife Refuge (Merced NWR), all San Joaquin Valley wildlife management areas and refuges are modeled as part of the west side operations. The Merced NWR has a 15,000 AF[7] demand for Merced River water via Merced ID, which is distributed monthly as shown in Table 3-28. This demand was not determined as part of a water budget approach, but was determined based on information provided by both Merced ID and Merced NWR.

Table 3-28: Merced NWR Monthly Demands (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	600	800	1,100	600	600	1,900	400	200	1,100	3,800	2,800	1,100

[4] The City of Stockton water treatment facility has an annual capacity of 40 TAF. The City's actual M&I demand exceeds 40 TAF, but this additional demand is satisfied through groundwater pumping, which is not represented in CALSIM II.

[5] The City of Modesto water treatment facility has an annual capacity of 34.6 TAF. The annual M&I demand within the Modesto ID demand area as shown in Table 2 27 approaches 65 TAF. Demands above the treatment plant's capacity represent demand for groundwater.

[6] The South County Project delivery of 25 TAF is in excess of the total M&I demand within the South San Joaquin ID demand area. This apparent discrepancy in information can be reconciled through the knowledge that the South County Project services municipalities outside South San Joaquin ID (including City of Tracy).

[7] This demand does not represent the consumptive demand for water, but is representative of Merced NWR's use of Merced River water.

West Side Demands

The water demand assumptions on the San Joaquin Valley west side are fundamentally different than the east side demand assumptions. Where the east side utilizes an approach to determine the land use within spatially defined demand areas and then estimates the volume and origin of water necessary to meet that land's requirements, the west side representation (with two exceptions[8]) relies only on surface water contract (or water rights) amounts to define demand. A land use-based approach to modeling the San Joaquin Basin west side could be a significant enhancement to CALSIM II in the future.

As mentioned previously in this document, there are three types of water demands represented in CALSIM II: agricultural, M&I, and wildlife refuge demands. The large majority of west side water users that are hydraulically connected to the San Joaquin River are Central Valley Project (CVP) contractors. CVP commitments on the west side include agricultural, M&I, refuge, and exchange contracts; non-CVP west side demands include Schedule II water rights, Patterson Water District water rights, and San Joaquin River main stem riparian diversions.
Table 3-29 through Table 3-32 below identify the west side water contracts and water rights included in CALSIM II that have some hydraulic connectivity (return flows) to the San Joaquin River[9].

Table 3-29: West Side Demands (Mendota Pool)

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Westlands WD (incl. Barcellos)	CVP Ag	50,000
Fresno Slough WD	CVP Ag	4,000
James ID	CVP Ag	35,300
Traction Ranch/F&G	CVP Ag	2,080
Tranquility ID	CVP Ag	13,800
Melvin Hughes	CVP Ag	70
R.D. 1606	CVP Ag	228
Exchange Contractors	CVP Ex	700,000
Grasslands WD	CVP Ref	19,118
Los Banos WMA	CVP Ref	7,952
San Luis NWR	CVP Ref	25,333
Mendota WMA	CVP Ref	27,594
West Gallo	CVP Ref	14,413
East Gallo	CVP Ref	0

[8] Mainstem diversions between the Merced and Tuolumne Rivers and between the Tuolumne and Stanislaus Rivers do not use contract/water rights amounts to define water demand.
[9] Table 3-29 should not be misinterpreted as a comprehensive table of all CALSIM II south-of-delta demands. The intent of this document is to detail water operations in the San Joaquin Basin that have an effect on the flow and water quality of the San Joaquin River. Those contracts in the San Joaquin Valley west side that do not have the potential of returning flow (or otherwise affecting flow/quality) to the San Joaquin River are not included in Table 2 30 (e.g., CVP San Felipe Division demands, State Water Project demands, Cross Valley Canal demands, etc.).

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Schedule II Water Rights	WR	34,813
Project Losses	Loss	101,500
CVP Ag		105,478
CVP M&I		0
CVP Exchange		700,000
CVP Refuge		94,410
Water Right		34,813
CVP Losses		101,500
CVP Total		**1,001,388**
TOTAL		**1,036,201**

Table 3-30: West Side Demands (Lower Delta-Mendota Canal)

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Panoche WD	CVP Ag	6,580
San Luis WD	CVP Ag	65,000
Broadview WD	CVP Ag	27,000
Laguna WD	CVP Ag	800
Eagle Field WD	CVP Ag	4,550
Mercy Springs WD	CVP Ag	13,300
Oro Loma WD	CVP Ag	4,600
Widren WD	CVP Ag	2,990
Exchange Contractors	CVP Ex	140,000
Grasslands via CCID	CVP Ref	83,824
Los Banos WMA	CVP Ref	7,501
Kesterson NWR	CVP Ref	11,147
Freitas – SJBAP	CVP Ref	7,053
Salt Slough – SJBAP	CVP Ref	7,859
China Island – SJBAP	CVP Ref	8,196
Volta WMA	CVP Ref	13,000
Grasslands via Volta Wasteway	CVP Ref	44,118
CVP Ag		124,820
CVP M&I		0
CVP Exchange		140,000
CVP Refuge		182,698
Water Right		0
CVP Losses		0
CVP Total		**447,518**
TOTAL		**447,518**

Table 3-31: West Side Demands (Upper Delta-Mendota Canal)

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
Plainview WD	CVP Ag	20,600
Banta Carbona ID	CVP Ag	25,000

Contractor / Water Right Holder	Contract Type	Annual Demand (AF)
West Side ID	CVP Ag	7,500
Davis WD	CVP Ag	5,400
Del Puerto WD	CVP Ag	12,060
Hospital WD	CVP Ag	34,105
Kern Canyon WD	CVP Ag	7,700
Salado WD	CVP Ag	9,130
Sunflower WD	CVP Ag	16,625
West Stanislaus WD	CVP Ag	50,000
Mustang WD	CVP Ag	14,680
Orestimba WD	CVP Ag	15,860
Patterson WD	CVP Ag	16,500
Foothill WD	CVP Ag	10,840
Quinto WD	CVP Ag	8,620
Romero WD	CVP Ag	5,190
Centinella WD	CVP Ag	2,500
City of Tracy	CVP M&I	10,000
Patterson WD Water Rights	WR	6,000
Project Losses	Loss	18,500
CVP Ag		262,310
CVP M&I		10,000
CVP Exchange		0
CVP Refuge		0
Water Right		6,000
CVP Losses		18,500
CVP Total		**290,810**
TOTAL		**296,810**

Table 3-32: West Side Demands (Main Stem Diversions)

Riparian Water Users	Annual Demand (AF)
From Merced River to Tuolumne River	Varies – See Appendix A
From Tuolumne River to Stanislaus River	Varies – See Appendix A

Unlike other water demands on the west side, San Joaquin River west bank riparian demands are not tied to contract amounts. These demands are more similar to east side diversion requirements which vary according to hydrologic conditions within the basin. However, unlike east side demands, west bank riparian diversion requirements were not determined as part of a water budget analysis, but were correlated to corresponding east bank riparian demands using historical data.

4. Accretions/Depletions

Accretions for the San Joaquin River and its major tributaries were estimated by performing a mass-balance for each major river reach. Well established gages (with long periods of record) were used to define upstream and downstream flow points for the mass-balance calculations.

The objective was to establish an accretion/depletion (rainfall runoff/seepage) estimate that does not include the effect of development. Therefore, estimated or recorded historical diversions were added to stream flow and estimated or recorded historical return flows were subtracted. This procedure removes the effects of development on surface inflows and diversions; however, it does not remove the changes in stream-groundwater interaction resulting from development. That component can be addressed when the groundwater modeling portion of the hydrology is complete.

The accretion/depletion mass-balance accounted for water entering and leaving river reaches using the following formula:

Accretion / Depletion =

+ *Downstream River gage*
- *Upstream River gage*
+ *Diversions*
- *Return flow*

The remaining result of this equation was a value equal to the precipitation runoff and historical stream-groundwater interaction, and gage errors. The value is absent of return flows and diversions which will be simulated by CALSIM II.

Land use changes cause a change in rainfall runoff relationships during the passage of time. The previously described accretion/depletion values required adjustment so that rainfall runoff was appropriate for the projected (then current) level of development. The adjustment was designed to modify river accretion/depletion to reflect increases or decreases in runoff resulting from land use changes over time. Output from the DWR CU model is used to estimate this change through the following equation:

Runoff adjustment =

(Projected replaced native vegetation CU - Projected CU of precipitation by crops)
minus
(Historical replaced native vegetation CU - Historical CU of precipitation by crops)

Groundwater

Groundwater is an extremely important component of San Joaquin River Basin hydrology and is the most difficult to simulate. Groundwater conditions affect the stream-groundwater interaction (stream gains and loss). An attempt was made to disaggregate the stream-groundwater interaction from the accretion/depletion values previously described. Existing information from CVGSM in terms of the stream-groundwater interaction appeared to grossly misrepresent the magnitude and direction of flow into or out of the stream reaches. Since the development of a revised groundwater model has not been performed, the accretion/depletion calculation remains an aggregated value of precipitation runoff and stream-groundwater interaction. CALSIM II does not dynamically model the interaction within the Basin of groundwater with streamflow.

In the context of water supply within CALSIM II, groundwater is assumed to provide a water source for demands not met from surface supplies.

Description of Accretions by Reach

River accretions/depletions for key reaches of each tributary are described in this section. The stream gages used in the estimation procedures are also described.

Calaveras River

For the purposes of defining river accretions and depletions, the Calaveras River was identified as having two significant reaches: from New Hogan Dam to Bellota and from Bellota to the San Joaquin River confluence. A description of accretion/depletion estimates for both of these reaches follows.

New Hogan Dam to Bellota

Both accretions (rainfall runoff) and depletions (seepage) were estimated for the Calaveras River reach from New Hogan Dam to Bellota. Monthly rainfall runoff from 1922-1998 was calculated based on available data. The data available to estimate the rainfall runoff were:

- New Hogan release (1961-present)
- Calaveras River at Jenny Lind (1922-1966)
- Cosgrove Creek near Valley Springs, Ca (1930-1969)
- Precipitation (three station average of Galt - B03301, Lodi - B05032, and Oakdale - B06303)

During the time period 1961-1966, there were two coincidental river gage records to calculate accretions. These records can only be used to estimate accretions from New Hogan to Jenny Lind. Based on previous work performed (by MBK Engineers; approximately 1968 and 1980) and verified with the latest available data, rainfall runoff from New Hogan to Jenny Lind can be estimated as 1.4 times

the Cosgrove Creek (near Valley Springs, California) USGS recorded gage flow. Cosgrove Creek flows were extended from 1967 to 1998 using a monthly regression with precipitation, and then multiplying by 1.4 to estimate runoff from New Hogan to Jenny Lind. To estimate the accretions from New Hogan to Bellota, the New Hogan to Jenny Lind accretions were multiplied by a drainage area ratio of 1.5. These accretions are input to CALSIM II as a DSS time series.

Due to insufficient data, depletions (from seepage) were not able to be calculated. CALSIM II assumes a constant 13 cfs depletion for this reach.

Bellota to San Joaquin River Confluence

Accretions and depletions on the Calaveras River below Bellota could not be calculated because of insufficient data. Depletions were assumed to be a constant 6.5 cfs, but no assumption was made for accretions.

Stanislaus River

The Stanislaus River accretions/depletions were estimated for three reaches:

- New Melones Reservoir to Tulloch Reservoir
- Tulloch Reservoir to Goodwin Dam
- Goodwin Dam to Ripon

New Melones Reservoir to Tulloch Reservoir

Accretions for the reach between Melones and Tulloch were estimated to be 20 percent of the unimpaired runoff of the Calaveras River at Jenny Lind. This relationship was developed by DWR planning staff, is based on relative drainage area, and is documented in DWR's September 1995 publication on "Central Valley Future Water Supplies for Use in DWRSIM".

Tulloch Reservoir to Goodwin Dam

Accretions/depletions from Tulloch Reservoir to Goodwin Dam were estimated to be 1.5 percent of the unimpaired runoff of the Calaveras River at Jenny Lind. This relationship was developed by DWR planning staff, is based on relative drainage area, and is documented in DWR's September 1995 publication on "Central Valley Future Water Supplies for Use in DWRSIM".

Goodwin Dam to Ripon

Accretions/depletions for the reach between Goodwin Dam and Ripon were calculated by the following equation.

Accretions/depletions =

	Stanislaus River flow at Ripon
+	*River diversions*
-	*Modesto ID return flows*
-	*Stanislaus River flow below Goodwin*

where,

Stanislaus River flow at Ripon

- Stanislaus River flow at Ripon for 1922-1940 is estimated based on a regression with Goodwin flow, and 1941-1998 is from the USGS record.
- Stanislaus River flow at Ripon for 1922-1940
  = 1.01 * (Stanislaus River flow below Goodwin Dam
  - River Diversions between Goodwin Dam and Ripon
  + Modesto ID return flow upstream from Ripon)
  + 9,684 AF
  (R Squared = 0.99)

Stanislaus River flow below Goodwin Dam

- 1922-1933 Stanislaus River at Knights Ferry
- 1933-1957 Stanislaus River below New Melones plus New Melones Reservoir to Tulloch Reservoir accretions/depletions plus Tulloch Reservoir to Goodwin Dam accretions/depletions minus Oakdale ID and South San Joaquin ID Diversions
- 1957-1999 USGS

Stanislaus River Diversions

- River diversions are from DWR Bulletin 23 and Bulletin 130, SWAM model data, and estimations. Monthly diversion data from DWR bulletins are available for the diversion season from about 1930 through 1958, and year-round from 1959 through 1970. Annual SWAM model data are available from 1970 through 1994. Diversions during the irrigation season from 1922 through 1929 are approximated based on averages from 1932 through 1940 and winter diversions are approximated using average diversions from 1958 through 1970. Annual SWAM data is distributed on a monthly pattern using average monthly diversions from 1958 through 1970. Ten percent of the Stanislaus River diversions are assumed to occur above Ripon and 90 percent between Ripon and the San Joaquin River, based on DWR Bulletin 130 data.

Tuolumne River

Accretions/depletions for the lower Tuolumne River were represented for one reach between LaGrange Dam and Modesto, determined by the following equation:

Accretions /depletions =

Tuolumne River flow at Modesto
\+ *River Diversions*
\- *Turlock ID return flow to Tuolumne River above Modesto*
\- *Modesto ID return flow to Tuolumne River above Modesto*
\- *Tuolumne River below LaGrange*

where,

Tuolumne River flow at Modesto

- Tuolumne River flow at Modesto for 1922-1940 is estimated based on a regression with the Tuolumne City gage, and 1940-1998 is from the USGS record
- Tuolumne River flow at Modesto for 1922-1940
  = 1.03 * (Tuolumne River below LaGrange
  – River Diversions + Turlock ID and Modesto ID return flow between Modesto and Tuolumne City) + 16804 AF

Tuolumne River Diversions

- River diversions are from DWR Bulletin 23 and Bulletin 130, SWAM model data, and estimations. Monthly diversion data from DWR bulletins are available for the diversion season from about 1930 through 1958 and year-round from 1959 through 1970. Annual SWAM model data are available from 1970 through 1994. Diversions during the irrigation season from 1922 through 1929 are approximated based on averages from 1932 through 1940 and winter diversions are approximated using average diversions from 1958 through 1970. Annual SWAM data is distributed on a monthly pattern using average monthly diversions from 1958 through 1970. Based on DWR Bulletin 130, 24 percent of Tuolumne River diversions occur above the Modesto gage, 33 percent occur between Modesto and Tuolumne City, and 43 percent occur below Tuolumne City.

Tuolumne River below LaGrange

- Tuolumne River below LaGrange for 1922-1970 is calculated using Tuolumne River above LaGrange minus Modesto ID and Turlock ID diversions, and 1970-1998 taken from the USGS record.

Merced River

The Merced River accretions/depletions were described for three reaches:

- Exchequer to Crocker-Huffman Dam
- Crocker-Huffman to Cressey
- Cressey to Stevinson

Merced River Accretion from Exchequer to Crocker-Huffman Dam

Accretions/depletions for the Merced River from Exchequer to Crocker-Huffman Dam were determined by the following equation:

Accretions/depletions =

Merced River below Crocker-Huffman Dam
\+ *Merced ID Main Canal Diversion*
\+ *Merced ID North Canal Diversion*
\- *Merced River below Exchequer*

where,

Merced River below Crocker-Huffman Dam

- Merced River below Crocker-Huffman Dam for 1922-1939 is estimated based on a regression with the Merced Falls gage, and 1939-1998 records were provided by Merced ID.
- Merced River above Crocker-Huffman Dam 1922-1939
  = 0.952 * (Merced River below falls + Merced ID Main Canal) + 1666 AF
  (R Square = 0.985)

Flow below Crocker-Huffman Dam is calculated by subtracting Merced ID Main Canal.

Merced ID diversions

- Merced ID Main Canal and North Canal diversions were provided by Merced ID

Merced River below Exchequer

- Merced River below Exchequer for 1922-1964 is estimated based on a regression with Merced Falls gage, 1965-1999 taken from USGS record
- Merced River below Exchequer 1922-1964
  = 0.994 * (Merced River below falls + Merced ID North Canal) + 417 AF
  (R Square = 0.998)

Merced River Accretion from Crocker-Huffman Dam to Cressey

Accretions/depletions between Crocker-Huffman Dam and Cressey were determined by the following equation:

Accretions/depletions =
Merced River at Cressey
\+ *River Diversions*
\- *Merced River below Crocker-Huffman Dam*

where,

Merced River at Cressey

- Merced River at Cressey for 1922-1941 is estimated based on a regression, and 1942-1998 from DWR records
- Merced River at Cressey for 1922-1941
  = 1.13 * (Merced River below falls + Merced ID Main Canal + river diversions) + 1023.7 AF
  (R Square = 0.962)

Merced River Diversions

- River diversions are from DWR Bulletin 23 and Bulletin 130, SWAM model data, and estimations. Monthly diversion data from DWR bulletins are available for the diversion season from about 1930 through 1958 and year round from 1959 through 1970. Annual SWAM model data are available from 1970 through 1994. Diversions during the irrigation season from 1922-1929 are approximated based on averages from 1930-1940, and winter diversion are approximated using average diversions from 1960-1963. Annual SWAM data is distributed on a monthly pattern using average monthly diversions from 1968-1970. This 3 year period was selected based on the construction of New Exchequer. The Merced River diversions are distributed to river reaches based on diversion records for 1966-1970; 78 percent of the total diversion is assumed to occur above Cressey, 17 percent between Cressey and Stevinson, and 5 percent below Stevinson.

Merced River Accretion from Cressey to Stevinson

Accretions/depletions between Cressey and Stevinson were determined by the following equation:

Accretions/depletions =

	Merced River at Stevinson
+	*River diversions*
-	*Merced ID return flows in Livingston Lateral*
-	*Turlock ID Return flows*
-	*Merced River at Cressey*

where,

Merced River at Stevinson

- Merced River at Stevinson for 1922-1940 is estimated based on a regression with the Livingston gage, and 1941-1998 taken from USGS records
- Merced River at Stevinson for 1922-1940
  = 0.962 * (Merced River at Livingston) + 2991 AF
  (R Square = 0.999)

Merced ID flow to Merced River

- Merced ID flow to the Merced River from the Livingston lateral for 1926-1999 is provided by Merced ID, and 1922-1926 is estimated using averages.

San Joaquin River Main Stem

San Joaquin River main stem accretions/depletions encompass the river reach from Vernalis to the confluence of the Merced River. San Joaquin River flow at Vernalis and Newman are the only available long-term (1922-1998) flow records

in this reach. The accretions/depletions for this reach also include the accretions/depletions of the lower Stanislaus River below Ripon and the lower Tuolumne River below Modesto.

The San Joaquin River Basin has experienced numerous physical changes from 1922 through 1998. Both reservoir construction on San Joaquin River tributaries and levee construction in the valley floor have changed the Basin's flow characteristics. Flooding in the valley floor was more severe before the construction of upstream reservoirs, which resulted in difficulties measuring flows throughout the valley. Also, as levees were constructed in the valley, flood flows that typically bypassed stream gages would remain in stream channels more often, allowing more accurate flow measurements. These changes have had a significant effect on the estimate of accretions/depletions along the San Joaquin River.

Annual San Joaquin River accretions/depletions were initially developed using a mass-balance approach. The results are presented in Figure 4-1. An initial mass-balance estimate of accretions/depletions for this river reach indicates the river was losing water during the 1920s. However, this finding does not seem reasonable as the Vernalis stream flow gage was not in place until about 1929, and flows at Vernalis before this date were roughly estimated based on Stanislaus River at Ripon, Tuolumne River at Modesto, and San Joaquin River at Newman (1957 Joint Hydrology Study) records. From approximately 1930 to 1970, there were several reservoirs built and levees that were constructed, and the trend was an increase in annual accretions/depletions. After about 1970, the annual accretions/depletions are highly correlated to San Joaquin River Basin precipitation and wetness.

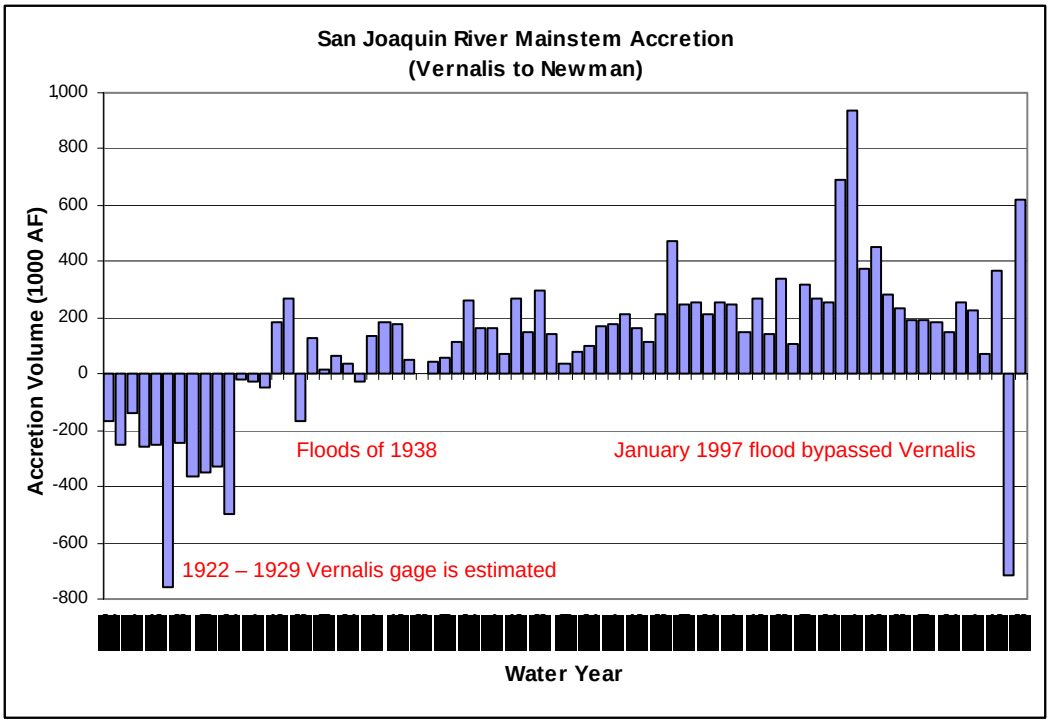


Figure 4-1: Annual San Joaquin River Main Stem Accretion from Vernalis to Newman (Based on Mass-Balance Only)

Since a goal of the hydrology development was to develop recent projected level accretions/depletions, and that the accretions/depletions apparent from a mass-balance of recorded flow seemed for some periods to be unreasonable, a synthetic record of the river's gains and losses for the period prior to 1970 was developed. San Joaquin River main stem accretions/depletions prior to 1970 were estimated based on relationships between: 1) gains/losses that occurred after 1970 and, 2) precipitation and flows entering the main stem of the San Joaquin River. Figure 4-2 illustrates the estimated annual accretions/depletions using regression equations for years prior to 1970 and a strict mass-balance approach for after 1970.

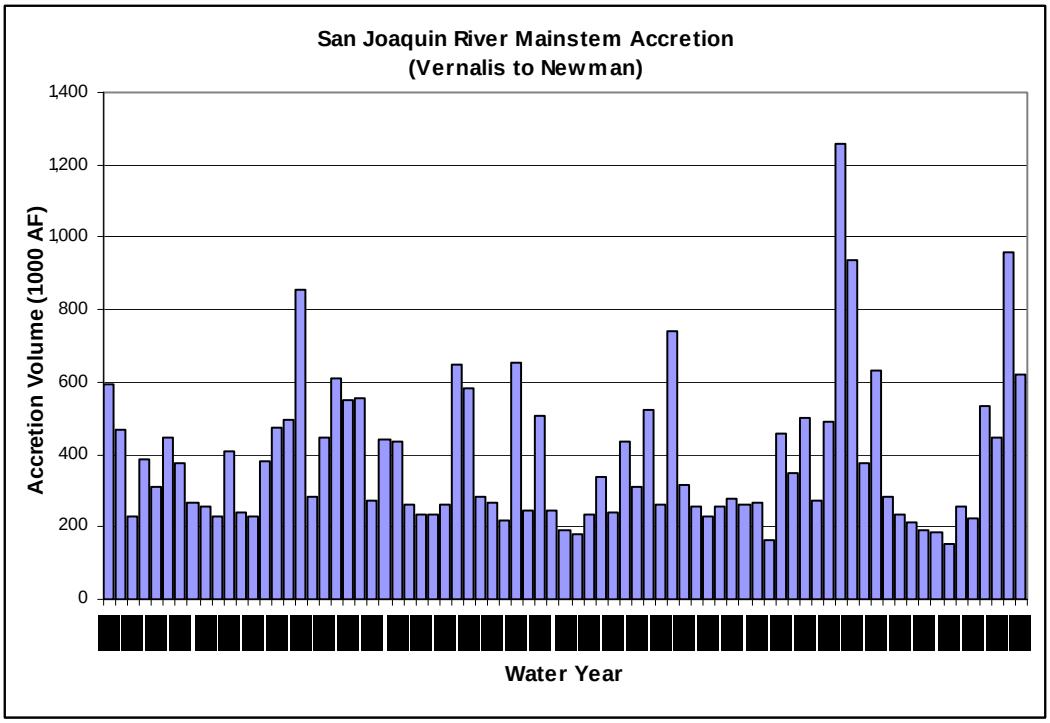


Figure 4-2: Annual San Joaquin River Main Stem Accretion from Vernalis to Newman (Based on Mass-Balance and Regression Analysis)

The San Joaquin River main stem accretions/depletions estimates for the 1970-1998 period were determined by the following equation:

Newman to Vernalis accretions/depletions =

	San Joaquin River at Vernalis
-	*Stanislaus River at Ripon*
-	*Tuolumne River at Modesto*
-	*San Joaquin River at Newman*
-	*Merced River Slough*
+	*San Joaquin River diversions*
+	*Stanislaus River diversions downstream from Ripon*
-	*Return flow from San Joaquin River Diversions*
-	*Turlock ID return flow*
-	*Modesto ID return flow*
-	*Return flow from the west side of the San Joaquin Valley*
+	*Runoff adjustment*

where,

<u>*San Joaquin River at Vernalis*</u>

- San Joaquin River at Vernalis for 1922-1923 and 1925-1929 is from DWR planning data and 1924, 1930-1998 is from USGS records.

<u>*San Joaquin River at Newman*</u>

- San Joaquin River at Newman is from USGS records.

Merced River Slough

- Merced River Slough for 1922-1941 and for 1973-1998 is based on a regression with Merced River at Stevinson, and 1942-1972 is from USGS records.
- Merced River Slough for 1942-1972
  = 0.189 * (Merced River at Stevinson) - 3680 AF
  (R Square = 0.626)

San Joaquin River Diversions

- River diversions are from DWR Bulletin 23 and Bulletin 130, SWAM model data, and estimations. Monthly diversion data from DWR bulletins are available during for the diversion season from about 1930 through 1958, and year-round from 1959 through 1970. Annual SWAM model data are available from 1970 through 1994. Diversions during the irrigation season from 1922-1929 are approximated based on averages from 1932-1940 and winter diversions are approximated using average diversions from 1958-1970. Annual SWAM data is distributed on a monthly pattern using average monthly diversions from 1958-1970.

Return flow from San Joaquin River Diversions

- Return flows from San Joaquin River diversions are assumed to be 30 percent of diversions.

Modesto ID and Turlock ID Return Flows

- These return flows are documented in the discussion of their respective district operations.

Return flow from the west side of the San Joaquin Valley

- Return flows from the west side of the San Joaquin Valley are estimated as 30 percent of contractual deliveries (surrogate of total water supply) to Delta-Mendota Canal contractors.

Table 4-1 contains the coefficients used for estimating San Joaquin River accretions/depletions for 1922 through 1970, and during the months after 1970 when the record appeared to indicate flood flow bypassed stream gages. DSA 49 precipitation for the current month and previous month are two coefficients used. Upstream flow in the Stanislaus River at Ripon, Tuolumne River at Modesto, and San Joaquin River at Newman in the current and previous months are also used. October accretions were not able to be calculated based on these coefficients; therefore, the average of September and November accretions/depletions are used for October.

Table 4-1: Coefficients used for estimating San Joaquin River Basin Accretions/Depletions

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Intercept		7,669	12,575	0	0	0	13,109	13,852	21,036	16,656	18,702	17,814
Previous Month Precipitation		0	0	0	0	0	0	0	0	0	0	0
Current Month Precipitation		0	0	0	0	0	0	0	0	20,780	0	0
Previous Month Upstream Flow		0.127	0	0.166	0.063	0.067	0	0	0.02	0	0	0.078
Current Month Upstream Flow		0	0.068	0	0.025	0.054	0.053	0.075	0	0.11	0.1	0

Water quality calculations and New Melones Reservoir operation procedures within CALSIM II require the determination of flow and water quality in the San Joaquin River upstream of the Stanislaus River confluence. This upstream location is indicative of the Maze Boulevard crossing of the San Joaquin River. The division of the San Joaquin River accretions/depletions above and below this site is estimated as follows:

Vernalis to Maze

- 5 percent of Vernalis to Newman

Maze to Newman

- 95 percent of Vernalis to Newman

San Joaquin River Drainage Area Upstream from Merced River

Above Fremont Ford (representing the drainage upstream of the confluence with the Merced River), the San Joaquin River drainage area covers approximately 8,247 square miles. More than 16 riparian diversions have been identified between Gravelly Ford and Fremont Ford by DWR (Bulletin 130-68). These diversions averaged 728,900 AF per year between 1922 and 1980 (Reclamation et al., 1990). Most of these diversions are at or below Mendota Pool and are currently supplied by water from the Delta-Mendota Canal.

Historically, the San Joaquin River (between Gravelly Ford and Fremont Ford) received inflow from several large tributaries, including the Fresno and Chowchilla Rivers. Currently, most of the flow in the Fresno and Chowchilla Rivers is diverted, reaching only the San Joaquin River during flooding events. The rest of the time, flow in this reach of the San Joaquin River consists primarily of imported Delta water via the Delta-Mendota Canal, which is released from the Mendota Pool for subsequent diversion, agricultural returns, and releases from

wildlife areas. Between Sack Dam and the Salt Slough confluence, an approximate reach length of 54 miles, there is usually slight or no flow. Mud and Salt Sloughs contribute irrigation return flows to the lower end of this reach.

Accretions/depletions for the San Joaquin River drainage area upstream from Merced River include accretions for the Fresno River, Chowchilla River, and the San Joaquin River from Friant to Gravelly Ford, the Mendota Pool area, and minor streams upstream from the Merced River. Accretions/depletions were calculated for these river reaches.

San Joaquin River Upstream Accretions/Depletions

Due to the lack of available records, only a single composite estimate of accretions/depletions for the area upstream of the Merced River was made. This estimate was determined by the following equation:

San Joaquin River drainage area accretions upstream from Merced River =

	San Joaquin River at Newman
+	*Merced River Slough*
+	*Merced River at Stevinson*
-	*Chowchilla River below Buchanan Dam*
-	*Fresno River below Hidden Dam*
-	*San Joaquin River below Friant*
-	*Madera Canal at Head*
-	*James Bypass flow to Mendota Pool*
-	*Delta Mendota Canal flow to Mendota Pool*
+	*San Joaquin River diversions from Friant to Gravelly Ford*
+	*Mendota Pool diversions*
+	*Madera ID diversions*
+	*Chowchilla WD diversions*
-	*Return flows*
+	*Runoff Adjustment*
-	*Seepage estimates for Chowchilla River, Fresno River, San Joaquin River from Friant to Gravelly Ford, San Joaquin River at Gravelly Ford to Mendota Pool, and Mendota Pool*

where,

Chowchilla River below Buchanan Dam

- Chowchilla River below Buchanan Dam for 1922-1923 and 1931-1998 is from USGS records and 1924-1930 is from DWR planning data.

San Joaquin River below Friant

- Flow for the San Joaquin River below Friant is from USGS records.

Madera Canal at Head

- Flow for the Madera Canal at Head is from USGS records.

James Bypass flow to Mendota Pool

- James Bypass flow to Mendota Pool for 1922-1927 is from DWR planning data, 1928-1977 is from DWR records, and 1978-1998 is from USGS records.

Delta Mendota Canal flow to Mendota Pool

- Delta-Mendota Canal flow to Mendota Pool is from USBR reports of operation, and DWR Bulletin 130 when USBR reports were unavailable.

Mendota Pool diversions

- Mendota Pool diversions for 1922-1949 are estimated based on San Joaquin River flow at Friant, San Joaquin River losses and diversion above Mendota Pool, James Bypass flow, and average diversions from 1950-1998. Diversions from 1950-1999 are from DWR Bulletin 23 and Bulletin 130, DWR San Joaquin Division records (1949-1981), and USBR records (1982-1999)

Madera ID diversions

- Madera ID diversions from 1922-1939 are estimated based on a 200 cfs water right and water availability, and 1939-2000 records provided by Madera ID

Chowchilla WD diversions

- Chowchilla WD diversions are estimated based on Madera Canal delivery and flow in the Chowchilla River. Maximum monthly diversions, determined by recent operations, limit the use of springtime flows.

Fresno River Accretions

Flow data prior to 1951 is unavailable for the lower Fresno River; therefore, the Fresno River accretions/depletions estimate was used to estimate seepage only. Precipitation runoff was included in the accretions/depletions calculation for the entire San Joaquin River drainage upstream from the confluence of the Merced River. Fresno River accretions/depletions for 1952-1998 were calculated using the following equation:

Fresno River accretion from Hidden to gage 8 miles west of Madera =

	Fresno River flow 8 Miles west of Madera
+	*Madera ID Main Canal diversion*
-	*Fresno River below Hidden Dam*
-	*Madera Canal release for Madera ID diversion*
-	*Madera Canal flood release to Fresno River*

where,

Fresno River below Hidden Dam

- Hidden Dam release for 1922-1941 is estimated from a regression with Fresno River at Knowles, flow for 1942-1998 is from USGS records.
- Hidden Dam release for 1922-1941
  = 1.51 * Fresno River at Knowles
  (R Squared = 0.96)

Fresno River flow 8 Miles west of Madera

- Fresno River flow 8 Miles west of Madera, Madera ID Main Canal diversion, Hidden Dam release, Madera Canal release for Madera ID diversion, and Madera Canal flood release to Fresno River data were all provided by Madera ID.

Chowchilla River Accretions

An accretions/depletions estimate for the lower Chowchilla River, Ash Slough, and Berenda Slough was not possible because flow data is unavailable. Precipitation runoff was included in the accretion calculation for the entire San Joaquin River drainage upstream from the confluence of the Merced River. Seepage estimates were extracted from a DWR operation study of Chowchilla WD and Buchanan Dam. Seepage was estimated as 4,200 AF per month, or the sum of release from Buchanan Dam and Madera Canal release to the Chowchilla River, whichever was less.

San Joaquin River from Friant Dam to Gravelly Ford

Since the completion of Friant Dam in 1941, the majority of the annual flow of the San Joaquin River at the dam has been diverted to the Friant-Kern and Madera Canals. Average monthly releases from Friant Dam to the San Joaquin River since 1941 have included releases to satisfy water rights and contractual obligations above Gravelly Ford and flood control releases. Approximately 20 small diversions are located between Friant Dam and Gravelly Ford (DWR Bulletin 130).

Flow data for the San Joaquin River at Gravelly Ford is unavailable before 1974; therefore, the accretions/depletions estimate for 1974-1998 was used to estimate seepage for the reach. Precipitation runoff was included in the accretions/depletions calculation for the entire San Joaquin River drainage upstream from the confluence of the Merced River. The accretions/depletions (seepage) for the reach were estimated by the following equation:

San Joaquin River Accretion from Friant to Gravelly Ford 1974-1998 =
San Joaquin River at Gravelly Ford
\+ *River Diversions*
\- *San Joaquin River below Friant Dam*

where,

San Joaquin River below Friant Dam

- From USGS records.

San Joaquin River at Gravelly Ford

- From USBR records.

San Joaquin River Diversions

- River diversions are from DWR Bulletin 23 and Bulletin 130, SWAM model data, and estimations. Monthly diversion data from DWR Bulletins are available about 1949 through 1970. Annual SWAM model data are available from 1970 through 1994. Diversions from 1922-1949 are approximated based on averages from 1950-1970. Annual SWAM data is distributed on a monthly pattern using average monthly diversions from 1950-1970.

San Joaquin River from Gravelly Ford to Mendota Pool

The San Joaquin River reach between Gravelly Ford and Mendota Pool was estimated to lose up to 200 cfs of the available flow at Gravelly Ford. This estimate is consistent with information acquired from pilot projects recently performed on the San Joaquin River.

Salt Slough and Mud Slough

Salt Slough and Mud Slough primarily convey agricultural and wildlife area drainage water to the San Joaquin River. During the winter and spring, flows in the sloughs consist primarily of a combination of subsurface agricultural drainage, precipitation runoff, and surface runoff discharges from agricultural areas and wildlife areas. Summer and fall flows consist primarily of agricultural tail water, irrigation district spill water, and subsurface agricultural drainage. Following the closure of Kesterson Reservoir and the San Luis Drain in 1985, some amount of agricultural subsurface drainage from water users on the west side of the San Joaquin Valley is routed to Mud Slough (north) into the San Joaquin River.

The Salt Slough and Mud Slough systems are modeled in CALSIM II as a combined stream network. As a component of its connection to the San Joaquin River, a base flow is assumed for the streams. Flow from the Grasslands Bypass Project is explicitly modeled in CALSIM II.

5. Rim Basin Flows

San Joaquin watershed "rim basins" consist of watersheds in the Sierra Nevada Mountains and foothills that drain into the San Joaquin Valley floor. Rim basins are represented in CALSIM II as inflows at specific locations. For the San Joaquin River portion of CALSIM II, rim basins typically flow into reservoirs, and are input into CALSIM II as:

- San Joaquin River inflow to Millerton Lake
- Fresno River inflow to Hensley Lake
- Chowchilla River inflow to Eastman Lake
- Merced River inflow to Lake McClure
- Tuolumne River inflow to Don Pedro Reservoir
- Stanislaus River inflow to New Melones Reservoir
- Littlejohns Creek flow into Central San Joaquin WCD
- Calaveras River inflow to New Hogan Reservoir
- Kings River flow to James Bypass

San Joaquin River Inflow to Millerton Lake

Above Friant Dam, the San Joaquin River drains an area of approximately 1,676 square miles and has an average annual unimpaired runoff of 1.7 million AF. The median historical unimpaired annual runoff is 1.4 million AF, with a range of 0.4 to 4.6 million AF. Several reservoirs in the upper portion of the San Joaquin River watershed, including Mammoth Pool and Shaver Lake, are primarily used for hydroelectric power generation and have a combined storage capacity of approximately 620,000 AF. The operation of these reservoirs affects the inflow to Millerton Lake.

Millerton Lake inflow is derived from the modeling output of the "Base Plan" that used the Upper San Joaquin River Basin Model (USAN), which simulates current San Joaquin River operations from headwaters to Millerton Lake. USAN is a daily time step model and its Millerton Lake inflow data have been converted to monthly average values for CALSIM II.

Fresno River Inflow to Hensley Lake

The Fresno River is a tributary to the San Joaquin River that drains a watershed of approximately 237 square miles in foothills of the Sierra Nevada. Because of the relatively low elevation of the watershed, most of the flow in the Fresno River results from rainfall.

Historically, the Fresno River has behaved as an ephemeral stream with large winter flood flows and near zero summertime flows. The Fresno River ultimately discharges into the East Side Bypass. Fresno River inflow to Hensley Lake is estimated as the flow below Hidden Dam, adjusted for change in contents and evaporation in Hensley Lake.

Chowchilla River Inflow to Eastman Lake

The Chowchilla River, a tributary to the San Joaquin River, drains a watershed of approximately 236 square miles in the Sierra Nevada. Because of the relatively low elevation of the watershed, most of the flow in the Chowchilla River results from rainfall.

Historically, the Chowchilla River has behaved as an ephemeral stream with large winter flood flows and near zero summertime flows. The Chowchilla River ultimately discharges into the East Side Bypass. Chowchilla River inflow to Eastman Lake is estimated as the flow below Buchanan Dam, adjusted for change in contents and evaporation in Eastman Lake.

Merced River Inflow to Lake McClure

The Merced River originates in the Sierra Nevada, and drains an area of approximately 1,273 square miles east of the San Joaquin River. Portions of the upper Merced watershed drain national parklands. The average unimpaired runoff in the Basin is approximately 1 million AF per year (AF/year). The median historical unimpaired annual runoff is 0.8 million AF, with a range of 0.2 to 2.8 million AF.

Merced River inflow to Lake McClure is estimated as the flow below Exchequer Dam, adjusted for change in contents and evaporation in Lake McClure.

Tuolumne River Inflow to New Don Pedro Reservoir

The Tuolumne River originates in the Sierra Nevada and drains a watershed of approximately 1,540 square miles. The Tuolumne River is the largest tributary to the San Joaquin River with an annual average unimpaired runoff of approximately 1.95 million AF. The median historical unimpaired annual runoff is 1.8 million AF, with a range of 0.4 to 4.6 million AF.

Flow in the Tuolumne River upstream of New Don Pedro Reservoir is significantly influenced by the operations of the City and County of San Francisco’s Hetch Hetchy Water and Power Project. Inflow to New Don Pedro Reservoir is included in CALSIM II as a time series data set that has been provided by San Francisco. The data is the result of a simulation of long-term

project operations with current facilities. Inflow data for 1922-1996 is simulated by San Francisco's modeling. Data after 1996 is equal to actual computed inflow to New Don Pedro Reservoir.

Stanislaus River Inflow to New Melones Reservoir

The Stanislaus River originates in the Sierra Nevada and drains a watershed of approximately 900 square miles. The average unimpaired runoff in the Basin is approximately 1.2 million AF/year; the median historical unimpaired annual runoff is 1.1 million AF, with a range of 0.2 to 3.0 million AF. Snowmelt contributes the largest portion of the flows in the Stanislaus River, with the highest runoff occurring in the months of May and June. Basin runoff is affected by upstream reservoirs.

Inflow to New Melones Reservoir is a times series representing a combination of planning study inflows and actual recorded inflow for recent years developed by Reclamation.

Littlejohns Creek Inflow to Central San Joaquin Water Conservation District

Littlejohns Creek flows into Central San Joaquin WCD and provides a source of water for district irrigation. A record of full natural flow on Littlejohns Creek was available from the 2001 San Joaquin County Water Management Plan (prepared by Camp Dresser & McKee) and was incorporated into CALSIM II as a monthly time series.

Calaveras River Inflow to New Hogan Reservoir

The Calaveras River originates in the Sierra Nevada, drains an area of approximately 363 square miles, and enters the San Joaquin River near the City of Stockton. The Calaveras River watershed is almost entirely below the effective average snowfall level (5,000 feet), and receives nearly all of its flow from rainfall. As a result, nearly all of the annual flow occurs between November and April. The median historical unimpaired annual runoff is 130,000 AF, with a range of 8,000 to 600,000 AF. Seepage from the north fork of the Stanislaus River also enters the Basin from diversion canals and reservoirs. In the late summer/early fall, a portion of the river in the valley is commonly subject to periods of low or no flow for numerous days or weeks.

Inflow to New Hogan for 1922 through 1963 is estimated as the Calaveras River flow at Jenny Lind, plus estimated accretions from New Hogan to Jenny Lind adjusted for change in contents of Old Hogan Reservoir and evaporation. The U.S. Army Corps of Engineers (COE) data is used from 1963 to 1998.

Kings River to James Bypass

James Bypass flow to Mendota Pool was provided by DWR planning staff. The flow is equal to historical for the period after Pine Flat Dam was constructed. Flows prior to construction of Pine Flat were estimated by DWR planning staff.

6. Regulations and Agreements

Minimum in-stream flow requirements and agreements governing in-stream flows that have an effect on San Joaquin River hydrology and operations are described in this section.

San Joaquin River below Friant Dam

Other than flood control releases, the release from Friant Dam to the San Joaquin River is normally limited to that amount necessary to maintain diversions by riparian and contractor users below Friant Dam to a location near Gravelly Ford. Water diverted to the fish hatchery below Friant Dam and returned to the river partially serves that purpose. Review of historical operation records provides guidance in estimating the minimum downstream release. From an analysis of the historical record (1990-1994) for periods when no flood control releases were made, an annual release of 116,700 AF was estimated to be the current minimum release necessary to meet downstream diversions (including seepage). Table 6-1 illustrates the assumed monthly distribution of this release requirement.

Table 6-1: Estimated Millerton Lake Minimum River Release Requirement (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
10.1	7.4	6.7	4.5	5.0	6.6	9.0	10.9	12.9	14.4	15.7	13.4

Total: 116,700 AF

Fresno River

Flow in the Fresno River must be maintained at a level sufficient to satisfy water right holder diversions downstream from Madera ID. This requirement is zero during dryer years; however, in wetter years the required flow is about 4,000-5,000 AF/year. The actual flow that must be released from Hensley Lake is determined through complicated daily accounting of Fresno River flows and Hensley Lake storage. For the purpose of CALSIM II simulation, the schedule outlined in Table 6-2 is assumed:

Table 6-2: Required flow below Madera ID diversion (1,000 AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Normal	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	4.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Merced River

Due to a water rights agreement known as the Cowell Agreement, the Merced ID must make available below Crocker-Huffman Diversion Dam an amount of water that can then be diverted from the Merced River at a number of private ditches between Crocker-Huffman Diversion Dam and Shaffer Bridge. Two additional riparian diversions not covered under the Cowell Agreement exist off of the Merced Falls pool. The Merced River also has flow requirements as set forth by the Federal Energy Regulatory Commission (FERC) and the Davis-Grunsky contract between the State of California and Merced ID.

In order to satisfy the flow requirements and the Cowell Agreement, the district operates to a target flow below Crocker-Huffman Diversion Dam equal to the Cowell Agreement entitlement plus the FERC/Davis-Grunsky flow requirements. The flow below Crocker-Huffman Diversion Dam must equal the greater of the Davis-Grunsky and FERC flows, plus the Cowell Agreement entitlement. The flow requirement and Cowell Agreement entitlements are listed in Table 6-3, and are implemented in CALSIM II.

Table 6-3: Merced River Minimum Flow Requirements (cfs)

Month	Davis Grunsky Crocker-Huffman Dam to Shaffer Bridge	FERC At Shaffer Bridge		Cowell Agreement Entitlement
		Normal Year [1]	Dry Year [2]	
Oct 1-15	0	25	15	50 [3]
Oct 16-31	0	75	60	50 [3]
Nov	180-220	100	75	50 [3]
Dec	180-220	100	75	50 [3]
Jan	180-220	75	60	50 [3]
Feb	180-220	75	60	50 [3]
Mar	180-220	75	60	100
Apr	0	75	60	175
May	0	75	60	225
Jun	0	25	15	250 [4]
Jul	0	25	15	225 [4]
Aug	0	25	15	175 [4]
Sep	0	25	15	150 [4]

[1] Normal year as defined by FERC license: Forecasted April through July inflow to Lake McClure is equal to or greater than 450,000 AF, as published in DWR May 1 Bulletin 120.
[2] Dry year as defined by FERC license: Forecasted April through July inflow to Lake McClure is less than 450,000 AF, as published in DWR May 1 Bulletin 120.
[3] Entitlement is equal to 50 cfs or the natural flow of the Merced River (inflow to Lake McClure), whichever is less.
[4] If the natural flow of the Merced River falls below 1,200 cfs in the month of June, the entitlement flows are reduced accordingly from that day: 225 cfs flow for next 31 days; 175 cfs flow for next 31 days; 150 cfs for next 30 days; 50 cfs for the remainder of September

Tuolumne River

Minimum flows for the Tuolumne River are required by the FERC license for the New Don Pedro Project. The FERC license identifies ten year type classifications for the Tuolumne River, of which only seven have distinctly different minimum flow schedules.

Table 6-4: Tuolumne River FERC Flow Requirement Classification

Year Type Classification	San Joaquin Basin 60-20-20 Index (1000 AF)
Critical and Below	<1500
Median Critical	1500
Intermediate Critical/Dry	2000
Median Dry	2200
Intermediate Dry/Below Normal	2400
Median Below Normal	2700
Intermediate Below Normal/ Above Normal	3100
Median Above Normal	3100
Intermediate Above Normal/ Wet	3100
Median Wet/ Maximum	3100

For each year type classification, a basic schedule of flows is identified for the break point for the year type. For example, if the San Joaquin Basin Index is 1,550 thousand acre-feet (TAF) the year is classified as Median Critical and its basic schedule is a volume of 103,000 AF. The FERC license requires an interpolation of schedules within year type classifications. Therefore, the annual FERC requirement for this example is a linearly interpolated volume between the Median Critical schedule (103,000 AF) and the Intermediate Critical/Dry schedule (117,016 AF).

For CALSIM II modeling purposes, the amount of water determined from the interpolation (e.g., above 103,000 AF) is assumed to be added to the basic schedule during the out migration pulse flow period. The flow schedules are implemented on an April through following March flow year. CALSIM II inputs the flow requirements through time series data.

Table 6-5: Tuolumne River Minimum Flow Schedules

	Critical and Below	Median Critical	Intermediate Critical/ Dry	Median Dry	Intermediate Dry/ Below Normal	Median Below Normal	Intermediate Below Normal/ Above Normal and Above

	Critical and Below	Median Critical	Intermediate Critical/ Dry	Median Dry	Intermediate Dry/ Below Normal	Median Below Normal	Intermediate Below Normal/ Above Normal and Above
Annual Volume (AF)	94,000	103,000	117,016	127,507	142,502	165,002	300,923
October 1 – 15	100	100	150	150	180	200	300
Attraction Pulse Flow (AF)	None	None	None	None	1,676	1,736	5,950
October 16-May 31	150	150	150	150	180	175	300
Out migration Pulse Flow (AF)	11,091	20,091	32,619	37,060	35,920	60,027	89,882
June 1 – September 30	50	50	50	75	75	75	250

Note: Units are in average monthly cfs unless otherwise noted.

Stanislaus River

1997 New Melones Interim Plan of Operations

The New Melones Interim Plan of Operations (IPO) documents a stakeholder-based allocation of supply to four purposes: fishery, water quality, Bay-Delta flow, and water supply. In this discussion, fishery refers to flow requirements of the 1987 Reclamation, Department of Fish and Game (DFG) Agreement and prescriptive use of Central Valley Project Improvement Act (CVPIA) 3406(b)(2); water quality refers to State Water Resources Control Board (SWRCB) Decision 1641 (D-1641) salinity objectives at Vernalis; Bay-Delta flow refers to D-1641 flow requirements at Vernalis (not including pulse flows during the April 15 - May 16 period, “Vernalis Adaptive Management Plan”); and water supply refers to CVP contractors, Stockton East WD and Central San Joaquin WCD.

Table 6-6 below identifies the allocation of annual water supply to each of the purposes. The allocations are linearly interpolated based on the value of the end-of-February New Melones Storage, plus the March - September forecast of inflow to the reservoir. Water is provided to Oakdale ID and South San Joaquin ID in accordance with their settlement with Reclamation (water year basis). Required releases to the Stanislaus River below Goodwin Dam are accounted in the following order: 1) releases up to the amount of the fishery pattern are debited from the annual fishery allocation; 2) releases up to the amount of the D-1641 Bay-Delta flow requirement, excluding the amount of fishery release, are debited from the annual Bay-Delta flow allocation; and 3) releases up to the amount of the Vernalis water quality requirement, excluding the amount of fishery and Bay-

Delta flow allocations, are debited from the annual Vernalis water quality allocation.

Table 6-6: New Melones Interim Plan of Operation Allocations (1,000 AF)

New Melones Storage Plus Inflow		Fishery		Vernalis Water Quality		Bay-Delta		CVP Contractors	
From	To	From	To	From	To	From	To	From	To
0	1,400	0	98	0	70	0	0	0	0
1,400	2,000	98	125	70	80	0	0	0	0
2,000	2,500	125	345	80	175	0	0	0	59
2,500	3,000	345	467	175	250	75	75	90	90
3,000	6,000	467	467	250	250	75	75	90	90

Additional releases are made to the Stanislaus River below Goodwin Dam if necessary, to meet the Decision 1422 (D-1422) dissolved oxygen content objective. Those releases are defined in CALSIM II by a surrogate flow requirement. Releases from Goodwin Dam to the Stanislaus River (except for flood control) do not exceed 1,500 cfs.

Deliveries to the Oakdale ID and South San Joaquin ID are limited by the following equation:

Oakdale ID/South San Joaquin ID Maximum Diversion

- Annual volume equals 600 TAF unless water year inflow is less than 600 TAF.
- When less than 600 TAF the following formula is applied:

  Entitlement = Inflow + (600 – Inflow) / 3

The districts are assumed to each have entitlement to one-half of the water determined available.

1987 Reclamation, Department of Fish and Game Agreement, and U.S. Fish and Wildlife Service Discretionary Use of CVPIA 3406(b)(2)

Depending on the fishery allocation (0 - 467 TAF/Yr) under the New Melones IPO, the fishery release volume at Goodwin Dam is managed under the base and pulse flow schedules shown in Table 6-7 below. Values are interpolated between the seven discrete schedules. Fishery releases are based on the 1987 Reclamation-DFG agreement and U.S. Fish and Wildlife Service (FWS) discretionary use of the CVPIA 3406(b)(2) account to support release goals established by the Anadromous Fish Restoration Program (AFRP).

Table 6-7: Stanislaus River Minimum and Pulse Flow Schedules

Annual Fishery Allocation (TAF)	0	98.4	243.3	253.8	310.3	410.2	466.8
Minimum Flow Schedules (cfs)							
January	0	125	250	275	300	350	400
February	0	125	250	275	300	350	400
March	0	125	250	275	300	350	400
April	0	250	300	300	900	1500	1500
May	0	250	300	300	900	1500	1500
June	0	0	200	200	250	800	1500
July	0	0	200	200	250	300	300
August	0	0	200	200	250	300	300
September	0	0	200	200	250	300	300
October	0	110	200	250	250	350	350
November	0	200	250	275	300	350	400
December	0	200	250	275	300	350	400
Pulse Flow Schedules (cfs)							
Apr 15 – May 16	0	500	1500	1500	1500	1500	1500

State Water Resources Control Board Decision 1422

CALSIM II has neither the ability to predict or adjust operations for dissolved oxygen within the Stanislaus River. D-1422 requires that water be released from New Melones to maintain the dissolved oxygen concentration in the Stanislaus River at a value of at least 7 mg/l as measured near Ripon. As a surrogate, specific volumes of release are made from Goodwin Dam as required, to meet this criterion. The surrogate volumes are shown in Table 6-8 below.

Table 6-8: Surrogate Dissolved Oxygen Release Volumes (1,000 AF)

Month	Release Volume
June	13.2
July	16.2
August	16.4
September	14.3

State Water Resources Control Board Decision 1641 – Vernalis Water Quality and Flow

The salinity objective near Vernalis was originally defined in SWRCB D-1422. SWRCB D-1641 provisions have revised this requirement. CALSIM II calculates the salinity concentration at Vernalis by evaluating the blended flows and their associated assumed salinity concentrations that reach Vernalis. D-1641 requires salinity near Vernalis to be less than 0.7 electrical conductivity (EC) for April - August and less than 1.0 EC September - March. Releases are made from New Melones, as required, up to the allocation provided by the New Melones IPO, to meet this criterion.

D-1641 also requires the flow at Vernalis to be maintained during the February through June period. The flow requirement is based on the required location of

"X2" and the San Joaquin Basin Index according to Table 6-9. The objectives of the Vernalis Adaptive Management Plan (VAMP - see below) become the flow objective during the period April 15 through May 16. Releases are made from New Melones, as required, but are limited by the Bay-Delta allocation determined by the New Melones IPO.

Table 6-9: Bay-Delta Vernalis Flow Objectives (average monthly cfs)

San Joaquin Basin Index	X2 Required West of Chipps	X2 Required East of Chipps
Wet	3420	2130
Above Normal	3420	2130
Below Normal	2280	1420
Dry	2280	1420
Critical	1140	710

San Joaquin River

The San Joaquin River Agreement (SJRA) provides for the acquisition of water by the Department of the Interior (Interior) from certain San Joaquin River Group Authority (SJRGA) members for use as a pulse flow at Vernalis during April and May, and the acquisition of other water for use during other times of the year. The water is needed to support the VAMP during the pulse flow period and to assist Interior in meeting the Anadromous Fish Restoration Plan, Bay-Delta flow objectives and the FWS Biological Opinion for Delta Smelt. As part of the VAMP, the CVP and State Water Project (SWP) exports during the VAMP test period (April/May) will be managed to specified levels.

Four components of water are provided by certain SJRGA members: Merced ID, Turlock ID, Modesto ID, Oakdale ID, South San Joaquin ID and the San Joaquin River Exchange Contractors Water Authority (Exchange Contractors).

- Up to 110,000 AF/year towards meeting the VAMP flow target. Water provided under this component is divided among the SJRGA members. This water is to only be used during the VAMP 31-day test flow period;
- Additional water from Merced ID (12,500 AF) during October of all years. This flow is provided above the "existing flow" in the Merced River during October.
- Additional water from Oakdale ID (15,000 AF) every year to be available to Reclamation. In addition to this water, any of the (up to) 11,000 AF of Oakdale ID VAMP water not provided towards meeting the VAMP flow target is also available to Reclamation;
- Additional water from willing SJRGA members above the 110,000 AF to achieve full "double-step" flow targets.

The VAMP flow target is determined by a series of procedures and conditions based on the flow at Vernalis which would occur in the absence of the SJRA ("existing flow"), and the San Joaquin Valley Water Year Hydrologic Classification. The SJRA provides a VAMP flow target that will be incrementally larger than the existing flow at Vernalis consistent with Table 6-10.

Table 6-10: VAMP Flow Targets (cfs)

Existing Flow at Vernalis			VAMP Test Flow Target
0	To	1,999	2,000 [1]
2,000	To	3,199	3,200
3,200	To	4,449	4,450
4,450	To	5,699	5,700
5,700	To	7,000	7,000

[1] For the purpose of determining water to be provided by the SJRGA's members only. The VAMP Test Flow Target is 3,200 cfs.

The SJRA assigns a numeric adjunct (60-20-20 Indicator) to the San Joaquin Valley Water Year Hydrologic Classification: a wet year is assigned the numeric value of 5, an above normal year is assigned the numeric value of 4, a below normal year is assigned the numeric value of 3, a dry year is assigned the numeric value of 2, and a critical year is assigned the numeric value of 1. In any year when the sum of the current year's 60-20-20 indicator and previous year's 60-20-20 indicator is seven (7) or greater, the 31-day flow target will be the flow target one level higher than that established by Table 6-10 above (e.g., if the existing flow is 3,500 cfs then the flow target will be 5,700 cfs). This condition is referred to as a "double-step".

The SJRA also provides for relaxation of this obligation during sequential dry-year periods. During years when the sum of the current year's 60-20-20 Indicator and the previous two years' 60-20-20 Indicator is four (4) or less (a sequence of dry and critical years), the SJRGA members will not be required to provide water above the existing flow.

The agreement assumes that the Stanislaus River is operated in accordance with the New Melones IPO (see Section 6, page 75) and that releases under the plan are included in the "existing" flow at Vernalis.

The SJRGA has executed a "Division Agreement" which specifies the amount and order of the individual contributions of water by its members. The division of flow to provide up to 110,000 AF of water for VAMP is shown in Table 6-11 below.

Table 6-11: Division of VAMP Pulse Flow Water (AF)

Entity (in order of providing flow)	First 50,000 AF	Next 23,000 AF	Next 17,000 AF	Next 20,000 AF	Totals
Merced ID	25,000	11,500	8,500	10,000	55,000

Entity (in order of providing flow)	First 50,000 AF	Next 23,000 AF	Next 17,000 AF	Next 20,000 AF	Totals
Oakdale ID/South San Joaquin ID	10,000	4,600	3,400	4,000	22,000
Exchange Contractors	5,000	2,300	1,700	2,000	11,000
Modesto ID/Turlock ID	10,000	4,600	3,400	4,000	22,000

An additional 12.5 TAF of water above “existing” flow in the Merced River is provided by Merced ID in October of all years. Also, an additional 15.0 TAF of water and up to 11.0 TAF of any unused Oakdale ID VAMP water is made available to Reclamation by Oakdale ID. The additional 15.0 TAF of water from Oakdale ID is released in October above any flow that is already occurring under the IPO. Oakdale ID VAMP water not used during the VAMP period is released to the Stanislaus River evenly distributed among November and December. Releases needed for VAMP flow objectives in excess of 110,000 AF are not provided in the modeling.

7. East Side Tributary Operations

This section describes San Joaquin Basin east side tributary operations as implemented in CALSIM II. Included in this section is a description of major reservoirs, their losses, and their flood control parameters. Also included is a description of district and non-district operations for meeting demands; specifically, CALSIM II protocols for determining water supply availability, deliveries, distribution losses, and return flows.

San Joaquin River below Friant Dam

CALSIM II incorporates a dynamic operation of CVP Friant Division water diversions and operations. Canal diversions vary from year to year based on an annually variable water supply. The monthly distribution of an annual diversion is based on the historical delivery practices of the contractors. Minimum required releases below Friant Dam for riparian and contractor users are modeled as a constant annual requirement, consistent with recent records of operations.

Flood control operations for Millerton Lake and the lower San Joaquin River are based on the rain-flood space reservation requirements specified by the COE. The flood control operation during the snowmelt runoff period recognizes the competing objectives of water supply and flood control. The operation attempts to maximize water supply carry-over storage (into summer) while reducing the potential for downstream flooding.

Several fixed parameters and simulated inputs are included in the Benchmark model. These inputs and parameters represent attributes of Friant Division facilities or hydrology that do not vary.

Millerton Lake

Millerton Lake was formed by the completion of Friant Dam on the Upper San Joaquin River in 1942. The dam and reservoir are located 25 miles northeast of Fresno, California. Friant Dam is a concrete gravity structure that stands 319 feet high with a crest length of 3,488 feet, and Millerton Lake has a gross pool capacity of 520,528 AF. The dam and reservoir provide flood control, conservation storage, diversions to the Madera and Friant-Kern Canals, and recreational uses. Friant water is delivered to approximately one million acres of agricultural lands within Fresno, Kern, Madera, and Tulare Counties. (From Reclamation's *dataweb* website.)

Inflow

Information relating to San Joaquin River inflow to Millerton Lake can be seen in Section 5, page 68.

Reservoir Losses

Millerton Lake losses are assumed to only be evaporative in CALSIM II. The monthly evaporation volume is determined by multiplying evaporation rate estimates by the reservoir's water surface area, which is determined using the area-capacity relationship described in Table 7-1. The table was developed from data shown in the *Report on Reservoir Regulation for Flood Control, Friant Dam and Millerton Lake, San Joaquin River, California*, Department of the Army, December 1955, Revised August 1980. Water surface acreage is approximated by linearly interpolating between storage values.

Table 7-1: Millerton Lake Storage-Area Relationship

Storage (TAF)	0	60	100	140	190	250	310	380	450	530
Area (Acres)	0	1,205	1,749	2,200	2,685	3,190	3,637	4,103	4,524	4,963

Monthly evaporation rates were estimated by DWR and input into CALSIM II as a time series. Attachment 1 provides more information on development of the Millerton Lake evaporation rates.

Flood Control Rules

Flood control is an important aspect of Friant Division operations, and is guided by objectives included in the *Report on Reservoir Regulation for Flood Control, Friant Dam and Millerton Lake San Joaquin River, California*, Department of the Army, December 1955, Revised August 1980. According these guidelines, at any given time Millerton Lake storage is identified to be within one of three zones: within the conservation space, when flood releases are not required; within the rain-flood space, when water stored in this space (including credit for available storage space in Mammoth Pool) will be released as rapidly as possible without exceeding 8,000 cfs below Little Dry Creek, or 6,500 cfs at the Mendota gage; or within the conditional space, when releases are required in excess of irrigation demand, and are determined based on forecasted runoff, available upstream space and forecasted irrigation demand.

The required rain-flood space is a fixed end-of-month constraint as identified in Table 7-2. During the heaviest precipitation months of November through January, 170,000 AF of reserved space is maintained. The amount of space required in Millerton Lake (in excess of 85,000 AF) is reduced by the amount of available space in Mammoth Pool. When necessary, CALSIM II logic creates a release to the San Joaquin River that is sufficient to keep storage from encroaching into the required rain-flood space. CALSIM II does not constrain releases in consideration of the downstream flow objectives.

Table 7-2: Millerton Lake Rain-flood Space (1,000 AF)*

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
85	170	170	170	42	0	0	0	0	0	0	0

* Space in excess of 85,000 AF can be replaced by an equal amount in Mammoth Pool

During the conditional space time period (modeled February through June), an algorithm is used to simulate the management of flood volumes over the entire period. The release necessary to operate within the conditional flood control space is determined for each month between February and May. This is done by making a forecast of the quantity of water anticipated to be spilled by the end of June.

The forecast requires an estimate of the available water supply, project deliveries, lake evaporation and minimum river releases through the end of June. The water supply forecast uses perfect foresight to predict the amount of Millerton inflow that will occur through the end of June. The deliveries, evaporation, and minimum river releases through the end of June are estimated. Using the water supply forecast, delivery forecast, current storage, and end of June full reservoir storage target (520,000 AF), the projected volume of spill through the end of June is computed. The projected spill volume is then distributed on a release schedule which is consistent with historical reservoir flood control operation.

Large projected spills are spread out over several months to surrogate the avoidance of large flows late in the season, while the release of small projected spill volumes is deferred until their release is necessary in May or June. The flood control release made for a given month is the greater of the computed rain-flood release or the conditional space release.

The management (shaping) of river releases for operation within the conditional space is determined by user input matrices that establish river releases based on the forecast of spill volumes. A different matrix is used for each month of forecast from February through May. The matrix for a subsequent month only differs from the previous month's matrix by the amount of flow volume that is determined to be passed during the previous month. The algorithm is not operative during June as it is assumed that Millerton Lake has an objective to fill by the end of June, and any required spill in excess of minimum releases will be determined by the balance of operations during the month.

Central Valley Project Friant Division

Friant Division canal diversions are not dependent on land use-based water demands. To model land use-based diversions for the Friant Division would require significant additional analyses that take into account the operation of other water resource supplies within the Tulare Lake Basin. The water diversions developed for CALSIM II mimic recent historical operations.

Water Supply Availability and Delivery Protocols

Delivery Patterns

A review of the historical record of water deliveries from the Friant Division was conducted. The record of those deliveries is contained in a database maintained by Reclamation. The protocol of the database attempts to categorize the different classifications of water deliveries made through the Friant Division. The review found several anomalies within the data, some of which could be explained by changing practices of classification (or institutional changes in classifications) and others that were apparently data entry errors or multiple accountings. Although questionable or possibly misinterpreted data were a problem, the review provided significant insight regarding the relationship between water supply availability and water delivery patterns for the Friant Division.

Most salient to the analysis are the data concerning monthly deliveries from the Friant-Kern Canal and the Madera Canal as water supply availability changes during a year. The data and analysis allowed development of a water delivery function (based on water supply availability at Millerton Lake) that is responsive to both flood control operations and other considerations within the Basin that affect the delivery of water from the Friant Division, such as water availability from tributaries within the Tulare Lake Basin. Analysis also provided a coarse division of water deliveries between Class 1, Class 2, and other water classifications.

There is substantial variability in the monthly distribution of deliveries year-to-year. Analysis shows that definite trends occur between the total availability of water to Friant Division contractors and the pattern in which deliveries are taken. Most significantly affecting the pattern is the availability of Class 2 water. The availability of Class 2 water proportionately concentrates deliveries during the spring-time and also affects the pattern that Class 1 deliveries are made to contractors that have both Class 1 and Class 2 supplies. During years with Class 2 water available, contractors with both Class 1 and Class 2 supplies will tend to shift their delivery of Class 1 supplies to later in the year, thus extending the period of deliveries.

The model's water delivery function distributes a forecasted volume of water supply into monthly deliveries to the Friant-Kern and Madera Canals. Key to this distribution is the relationship between monthly deliveries and water supply availability. The model determines a forecasted volume of water availability. With that determination, the pattern of total water deliveries and the pattern of Class 1 deliveries are established. The product of the pattern and the water supply (limited by contract maximums) results in the monthly delivery of water. Inferred by the difference between the total delivery and the Class 1 delivery is Class 2 delivery.

From the many years of record, certain years of data were selected to develop guidance for establishing a water availability/delivery distribution pattern relationship. Years during which only Class 1 water was available provided an indication of the delivery pattern associated with limited water supplies, those

years when no Class 2 supply was available. The pattern is used to distribute a water supply that equals or is less than 800,000 AF (a full Class 1 supply). A second group of years was selected to represent the delivery patterns of Class 1 and total deliveries during years when the available water supply was near full Class1 and Class 2 allocations without exceeding a full Class 2 allocation (years when "Other" water may influence the delivery of Class 2 deliveries). Intermediate patterns between these two bounds of patterns were established to transition from the availability of only Class 1 supplies to the availability of full Class 1 and Class 2 supplies. The following figures illustrate the range of patterns used to distribute deliveries from the canals.

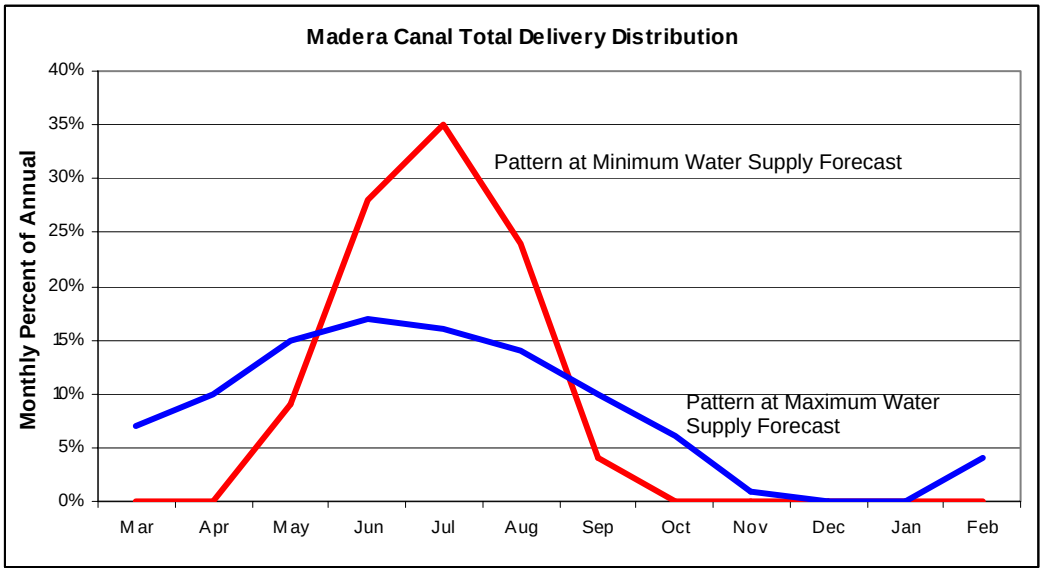


Figure 7-1: Total Madera Canal Delivery Pattern

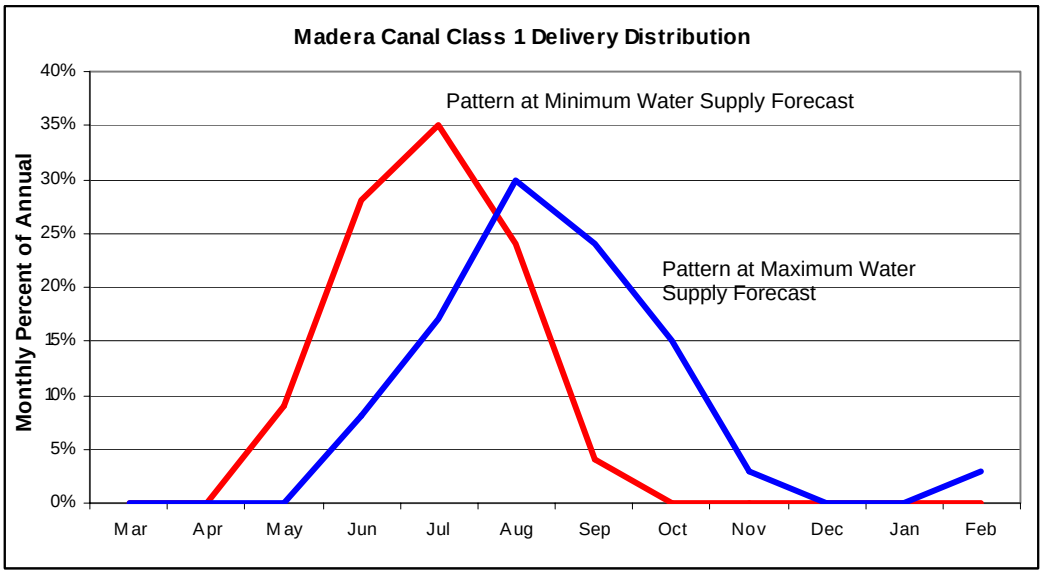


Figure 7-2: Madera Canal Class 1 Delivery Pattern

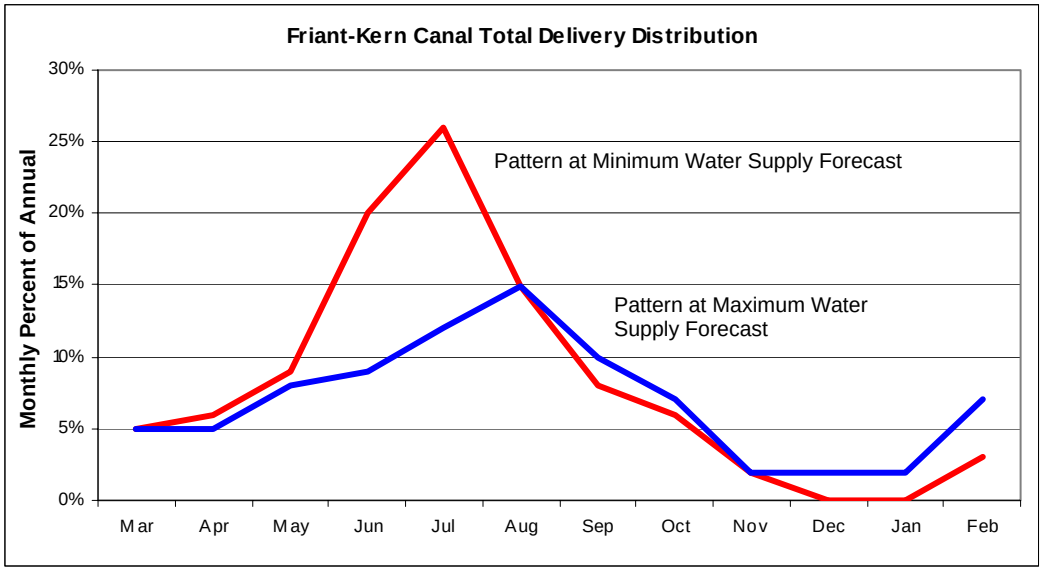


Figure 7-3: Total Friant-Kern Canal Delivery Pattern

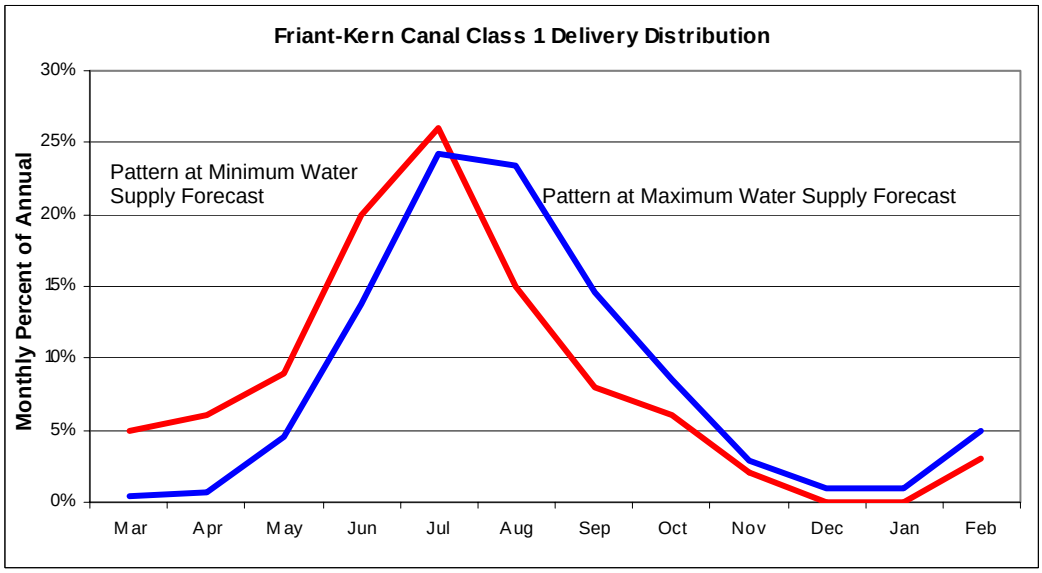


Figure 7-4: Friant-Kern Canal Class 1 Delivery Pattern

Delivery Adjustments

There are two adjustments made to deliveries after initial allocations are made with the delivery logic. One is based on wetness in the Tulare Lake Basin and the other is based on flood control releases from Friant. Deliveries from the Friant-Kern canal are reduced when there is abundant surplus in the Tulare Lake Basin tributaries and Tulare Lake Basin water users are receiving flood flows from their local tributary projects. Conversely, deliveries to both the Friant-Kern and Madera Canals are increased when spills from Friant can be delivered. The model assumes an increased demand for water when Friant is spilling. The demand for surplus is a user defined input to the model. The increased flood flow demand

logic will not occur during months when the Tulare Lake Basin tributary logic reduces deliveries.

Procedural Delivery Logic

Annual water deliveries for the Friant Division are determined in March of each year and updated monthly through June. The allocation is estimated by summing the total water available from storage and inflow and subtracting requirements and losses. The remainder is the water available for delivery. The following equation is used to estimate water delivery at any point during the allocation season.

Water available for delivery =

	Sum of current month through September Millerton inflow
+	*Beginning of month Millerton Storage*
-	*Millerton target (end of September) carryover storage*
-	*Average current month through September evaporation*
-	*Minimum Friant release to SJR for current month through September*
-	*Losses for current month through September*

Water is allocated to Class 1 and Class 2 deliveries based on the annual volume of available water. If the annual volume is less than the full Class 1 contract amount, Class 1 is set to the annual volume of available water. If the annual volume is greater than the Class 1 contract amount, Class 1 is set to full contract amount and the remainder is allocated to Class 2, up to the full Class 2 contract amount.

The monthly delivery patterns are based on the total annual volume of delivery. Lookup tables in the model contain the monthly delivery patterns. Four lookup tables are used to determine monthly patterns for total delivery to the Friant-Kern and Madera Canals and Class 1 delivery to the Friant-Kern and Madera Canals. Monthly Class 2 delivery is the difference between total deliveries and Class 1 deliveries. The deliveries determined using this logic is based solely on water supply availability at Friant without consideration of wetness in the Friant service area and delivery of flood control releases. The adjustments for these factors are made subsequently in the model.

Distribution Losses Protocol

Canal losses were developed through a comparison of historical water deliveries and canal diversions. Using the same selective analytical process of evaluating certain years and months of diversion and delivery data, an estimate of monthly un-accounted for diversions (losses) was developed. When diversions are occurring within the model, losses become an additional diversion requirement of the Madera and Friant-Kern Canals. The estimated losses for the two canals are shown in Table 7-3 and Table 7-4 below.

Table 7-3: Friant-Kern Canal Losses (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
5	4	1	1	2	3	4	5	6	7	7	6

Table 7-4: Madera Canal Losses (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0	0	0	0	0	0	0	2	3	4	3	0

Return Flow Protocol

Friant Division deliveries to the Friant-Kern and Madera Canals do not have any directly associated return flows.

Mendota Pool

Operations at Mendota Pool are discussed in detail in Section 8, page 124.

Fresno River

The only regulating reservoir on the Fresno River is Hensley Lake (formed by Hidden Dam), which was completed and operational in 1975. Hidden Dam is operated by the COE and releases are coordinated with Reclamation operations at Friant Dam. Madera Canal, which conveys water northwest from Friant Dam, crosses the Fresno River approximately three miles downstream from Hidden Dam. Deliveries from Madera Canal to CVP contractors are made via the Fresno River, as are flood spills during flood control operations.

Hensley Lake

Hensley Lake is operated to protect the Fresno River from flood damage and provide water supply for irrigation. The maximum storage is 90,000 AF, and dead storage is 5,000 AF. The operation of Hensley Lake is governed by the diversion requirement of Madera ID, with consideration given to water supplied by the Friant system. Both the pattern and quantity of water supplied from Friant influences the operation of Hensley Lake. Operational rules for Hensley Lake are developed to best use water supply from both water supply sources.

Inflow

For information related to Hensley Lake inflow, refer to Section 5, page 68.

Reservoir Losses

In CALSIM II, Hensley Lake losses are assumed only to be evaporative. Evaporation is estimated by multiplying a predefined (time series) evaporation rate by the reservoir surface area. Attachment 1 provides details on the development of the Hensley Lake evaporation rate time series.

Flood Control Rules

The Fresno River Basin is a rain-fed basin with little or no snowmelt. Although actual storage limits are conditional, CALSIM II assumes that end-of-month

allowable storage is static for each year. Table 7-5 describes the maximum allowable end-of-month storage for flood control used in the model.

Table 7-5: Maximum Allowable Storage at Hensley Lake (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
46	25	27	33	40	50	75	90	90	90	90	69

Madera Irrigation District

Madera ID is situated north of the San Joaquin River and adjacent to the Fresno River. Madera ID relies on Millerton Lake water supplies (via the Madera Canal) and from Hensley Lake and the Fresno River. There are approximately 106,000 acres of irrigated land within Madera ID boundaries. Although Madera ID does not own and operate groundwater wells, there is significant reliance on groundwater pumping from private wells to satisfy irrigation demands within the district.

Water Supply Availability Protocol

The protocol for water management in modeling Madera ID operations in CALSIM II is:

1. Utilize groundwater pumping (amount estimated to be the minimum utilized regardless of the availability of surface supplies)
2. Millerton Lake surface supply
3. Fresno River surface supply
4. Supply remainder of demand with additional groundwater pumping

The Madera Canal delivery is dependant on the water supply available from Millerton Lake. When there is water available from Millerton Lake, Madera ID will use it to the extent possible and reduce use from other sources. CALSIM II determines the supply from Millerton Lake available to Madera ID then adjusts the operation of Hensley Lake to satisfy Madera ID demands.

The amount of water available from Hensley Lake and the Fresno River is estimated using a water supply forecast. The forecast and allocation of available supplies attempts to make surface deliveries on a pattern such that shortages do not exceed the existing ability of pumping groundwater within the district.

An April 1 forecast is made to determine the available supply in Hensley Lake and the Fresno River. In most years there is not enough surface water available to satisfy Madera ID demands; therefore, water supply available in Hensley Lake will be fully utilized in all but wet years. The carryover target for Hensley Lake for Madera ID is 15,000 AF in normal years and 8,000 AF in dry years.

April 1st Forecast

Supply =

April 1st storage in Hensley Lake
\+ *April 1st to September 30th inflow to Hensley Lake*
\- *carryover storage target*
\- *downstream requirements*
\- *Fresno River seepage*
\- *evaporation*

Demand =
Madera ID diversion requirement (not including M&I demands)
\- *minimum private groundwater pumping*

Delivery Protocol

When Madera ID surface water supplies are greater than the demand for surface water, full deliveries are made. When the supply is less than the demand, the available surface supply is delivered, and the residual demand is met through groundwater pumping. CALSIM II also includes a protocol that limits releases from Hidden Dam for Madera ID to the capacity of the Madera ID main canal, which is 200 cfs.

Distribution Losses Protocol

Annual distribution system loss assumptions for Madera ID were determined as part of the district's water budget, outlined in Section 3 (page 26). Distribution losses are assumed to be 30 percent of the surface diversion in dry years and 40 percent in normal years.

Return Flow Protocol

Madera ID return flows are assumed to be constant from year-to-year, varying by year-type and are returned to the Fresno River. However, returns only occur when there is an irrigation demand (i.e., when CUAW is greater than zero). The return flow estimates were determined as part of the district's water budget analysis, also discussed in Section 3. The Madera ID annual volume of return flow and its monthly distribution is shown in Table 3-2.

Non-District Lands East of Madera Irrigation District and Chowchilla Water District

The non-district demand area located directly east of Madera ID and Chowchilla WD extends as far east as the valley floor boundary. The San Joaquin River below Friant Dam and the Chowchilla River establish the southernmost and northernmost boundaries, respectively. Borders for this area are very similar to those of DAU 214; the main difference between this area and DAU 214 is that this area excludes all Madera ID lands whereas DAU 214 includes some Madera ID lands.

Water Supply Availability Protocol

In CALSIM II, non-district lands east of Madera ID and Chowchilla WD rely solely on groundwater pumping to meet agricultural water demands. Because

CALSIM II does not dynamically model groundwater-surface water interaction there is no protocol to reduce groundwater supplies.

Delivery Protocol

There is no surface water delivery to this area. Groundwater pumping is allowed by the model to completely satisfy the diversion requirement for every month in the simulation period.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Because there are no surface water deliveries to this demand area, there is no return flow assumption or protocol. This demand area has no effect on tributary operations.

Non-District Lands West of Madera Irrigation District and Chowchilla Water District

The non-district area west of Chowchilla WD and Madera ID is bounded on the west and south by the San Joaquin River. It includes Gravelly Ford and Clayton Water Districts. Boundaries for this area coincide with DAU 215, but the area does not include Columbia Canal Company.

Water Supply Availability Protocol

The CALSIM II diversion requirement for non-district lands west of Madera ID and Chowchilla WD is met through both surface water and groundwater. This area has three sources of surface water: 1) San Joaquin River delivery to Gravelly Ford WD, 2) Chowchilla Bypass delivery, 3) surface returns from Chowchilla WD. There is no explicit protocol to reduce supplies to water users in the area.

Delivery Protocol

Diversion requirements are first met through Chowchilla WD return flows. These returns are small and do not contribute greatly to meeting agricultural demands. San Joaquin River delivery to Gravelly Ford WD is the second priority in meeting agricultural demands for this area. Table 7-6 describes the San Joaquin River diversions and losses from Friant Dam to Gravelly Ford.

Table 7-6: Friant Dam Release for Down Stream Diversions and Losses (AF)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
All Years	2,640	3,600	4,360	5,160	5,760	6,280	5,360	4,040	2,960	2,680	1,800	2,000	46,640

After Gravelly Ford WD deliveries, Chowchilla Bypass may contribute up to 10 percent of the area's CUAW. Any demand not satisfied by these three surface water sources is met through groundwater pumping.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving non-district lands west of Madera ID and Chowchilla WD are returned to the Chowchilla River.

Chowchilla River

The only regulating reservoir on the Chowchilla River is Eastman Lake (formed by Buchanan Dam), which was completed and operational in 1976. Buchanan Dam is operated by the COE and releases are coordinated with Reclamation operations at Friant Dam. Generally, direct diversions from the Chowchilla River are supplemented by supplies from the Madera Canal. Releases from Buchanan Dam help meet the supplemental water demand and reduce the need for water from the Madera Canal. During flood control operations, Madera Canal spills can be released down Ash and Berenda Sloughs, approximately 10 miles downstream of Buchanan Dam.

Eastman Lake

Eastman Lake is operated to protect the Chowchilla River from flood damage and to provide water supply for irrigation. The maximum storage is 150,000 AF, and dead storage is 10,000 AF.

Inflow

For information related to Eastman Lake inflow, refer to Section 5, page 69.

Reservoir Losses

In CALSIM II, Eastman Lake losses are assumed only to be evaporative. Evaporation is estimated by multiplying a predefined (time series) evaporation rate by the reservoir surface area. Attachment 1 provides details on the development of the Eastman Lake evaporation rate time series.

Flood Control Rules

The Chowchilla River Basin is a rain-fed basin with little or no snowmelt. Although actual storage limits are conditional, CALSIM II assumes that end-of-

month allowable storage is static each year. Table 7-7 describes the maximum allowable end-of-month storage for flood control used in the model.

Table 7-7: Maximum Allowable Storage at Eastman Lake (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
120	105	105	112	117	125	140	150	150	150	150	135

Chowchilla Water District

Chowchilla WD is situated adjacent to the Chowchilla River. The district relies on surface water delivery from Millerton Lake via the Madera Canal and from Eastman Lake and the Chowchilla River. There are approximately 68,000 acres of irrigated land within Chowchilla WD boundaries.

Water Supply Availability Protocol

The protocol for water management in modeling Madera ID operations in CALSIM II is:

1. Utilize groundwater pumping (amount estimated to be the minimum utilized regardless of the availability of surface supplies)
2. Millerton Lake surface water supply
3. Fresno River surface supply
4. Supply remainder of demand with additional groundwater pumping

Madera Canal delivery is dependant on the water supply available from Millerton Lake. When there is water available from Millerton Lake, Chowchilla WD will use it to the extent possible and reduce use from other sources. CALSIM II determines the supply from Millerton Lake available to Chowchilla WD then adjusts the operation of Eastman Lake to satisfy Chowchilla WD demands.

The amount of water available from Eastman Lake and the Chowchilla River is estimated using a water supply forecast. The forecast and allocation of available supplies attempts to make surface deliveries on a pattern such that shortages do not exceed the existing ability of pumping groundwater within the district.

An April 1 forecast is made to determine available supply in Eastman Lake and the Chowchilla River. Carryover target for Chowchilla WD is about 80,000 AF in wetter years, 40,000 AF in normal type years and 10,000 AF in dry years.

April 1st Forecast

Supply =

	April 1st storage in Eastman Lake
+	*April 1st to September 30th inflow to Eastman Lake*
-	*carryover storage target*
-	*downstream requirements*
-	*Chowchilla River seepage*

- *evaporation*

Demand =

Chowchilla WD diversion requirement (not including M&I demands)

- *minimum private groundwater pumping*

Delivery Protocol

When Chowchilla WD surface water supplies are greater than the demand for surface water, full deliveries are made from the available supplies. When the supply is less than the demand, the available supply is delivered, and the residual demand is met through groundwater pumping.

Distribution Losses Protocol

Chowchilla WD distribution losses are assumed to be 35% of the surface water diversion (refer to Section 3, page 29).

Return Flow Protocol

As discussed in Section 3, there are no data available regarding flows leaving Chowchilla WD. For lack of better information, Chowchilla WD return flows are assumed to be equivalent to Madera ID returns in CALSIM II. Chowchilla WD splits the return flows to the Chowchilla Bypass and to non-project service areas. Return flow quantities are based on water year type and month.

Merced River

Agricultural development in the Merced River watershed began in the 1850s, and significant changes have been made to the hydrologic system since that time. The enlarged New Exchequer Dam forming Lake McClure was completed in 1967 and regulates releases to the lower Merced River. New Exchequer Dam is owned and operated by Merced ID for power production, irrigation, and flood control.

Releases from Lake McClure pass through a series of power plants and are re-regulated at McSwain Reservoir, which serves as an afterbay to New Exchequer Dam. Below McSwain Dam, water is diverted to Merced ID's Northside Canal at the Pacific Gas & Electric (PG&E) Merced Falls Dam for delivery to 4,100 acres of land within the district (USGS, 1992). The Crocker-Huffman Dam, Merced ID's main diversion point located downstream of the Merced Falls Dam near the town of Snelling, diverts water into the Main Canal.

Lake McClure

Lake McClure is operated to protect the Merced River from flood damage, generate hydroelectric power, provide water supply for irrigation and downstream uses, and provide in-stream flow for the Merced River. The maximum storage is 1,024,600 AF, dead storage is 3,000 AF, and the minimum pool district water supply storage is 115,000 AF.

Inflow

For information related to Lake McClure inflow, refer to Section 5, page 69.

Reservoir Losses

In CALSIM II, Lake McClure losses are assumed only to be evaporative. Evaporation is estimated by multiplying a predefined (time series) evaporation rate by the reservoir surface area. Attachment 1 provides details on the development of the Lake McClure evaporation rate time series.

Flood Control Rules

The model operates to satisfy minimum flow requirements but ignores the maximum allowable flow objective at Cressey (6,000 cfs). In actual operations, encroachment into the flood control space in Lake McClure has been more acceptable than exceeding flows of 6,000 cfs in the Merced River below Crocker-Huffman. This operation criterion is important in daily operations for flood protection, but has a minimal impact on monthly planning model operations. Flood control constraints included in CALSIM II are detailed below.

Lake McClure/New Exchequer Dam Flood Control Storage Limits

Rain Flood Space

The Lake McClure allowable storage based on rain flood considerations for flood control is described as follows:

- June 16 to August 31 – 1024.6 TAF
- September 1 to October 31 – Linear reduction from 1024.6 TAF to 674.6 TAF
- November 1 to March 15 – 674.6 TAF
- March 16 to June 15 – Linear increase from 674.6 TAF to 1024.6 TAF

Conditional Space (snow melt flood space)

During the months of March through July, depending on the forecasted runoff and demands, the allowable storage may fall anywhere between the above-defined rain flood space and the following maximum conditional space. Although this space may be required in actual operations, it is not incorporated in CALSIM II.

- March 1 to March 31 – Linear reduction from 674.6 TAF to 624.6 TAF
- April 1 to May 15 – 624.6 TAF
- May 16 to July 31 – Linear increase from 624.6 TAF to 1024.6 TAF

Table 7-8 summarizes the flood control storage limits implemented into CALSIM II, in terms of end-of-month storages.

Table 7-8: Maximum End-of-Month Storage for Flood Control (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
674.6	674.6	674.6	674.6	674.6	735.0	845.0	970.0	1024.6	1024.6	1024.6	850.0

Merced Irrigation District

Merced ID provides water to both district growers and sphere-of-influence water users, including El Nido ID, Le Grand-Athlone Water District, and individual growers near district boundaries. In all, more than 110,000 acres of land are irrigated using more than 320,000 AF of water annually. Merced ID operates Lake McClure to satisfy district, Merced NWR, Stevinson Water District (Stevinson WD), and sphere-of-influence water demands, as well as to satisfy Merced River downstream flow requirements.

The operation of Lake McClure is determined by the diversion requirement developed from the water budget. In most years there is enough water from runoff to the Merced River and storage in Lake McClure to satisfy Merced ID demands, supply the Merced NWR, and deliver water to Stevinson WD and areas within the Merced ID sphere-of-influence. During water short years, surface deliveries within Merced ID may be reduced. In those years, no water is available to lands within the sphere-of-influence. The allocation of water supply and the operation of Lake McClure are developed based on water supply forecasts and regulatory requirements.

Water Supply Availability Protocol

In CALSIM II modeling, a water supply forecast in the spring of each year determines if shortages in deliveries will occur. If it is determined that Merced ID will experience a water supply shortage, surface deliveries will be reduced. The forecast and allocation of available supplies attempts to make surface deliveries on a pattern such that shortages do not exceed the existing ability of Merced ID to pump groundwater.

A forecast in the April time step is used to balance available supply and demands to determine if surface deliveries can be satisfied.

April 1st Forecast

Supply =

	April 1st storage in Lake McClure
+	*April 1st to September 30th inflow to Lake McClure*
-	*required Merced River in-stream flow*
-	*releases for downstream water users*
+	*stream accretion from Exchequer to Crocker-Huffman Dam*
-	*carryover storage*

Demand =

	Merced ID diversion requirement (not including M&I demands)
+	*Merced NWR demand*
-	*district groundwater pumping*
-	*minimum private groundwater pumping*
+	*delivery to Stevinson WD*

+ *delivery to areas in Merced ID sphere-of-influence*

Delivery Protocol

If the surface water supply is greater than the demand for surface water, full surface water deliveries are made. If the supply is less than the demand, a reduction in delivery will occur. The first reduction in delivery will be made to areas outside the Merced ID boundary. If cutting deliveries to these areas is not sufficient, deliveries within the district will be reduced until the delivery is commensurate with supply, and the residual demand will be made up through groundwater pumping.

When storage in Lake McClure falls below 115,000 AF, releases can only be used for in-stream flows and deliveries to the Merced NWR. Merced ID is not allowed to release from storage under these circumstances. During periods of low storage CALSIM II determines how much water Merced ID can divert each month while storage remains above 115,000 AF.

Distribution Losses Protocol

Merced ID canal distribution loss is 150 TAF per year distributed April through October on a Merced ID irrigation demand pattern (see also Section 3, page 30).

Return Flow Protocol

In addition to deliveries made outside the Merced ID boundary, Merced ID is required to release water to Stevinson WD. Operational spills leaving the Merced ID west boundary are used to satisfy this requirement. In some cases operational spills are sufficient to satisfy the requirement, although many times additional releases must be made. Table 7-9 contains the flow entitlement for Stevinson WD for a normal water year:

Table 7-9: Stevinson WD Entitlements – Normal Year

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Total
Daily CFS	0	0	0	54.44	81.66	81.66	81.66	81.66	54.44	0	0	0	
Monthly AF	0	0	0	3,239	5,021	4,859	5,021	5,021	3,239	0	0	0	26,401.5

Note: To reach the annual entitlement amount the average daily CFS for April through September should not be less than 72.74 CFS.

When surface water deliveries to Merced ID are reduced due to lack of Merced River supply, flows to Stevinson WD can be reduced based on inflow to Lake McClure. In that event, the percent reduction in flow to Stevinson WD is consistent with the percent reduction in surface water supplied to Merced ID.

Return flows by Merced ID are also made back to the Merced River above Cressey. The quantity of return flow is determined by water year type and month, and only occurs when there is an irrigation demand (see Table 3-4).

Other Related Information

Minimum flows on the Merced River are stipulated by FERC at Shaffer Bridge and are based on projected inflow to Lake McClure Reservoir. Normal and above normal water year types are defined as inflow at or above 450 TAF. Dry water year types are inflows below 450 TAF. A time series of target minimum flows based on these two water year type levels and month is incorporated in CALSIM II.

Merced National Wildlife Refuge

The Merced NWR is the oldest refuge in the San Luis National Wildlife Refuge Complex. The refuge totals more than 8,200 acres and is the "primary wintering area for the largest flock of lesser sandhill cranes and Ross' geese in the Pacific Flyway." Additionally, the Merced NWR is a critical use area for a large variety of waterfowl and shorebirds. (From U.S. Fish and Wildlife Service – Pacific Region website)

Water Supply Availability Protocol

Merced NWR is supplied 15 TAF annually from Merced ID. There is no protocol to reduce the refuge water supply based on hydrologic or Lake McClure storage conditions. Lake McClure releases for Merced NWR are allowed even when the reservoir content falls below the 115,000 AF minimum operating target.

Delivery Protocol

Merced ID deliveries to the Merced NWR are limited by a 45 cfs conveyance capacity. Surface water deliveries are made to the refuge until either the refuge demand is met or until deliveries reach the 45 cfs conveyance limit.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

The Merced NWR operation in CALSIM II does not include a protocol for return flow back to the stream network.

Non-District Lands East of Merced Irrigation District

The non-district demand area located east of Merced ID extends as far east as the valley floor boundary. The area is bounded to the north by the Merced River and by the Chowchilla River to the south. These boundaries are very similar to DAU 211 boundaries, but areas within DAU 211 that fall within Merced ID are not included.

Water Supply Availability Protocol

As depicted in CALSIM II, non-district lands east of Merced ID rely solely on groundwater pumping to meet agricultural water demands. Because CALSIM II

does not dynamically model groundwater-surface water interaction, groundwater supplies are only restricted by demand.

Delivery Protocol

There is no surface water delivery to this area. Groundwater pumping is set up in the model to completely satisfy the diversion requirement for every month in the simulation period.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Because there are no surface water deliveries to this demand area, there is no return flow assumption or protocol. This demand area has no effect on tributary operations.

Non-District Lands West of Merced Irrigation District

The non-district[10] demand area located west of Merced ID generally lies between the Merced and Chowchilla Rivers and extends to the San Joaquin River. It includes Plainsburg and El Nido Irrigation Districts, as well as La Grande-Athlone, Turner Island, and Stevinson Water Districts. Boundaries for this area are similar to DAU 212, but do not include areas that fall within Merced ID. Non-district areas within DAU 210 are included in this area.

This area uses a combination of groundwater and limited surface water to satisfy crop irrigation requirements. Merced ID has an agreement to supply water to Stevinson Water District; this water is supplied through Merced ID laterals as operational spills. Merced ID also supplies water to its sphere-of-influence water users including El Nido Irrigation District (El Nido ID) through its El Nido canal, La Grande-Athlone Water District, and individual growers.

Water Supply Availability Protocol

Merced ID releases water to non-district lands west of it borders. Two separate surface water allocations are made for this area. Allocations for Stevinson WD are made first, according to the logic outlined previously in this section (page 96). Allocations for El Nido ID are then made based on the Lake McClure April forecast. El Nido ID is allocated Lake McClure water if the available supply is above Merced ID and Stevinson WD surface water demands, up to a maximum of 40 TAF. If the available surface supply based on the Lake McClure April forecast is not sufficient to meet Merced ID and Stevinson WD demands, the El Nido ID allocation is 0 TAF.

[10] The term “non-district” as used here may be construed a misnomer. There are actually districted lands within the boundaries of this demand area. However, these districts are relatively small and have a small, if any, affect on upstream reservoir operations.

Delivery Protocol

Surface water deliveries from Merced ID to Stevinson WD and El Nido ID contribute to meeting the demand area's aggregate diversion requirement. Allocations for both Stevinson WD and El Nido ID are distributed April through September. The distribution of Stevinson WD surface water is shown in Table 7-9 above; the El Nido allocation is distributed April through September on a CUAW pattern.

When surface water supply from Merced ID is not sufficient to meet the area's diversion requirement, groundwater pumping satisfies the remaining demand.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving non-district lands west of Merced ID are returned to the San Joaquin River below Salt Slough.

Non-District Riparian Lands Adjacent to the Merced River

The non-district riparian demand area adjacent to the Merced River relies on Merced River diversions to satisfy irrigation requirements. This area is bounded by Merced ID on the south and Turlock ID on the north.

Water Supply Availability Protocol

There is no protocol in CALSIM II to determine or reduce the availability of Merced River water for non-district riparian diverters adjacent to the Merced River.

Delivery Protocol

CALSIM II places a higher priority on riparian water diversions than Merced ID diversions. Riparian deliveries are made until demands are satisfied; there are no other operational criteria to constrain this area's river diversions.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving non-district riparian lands adjacent to the Merced River are returned to the Merced River at Cressey.

Tuolumne River

Flows in the lower portion of the Tuolumne River are controlled primarily by the operation of New Don Pedro Dam, which was constructed in 1971 jointly by Turlock ID and Modesto ID with participation by the City and County of San Francisco. The districts divert water to the Modesto Main Canal and the Turlock Main Canal a short distance downstream from New Don Pedro Dam at La Grange Dam.

New Don Pedro Reservoir

New Don Pedro Reservoir is located due east of Modesto, California on the Tuolumne River. The reservoir is 26 miles long and stores 2,030,000 AF of water at full capacity. Reservoir purposes include agricultural irrigation, hydroelectric power generation, fish and wildlife enhancement, recreation, and flood control.

Inflow

For information related to New Don Pedro Reservoir inflow, refer to Section 5, page 69.

Reservoir Losses

In CALSIM II, New Don Pedro Reservoir losses are assumed only to be evaporative. Evaporation is estimated by multiplying a predefined (time series) evaporation rate by the reservoir surface area. Attachment 1 provides details on the development of the New Don Pedro Reservoir evaporation rate time series.

Flood Control Rules

New Don Pedro Reservoir flood control constraints (reserved storage) are included in CALSIM II as a time series. The time series reflects end-of-month rain-flood reservation space and conditional reservation space during the snowmelt season per COE requirements.

Turlock Irrigation District

Turlock ID is situated adjacent and south of the Tuolumne River. Approximately 150,000 acres are irrigated within the district by a combination of diversions from the Tuolumne River at La Grange Dam and district and non-district groundwater pumping. Turlock ID owns New Don Pedro Reservoir jointly with the Modesto ID. Turlock ID is the operator of the facility.

Turlock ID is depicted within CALSIM II modeling as a demand center with a diversion at La Grange Dam. Diversions at La Grange Dam are demand-driven with Turlock ID water supply allocations normally sufficient to meet all needs. However, during droughts Turlock ID may reduce water allocations which will result in reduced water diversions. Concerns for carryover storage in New Don Pedro Reservoir can lead to reductions in water allocations.

The protocols developed for Turlock ID diversions at La Grange Dam incorporate considerations for the consumptive demand for water (land-use based demands), the historical application of water in excess of consumptive demand (including deep percolation), district operational practices, other district and non-district sources of supply, system operational spills and losses, and water supply allocations. The protocols to determine demand are described in Section 3 (page 32). The linkage between these parameters is shown in Figure 7-5 below.

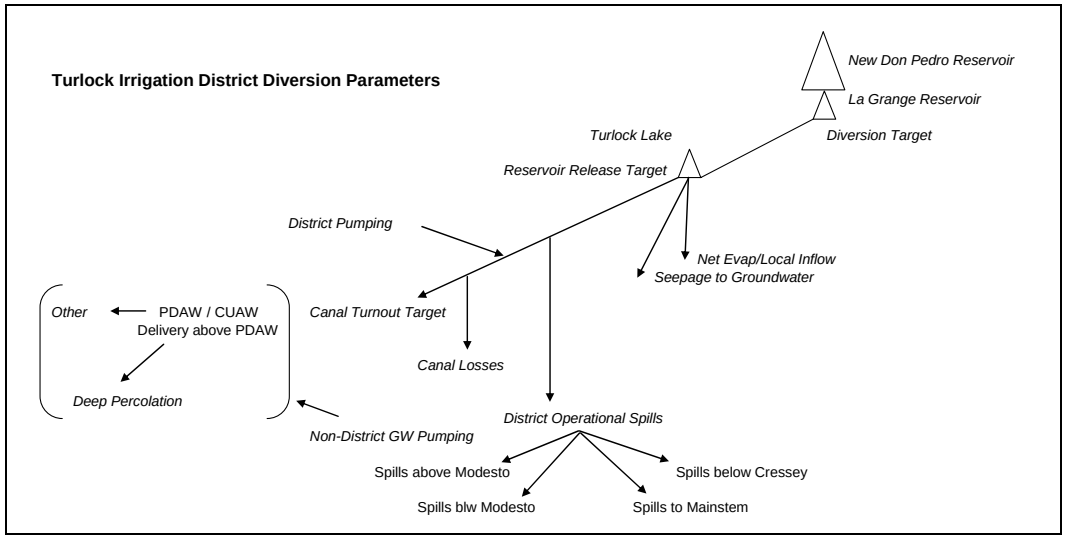


Figure 7-5: Turlock ID Diversion Parameters

Water Supply Availability Protocol

The New Don Pedro Reservoir water supply index (WSI) is computed as the sum of projected (using perfect foresight) April through July inflows and the New Don Pedro Reservoir end-of-March storage. The WSI factor for canal demands is described in Table 7-10.

Table 7-10: New Don Pedro Water Supply Index Factors

End-of-March Storage Plus April through July Inflow (TAF)	Demand Allocation Factor Applied to Canal Deliveries (Percent)
< 1400	50
1400 – 1600	50 – 85
1600 – 2000	85
> 2000	100

Delivery Protocol

Across drought sequences there may be a need to reduce the diversion below the canal demand in order to manage (maintain) storage in New Don Pedro Reservoir. Although Turlock ID's decision process for annual water supply allocations is dynamic and based on many circumstances, for modeling purposes delivery reductions occur based on the WSI factors in Table 7-10. At various levels of WSI, different levels of reduction to the canal demand will occur. The shortage between the original canal demand and the reduced diversion is met by additional Turlock ID groundwater pumping (up to a specified maximum amount), and then by additional non-district groundwater pumping (unconstrained) if any shortage still remains.

Distribution Losses Protocol

Canal distribution losses to Turlock ID are assumed to be the first 800 AF of surface water deliveries per month (see also Section 3, page 32).

Return Flow Protocol

The quantity of Turlock ID return flow is location specific, determined by water year type and month, and only occurs when there is an irrigation demand. Turlock ID returns water to three locations downstream of the district:

- Tuolumne River at Modesto (11% of Turlock ID returns)
- San Joaquin River above Maze (81% of Turlock ID returns)
- Merced River at Stevinson (8% of Turlock ID returns)

Turlock ID return flows were determined as part of the water budget detailed in Section 3 (described as "operation canal spills"). Monthly return flow volumes are shown in Table 3-6.

Non-District Lands East of Turlock Irrigation District

The non-district demand area located east of Turlock ID extends as far east as the valley floor boundary. The area is bounded to the north by the Tuolumne River and to the south by the Merced River. The boundaries are very similar to DAU 209 boundaries, but areas within DAU 209 that fall within Turlock ID or Merced ID are not included. A large portion of the irrigated lands in this area are within the borders of Eastside Water District, which relies on groundwater as its only water source.

Water Supply Availability Protocol

As represented in CALSIM II, non-district lands east of Turlock ID rely solely on groundwater pumping to meet agricultural water demands. Because CALSIM II does not dynamically model groundwater-surface water interaction, groundwater supplies are only restricted by demand.

Delivery Protocol

There is no surface water delivery to this area. Groundwater pumping is set up in the model to completely satisfy the diversion requirement for every month in the simulation period.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Because there are no surface water deliveries to this demand area, there is no return flow assumption or protocol. This demand area has no effect on tributary operations.

Modesto Irrigation District

Modesto ID is situated adjacent and north of the Tuolumne River. Over 60,000 acres are irrigated within the district by a combination of diversions from the Tuolumne River at La Grange Dam and district and non-district groundwater pumping. Modesto ID also treats and delivers water to the City of Modesto for municipal purposes. The district owns New Don Pedro Reservoir (2,030,000 AF) jointly with the Turlock ID.

Modesto ID is depicted within CALSIM II modeling as a demand center with a diversion at La Grange Dam Diversions at La Grange Dam are demand-driven with Modesto ID water supply allocations normally sufficient to meet all needs. However, during droughts Modesto ID may reduce water allocations which will result in reduced water diversions. Concerns for carry-over storage in New Don Pedro Reservoir can lead to reductions in water allocations.

The protocol developed for Modesto ID diversions at La Grange Dam incorporate considerations for the consumptive demand for water (land-use based), the historical application of water in excess of consumptive demand (including deep percolation), district operational practices, other district and non-district sources of supply, system operational spills and losses, and water supply allocations. The protocols to determine demand are described in Section 3 (page 34). The linkage between these parameters is shown in Figure 7-6 below.

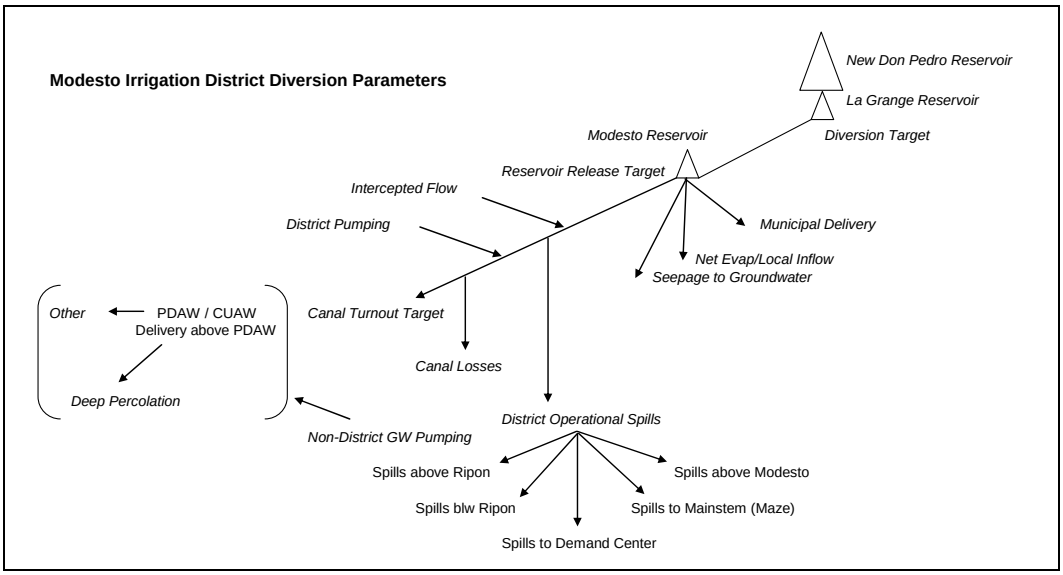


Figure 7-6: Modesto ID Diversion Parameters

The protocols develop a canal demand at La Grange Dam. If water supply conditions in New Don Pedro Reservoir are sufficient, the demand will be satisfied. However, if conditions warrant, the diversion may be reduced to a lower value. The protocol to reduce diversions to Modesto ID based on New Don Pedro Reservoir conditions is identical to the protocol described for Turlock ID.

Water Supply Availability Protocol

The New Don Pedro Reservoir WSI is computed as the sum of projected (using perfect foresight) April through July inflows and the New Don Pedro Reservoir end-of-March storage. The WSI factor for canal demands is described in Table 7-11.

Table 7-11: New Don Pedro Water Supply Index Factors

End-of-March Storage Plus April through July Inflow (TAF)	Demand Allocation Factor Applied to Canal Deliveries (Percent)
< 1400	50
1400 – 1600	50 – 85
1600 – 2000	85
> 2000	100

Delivery Protocol

Actual annual water supply allocation is dynamic and based on many circumstances. For modeling purposes, delivery reductions are based on the WSI defined in Table 7-11 above. The percent reduction, based on the supply index, is identified in the same table. Any shortages between the full canal demand and diversions will be met by additional Modesto ID groundwater pumping (up to a specified maximum amount based on the month), and then by additional non-district groundwater pumping (unconstrained) if any shortage still remains.

Distribution Losses Protocol

Canal distribution losses to Modesto ID are assumed to be the first 100 AF of surface water deliveries per month (see also Section 3, page 34).

Return Flow Protocol

The quantity of Modesto ID return flow is location specific, determined by water year type and month, and only occurs when there is an irrigation demand. Modesto ID returns water to five locations downstream of the district:

- Stanislaus River above Ripon (13% of Modesto ID returns)
- San Joaquin River before the confluence of the Stanislaus River (30% of Modesto ID returns)
- Non-project areas on the east bank of the San Joaquin River from the Tuolumne River to the Stanislaus River (24% of Modesto ID returns)
- San Joaquin River above Maze (20% of Modesto ID returns)
- Tuolumne River (13% of Modesto ID returns)

Modesto ID return flows were determined as part of the water budget detailed in Section 3 (described as "operation canal spills"). Monthly return flow volumes are shown in Table 3-11.

Non-District Riparian Lands Adjacent to the Tuolumne River

The non-district riparian demand area adjacent to the Tuolumne River relies on Tuolumne River diversions to satisfy irrigation requirements. This area is bounded by Turlock ID on the south and Modesto ID on the north.

Water Supply Availability Protocol

There is no protocol in CALSIM II to determine or reduce the availability of Tuolumne River water for non-district riparian diverters adjacent to the Tuolumne River.

Delivery Protocol

CALSIM II places a higher priority on riparian water diversions than diversions to both Turlock ID and Modesto ID. Riparian deliveries are made until demand is satisfied; there are no other operational criteria to constrain this area's river diversions.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving non-district riparian lands adjacent to the Tuolumne River are returned to the San Joaquin River between Newman and Maze Boulevard.

Stanislaus River

Agricultural water supply development in the Stanislaus River watershed began in the 1850s. Currently, the flow in the lower Stanislaus River is primarily controlled by New Melones Reservoir. Other water storage facilities in the Stanislaus River watershed include the Tri-Dam Project, a hydroelectric generation project that consists of Donnells and Beardsley Dams located upstream of New Melones Reservoir on the middle fork Stanislaus River, and Tulloch Dam and power plant approximately six miles downstream of New Melones Dam on the main stem Stanislaus River. Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. Under contractual agreements between Reclamation and Oakdale ID and South San Joaquin ID, Tulloch Reservoir provides afterbay storage to re-regulate power releases from New Melones power plant.

The main water diversion point on the Stanislaus is Goodwin Dam, located approximately 1.9 miles downstream of Tulloch Dam. Goodwin Dam, which was constructed by Oakdale ID and South San Joaquin ID in 1912, creates a re-regulating reservoir for releases from Tulloch power plant and provides for diversions to canals north and south of the Stanislaus River for delivery to Oakdale ID and South San Joaquin ID. Water impounded behind Goodwin Dam may be pumped into the Goodwin Tunnel for deliveries to Central San Joaquin WCD and the Stockton East WD.

New Melones Reservoir

New Melones reservoir was completed by the COE in 1978 and was approved for filling in 1983 with a storage capacity of about 2.4 million AF. The reservoir is located approximately 60 miles upstream from the confluence of the Stanislaus and San Joaquin Rivers and is operated by Reclamation as part of the CVP. It is operated primarily for purposes of water supply, flood control, power generation, fishery enhancement, water quality improvement, and recreation.

Inflow

For information related to New Melones Reservoir inflow, refer to Section 5, page 70.

Reservoir Losses

In CALSIM II, New Melones Reservoir losses are assumed only to be evaporative. Evaporation is estimated by multiplying a predefined (time series)

evaporation rate by the reservoir surface area. Attachment 1 provides details on the development of the New Melones Reservoir evaporation rate time series.

Flood Control Rules

New Melones storage is limited to the COE flood control envelope for rain-floods in accordance with Table 7-12.

Table 7-12: End-of-Month Storage for Flood Control (1,000 AF)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1,970	1,970	1,970	1,970	1,970	2,030	2,220	2,420	2,420	2,420	2,420	2,270

Results from preliminary CALSIM II modeling indicated that unless otherwise modified, New Melones storage would on occasion be above the September flood control envelope and thus CALSIM II would produce a “spill” during the fall. Normal operations would include foresight of this event and would likely distribute such a release earlier in the year. Iterative analysis to smooth this release during the summer demonstrated that target storages of 2,300 TAF in July, 2,130 TAF in August, and 2,000 TAF in September would prevent unreasonable fall-time spills. These storage levels are incorporated into CALSIM II as “level 4” storage.

Reclamation and the New Melones Interim Plan of Operations

CALSIM II operations of New Melones Reservoir are in accordance with the IPO. The model allocates deliveries to water rights settlement holders, to CVP contractors, and to fish and water quality objectives based upon a forecast using storage and anticipated runoff. The several operational requirements incorporated into the IPO are described in Section 6, page 75.

Oakdale Irrigation District (South of Stanislaus River)

The Oakdale ID encompasses approximately 72,000 acres and is situated on both sides of the Stanislaus River. Approximately 60 percent of the irrigated acreage in Oakdale ID is located on the south side of the river. The district has long-established water rights from the Stanislaus River and currently diverts, along with the South San Joaquin ID, from Goodwin Dam under an operational agreement with Reclamation. Oakdale ID also supplies water from groundwater and drainage pumping, and from pumping Stanislaus River water.

Oakdale ID and South San Joaquin ID both divert from Goodwin Dam through the Joint Main Canal to lands north of the Stanislaus River. Oakdale ID’s diversion to its southerly area is through its South Main Canal, which is conveyed directly into its canal and distribution system.

The Oakdale ID-South area is depicted within CALSIM II as a demand center with a diversion at Goodwin Dam. This diversion combined the South San Joaquin ID/Oakdale ID-North diversion at Goodwin Dam to the north, comprises the districts’ diversion that is accommodated through the operational agreement

(Agreement) with Reclamation. Oakdale ID's southerly service area is upslope of Modesto ID. At times, the operational spills of Oakdale ID and user tailwater are incorporated into Modesto ID's water supply. Also, Oakdale ID can cause operational spills into the Stanislaus River, and can spill to other down-slope areas such as the Dry Creek catchment (Tuolumne River).

Diversions at Goodwin Dam are demand-driven with the Agreement water supply normally sufficient to meet all needs. However, during droughts the Agreement water supply may become reduced, thereby necessitating reduced water allocations to the districts' users. Figure 7-7 below depicts the elements considered in the Oakdale ID-South operation.

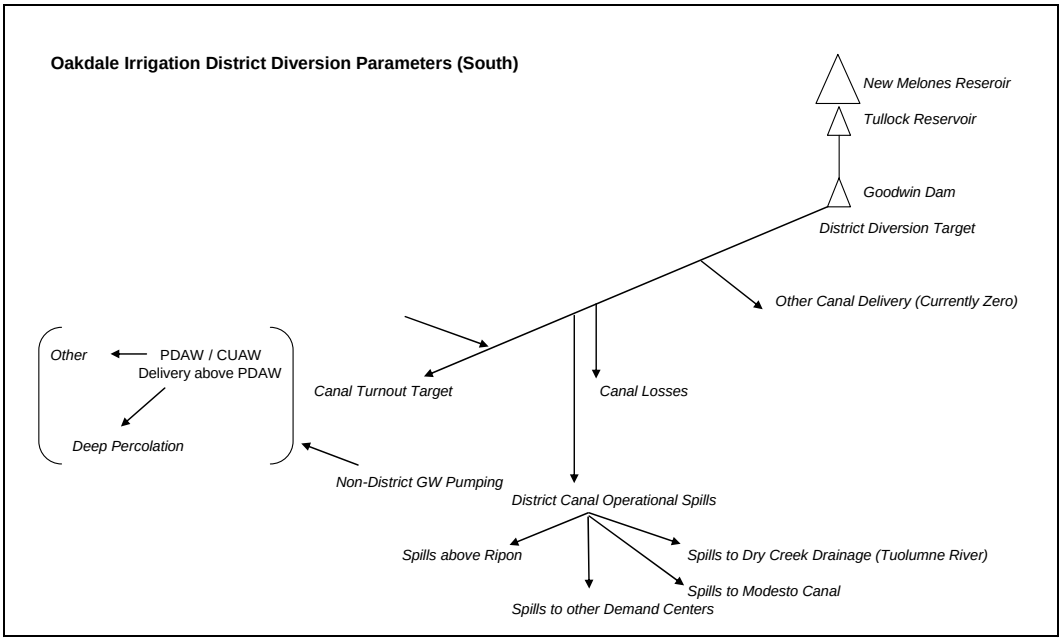


Figure 7-7: Oakdale ID (South) Diversion Parameters

Water Supply Availability Protocol

The Oakdale ID and South San Joaquin ID water allocation, per Agreement, depends on the quantity of water available from New Melones Reservoir. New Melones water supply in CALSIM II is defined as the sum of October through September inflow to New Melones Reservoir, which is forecasted in the model using perfect foresight.

Available New Melones (Agreement) water supply =
Sum of October through September New Melones Reservoir inflows

Delivery Protocol

The protocols developed for Oakdale ID-South diversions at Goodwin Dam incorporate considerations for the consumptive demand for water (land-use based), the historical application of water in excess of consumptive demand (including deep percolation), district operational practices, other district and non-

district sources of supply, system operational spills and losses, and the Agreement water supply.

The CALSIM II protocols develop a "diversion target" at Goodwin Dam. If the Agreement water supply is sufficient, the diversion target will be made. However, across drought sequences there may be a need to reduce the diversion below the diversion target in order to adhere to the Agreement water supply. The Agreement provides that the districts will be able to jointly divert up to 600,000 AF/year of New Melones inflow, except when inflow is less than 600,000 AF. During these times the districts are entitled to divert all New Melones inflow plus an amount equal to one-third the difference between 600,000 AF and the New Melones inflow.

For modeling purposes, any time there is a limit to the total diversions of the districts (combining both the Joint Main Canal and South Main Canal diversion targets), allocations will be divided among OID and SSJID equally. Diversion of the OID allocation will be distributed to the Joint Main Canal and South Main Canal based OID demand north and south of the Stanislaus River. When limited by water Agreement supply, the shortage will first be met by additional district groundwater pumping (up to a specified maximum amount), and then by additional non-district groundwater pumping (unconstrained) if any shortage still remains.

Distribution Losses Protocol

Canal losses in the Oakdale ID-South district are 2,000 AF per month of surface water conveyance (see also Section 3, page 36).

Return Flow Protocol

Set spills/return flows (which are imbedded in the diversion target) from Oakdale ID-South, serve down slope agricultural areas. The quantity of return flow is location specific, determined by water year type, and only occurs when there is an irrigation demand. Spills from Oakdale ID-South flow into the following areas:

- Tuolumne River (35% of Oakdale ID-South returns in all years)
- Modesto Irrigation District (30% of Oakdale ID-South returns in non-critical years, 20% in critical years)
- Stanislaus River (10% of Oakdale ID-South returns in non-critical years, 5% in critical years)
- Stanislaus River non-project (25% of Oakdale ID-South returns in non-critical years, 40% in critical years)

Oakdale ID-South return flows were determined as part of the water budget detailed in Section 3 (described as "operation canal spills"). Monthly return flow volumes are shown in Table 3-16.

Other Related Information

In addition to district-area water demands, Oakdale ID demands incorporate commitments to the SJRA and water sales to Stockton East WD. Oakdale ID's commitments to the SJRA include up to 11,000 AF per year towards VAMP, 15,000 AF of water towards fall (October) river releases, and any portion of the VAMP water not used during the VAMP pulse flow period also for fall releases (equally distributed for November and December). Oakdale ID's sale to Stockton East WD mirrors the sale by South San Joaquin ID.

Water is also delivered from Oakdale ID to Modesto ID under certain VAMP conditions when the Oakdale ID/South San Joaquin ID portion of VAMP releases cannot be made to the Stanislaus River. During these circumstances, water is delivered from Oakdale ID to Modesto ID via the South Main Canal into Modesto ID's canal system.

South San Joaquin Irrigation District and Oakdale Irrigation District (North of Stanislaus River)

The South San Joaquin ID encompasses approximately 72,000 acres and is situated adjacent and north of the Stanislaus River. The Oakdale ID also consists of approximately 72,000 acres and is situated on both sides of the Stanislaus River; the portion of Oakdale ID to the north of the river is upslope of the South San Joaquin ID. The districts (separately and jointly) have long-established water rights from the Stanislaus River and currently divert from Goodwin Dam under an operational agreement with Reclamation. They also supply water from groundwater and drainage pumping.

South San Joaquin ID and Oakdale ID both divert from Goodwin Dam through the Joint Main Canal to lands north of the Stanislaus River. The Joint Main Canal bifurcates several miles downstream, with South San Joaquin ID's water conveyed through its Main Canal into Woodward Reservoir and then subsequently released to its canal and distribution system. Oakdale ID's water is conveyed directly into its canal and distribution system. For purposes of CALSIM II modeling and this documentation, Oakdale ID's service area north of the Stanislaus River and South San Joaquin ID's service area have been combined into a single operation.

The South San Joaquin ID/Oakdale ID-North area is depicted within CALSIM II as a single demand center with a diversion at Goodwin Dam. This diversion, in combination with Oakdale ID's diversion at Goodwin Dam to its southerly service area, comprises the districts' diversion that is accommodated through the operational agreement (Agreement) with Reclamation. Oakdale ID's northerly service area is upslope of South San Joaquin ID. At times the operational spills of Oakdale ID and user tailwater are incorporated into South San Joaquin ID's water supply. Each of the districts can cause operational spills into the Stanislaus River, and each can spill to down-slope areas. South San Joaquin ID has use of Woodward Reservoir to regulate its storage supplies.

Diversions at Goodwin Dam are demand-driven with the Agreement water supply normally sufficient to meet all needs. However, during droughts the Agreement water supply may become reduced, thereby making necessary reduced water allocations to the districts' users. A depiction of the elements considered in the South San Joaquin ID/Oakdale ID-North operation protocols is shown in Figure 7-8 below.

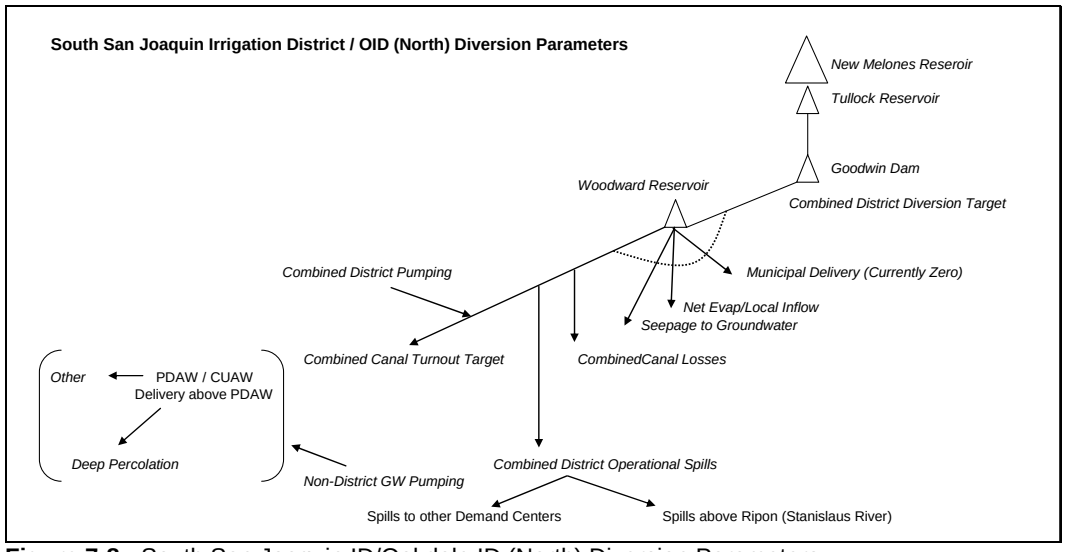


Figure 7-8: South San Joaquin ID/Oakdale ID (North) Diversion Parameters

Water Supply Availability Protocol

The Oakdale ID and South San Joaquin ID water allocation, per Agreement, depends on the quantity of water available from New Melones Reservoir. New Melones water supply in CALSIM II is defined as the sum of October through September inflow to New Melones Reservoir, which is forecasted in the model using perfect foresight.

Available New Melones (Agreement) water supply =
Sum of October through September New Melones Reservoir inflows

Delivery Protocol

The protocols developed for South San Joaquin ID/Oakdale ID-North diversions at Goodwin Dam incorporate considerations for the consumptive demand for water (land-use based), the historical application of water in excess of consumptive demand (including deep percolation), district operational practices, other district and non-district sources of supply, system operational spills and losses, and the Agreement water supply.

The protocols develop a "diversion target" at Goodwin Dam. If the Agreement water supply is sufficient, the diversion target will be made. However, across drought sequences there may be a need to reduce the diversion below the diversion target in order to adhere to the Agreement water supply. The

Agreement provides that the districts will be able to jointly divert up to 600,000 AF/year of New Melones inflow, except when inflow is less than 600,000 AF. During these times, the districts are entitled to divert all New Melones inflow plus an amount equal to one-third the difference between 600,000 AF and the New Melones inflow.

For modeling purposes, any time there is a limit to the total diversions of the districts (combining both the Joint Main Canal and South Main Canal Diversion targets), allocations will be divided among OID and SSJID equally. When limited by water Agreement supply, the shortage will first be met by additional district groundwater pumping (up to a specified maximum amount), and then by additional non-district groundwater pumping (unconstrained) if any shortage still remains.

Distribution Losses Protocol

Combined Oakdale ID-North and South San Joaquin ID canal losses are 2,000 AF per month of surface water conveyance (see also Section 3, page 37).

Return Flow Protocol

Set spills/return flows from Oakdale ID-North and South San Joaquin ID serve downstream agricultural areas. The quantity of return flow is location specific, determined by water year type, and only occurs when there is an irrigation demand from the two districts. Spills from Oakdale ID-North and South San Joaquin ID flow into the Stanislaus River (70% of total returns) and to non-district areas west of South San Joaquin ID (30% of total returns).

Oakdale ID-North and South San Joaquin ID return flows were determined as part of the water budget detailed in Section 3 (described as “operation canal spills”). Monthly return flow volumes are shown in Table 3-21.

Other Related Information

In addition to district-area water demands, South San Joaquin ID demands incorporate deliveries to the South County Project (scheduled to begin operation during 2005), commitments to the SJRA and water sales to Stockton East WD. The South County Project is modeled as a 25,000 AF delivery, equally distributed during the year. South San Joaquin ID’s commitment to the SJRA is determined dynamically each year, up to 11,000 AF. The sale to Stockton East WD is modeled as one-half of a 30,000 AF transfer by South San Joaquin ID and Oakdale ID, annually dependent upon water year inflow to New Melones (see Table 7-13).

Table 7-13: South San Joaquin ID/Oakdale ID Transfer to Stockton East WD (1,000 AF)

New Melones Inflow	Total Transfer Volume
0	8
450	12.5
500	30

Non-District Riparian Lands Adjacent to the Stanislaus River

The non-district riparian demand area adjacent to the Stanislaus River relies on Stanislaus River diversions to satisfy irrigation requirements. This area is bounded by Modesto ID on the south and South San Joaquin ID on the north.

Water Supply Availability Protocol

There is no protocol in CALSIM II to determine or reduce the availability of Stanislaus River water for non-district riparian diverters adjacent to the Stanislaus River.

Delivery Protocol

Riparian deliveries may be made until demand is satisfied; there are no other operational criteria to constrain this area's river diversions.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving non-district riparian lands adjacent to the Stanislaus River are returned to the Stanislaus River near its confluence to the San Joaquin River.

Non-District Lands East of Modesto Irrigation District and Oakdale Irrigation District

The non-district demand area located east of Modesto ID and Oakdale ID extends as far east as the valley floor boundary. The boundaries are very similar to DAU 207 boundaries, but areas within DAU 207 that fall within Modesto ID and Oakdale ID are not included.

Water Supply Availability Protocol

As represented in CALSIM II, non-district lands east of Modesto ID and Oakdale ID rely solely on groundwater pumping to meet agricultural water demands. Because CALSIM II does not dynamically model groundwater-surface water interaction, groundwater supplies are only restricted by demand.

Delivery Protocol

There is no surface water delivery to this area. Groundwater pumping is set up in the model to completely satisfy the diversion requirement for every month in the simulation period.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Because there are no surface water deliveries to this demand area, there is no return flow assumption or protocol. This demand area has no effect on tributary operations.

Calaveras River

The Calaveras River component of CALSIM II depicts the Calaveras River and New Hogan Reservoir as affected by Stockton East WD's operation of the reservoir. The depiction of the system is shown below and includes considerations for the operations of Stockton East WD, Calaveras County Water District (Calaveras County WD) and the Calaveras River.

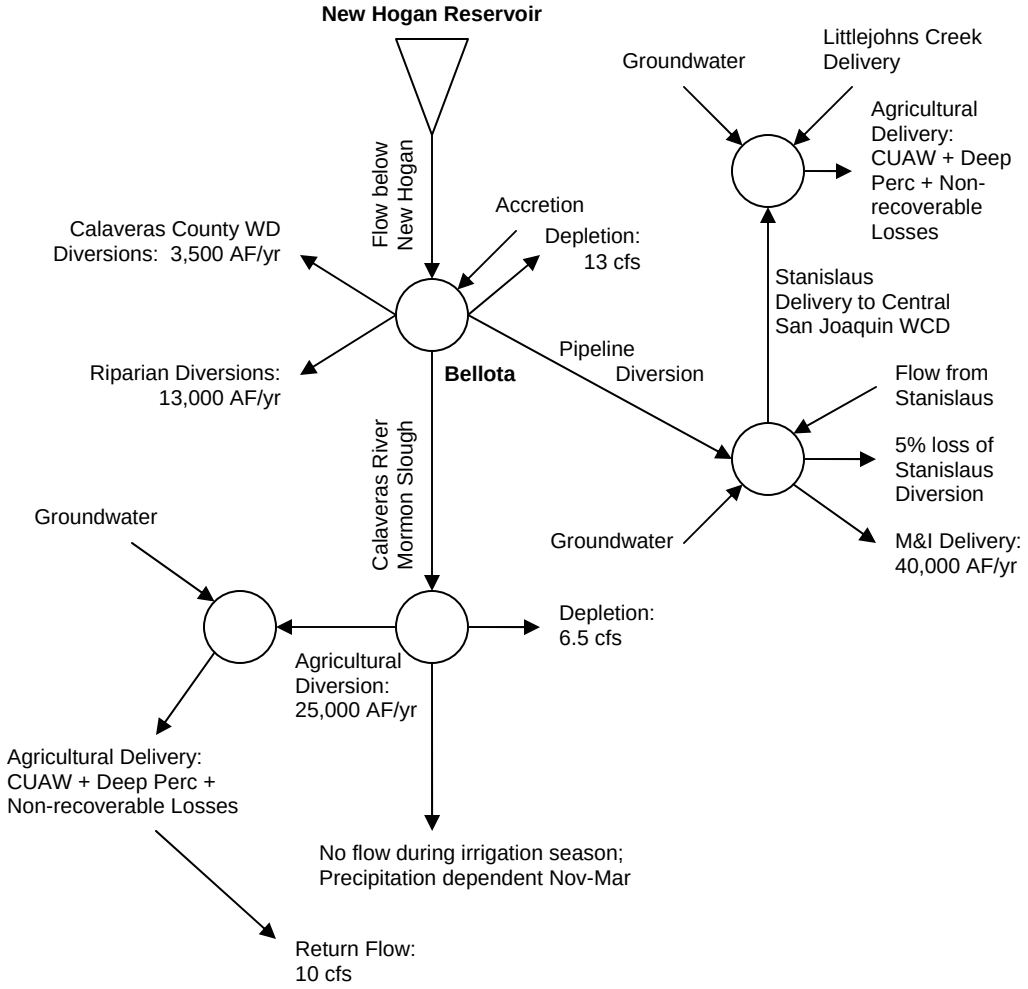


Figure 7-9: Schematic of Calaveras River System in CALSIM II

The system is depicted by several nodes that represent general geographical locations of water management or measurement. Accretions between New Hogan Reservoir and Bellota are added to river flow at Bellota along with a channel loss. At Bellota, riparian diversions and diversions to Calaveras County WD are also modeled along with the diversion to the Stockton East WD municipal water treatment plant. Groundwater, imports from the Stanislaus River, and New Hogan supplies are used to satisfy urban water demands.

New Hogan Reservoir

New Hogan Reservoir was formed by the completion of New Hogan Dam in 1964, which is owned by the COE. The reservoir is situated about 30 miles east of Stockton in the Sierra Nevada Mountains. Project purposes include flood protection to the city of Stockton and water supply for irrigation, drinking and hydroelectric power. New Hogan Reservoir has a storage capacity of roughly 317,000 AF.

Inflow

For information related to New Hogan Reservoir inflow, refer to Section 5, page 70.

Reservoir Losses

In CALSIM II, New Hogan Reservoir losses are assumed only to be evaporative. Evaporation is estimated by multiplying a predefined (time series) evaporation rate by the reservoir surface area. Attachment 1 provides details on the development of the New Hogan Reservoir evaporation rate time series.

Flood Control Rules

The COE flood control diagram for New Hogan Reservoir incorporates basin precipitation in its calculation of maximum allowable reservoir storage. To account for the variability in flood control space reservation due to basin hydrologic conditions, flood control parameters are implemented in CALSIM II as a monthly time series. Maximum allowable end-of-month storage is predefined for each month in the study period.

Stockton East Water District

Water Supply Availability Protocol

Operational rules for the Calaveras system were developed to allocate the water supply from New Hogan Reservoir. During the April time step of each year, CALSIM II estimates the water supply available for diversion using the following equation:

April 1st Forecast

Available Stockton East WD agricultural and urban water supply =

	End of March New Hogan Reservoir Storage
+	*April through September New Hogan Reservoir inflow*
-	*Carryover storage target (varies based on hydrology)*
-	*Evaporation estimate*
-	*River loss*
-	*Riparian diversions (always satisfied)*
-	*Calaveras County WD diversions (always satisfied)*

If the available water supply is not sufficient to meet the urban demand (40,000 AF) and the allowable agricultural diversion (25,000 AF), deliveries are reduced until commensurate with available supply.

Delivery Protocol

CALSIM II simulates four different deliveries within the Calaveras River Basin. These deliveries are made to:

- Calaveras County WD
- Non-district riparian water users
- Stockton East WD agricultural water users
- Stockton East WD urban water users

The protocols CALSIM II uses to make these deliveries are described below.

Calaveras County WD Delivery

Calaveras County WD diverts 3.5 TAF annually directly from the Calaveras River. This delivery does not contribute to meeting Stockton East WD's diversion requirements and is modeled such that there are no explicitly define losses or return flows associated with the delivery.

The Calaveras County WD diversion is split between M&I and agricultural uses (60% M&I, 40% agriculture). The monthly distributions of these two diversions are shown in Table 7-14 and Table 7-15 below.

Table 7-14: Calaveras County WD M&I Delivery Pattern (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
5.47	9.55	13.38	15.84	15.9	12.61	8.32	4.19	3.55	3.56	3.22	4.41

Table 7-15: Calaveras County WD Agricultural Delivery Pattern (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2.60	0.08	0.00	0.00	0.04	1.56	9.80	18.44	19.16	21.36	17.36	9.59

Non-District Riparian Delivery

Non-district riparian water users within the Calaveras Basin divert 13 TAF annually from the Calaveras River. This delivery does not contribute to meeting Stockton East WD's diversion requirements and is modeled such that there are no explicitly defined losses or return flows associated with the delivery. The entire riparian diversion is agricultural and is distributed on the pattern shown in Table 7-15 above.

Stockton East WD M&I and Agricultural Deliveries

Stockton East WD diverts Calaveras River water for both agricultural and urban uses. Deliveries to Stockton East WD are prioritized in CALSIM II in the following order:

- First priority for Stockton East WD is up to 20,000 AF over 18 months (13,350 AF over 12 months) to urban delivery

- Each additional acre-foot available is split between Stockton East WD agricultural and urban delivery until full urban delivery is met. If diversions from the Stanislaus River are available to meet urban deliveries, additional water may be available to satisfy agricultural deliveries.

As implemented, the maximum New Hogan Reservoir agricultural allocation is 25 TAF/year. The annual land use based demands (i.e., CUAW plus losses) are much greater than the allowable Calaveras River diversion and therefore groundwater pumping is relied on to meet the agricultural delivery requirement.

As with the agricultural allocation, the New Hogan M&I allocation is not sufficient to meet the annual demand (40 TAF). Stockton East WD is depicted in CALSIM II as using several water sources to satisfy the M&I water requirements. The district first uses New Melones CVP contract water and/or Stanislaus River transfer water from South San Joaquin ID and Oakdale ID to meet its M&I requirements. As modeled, Stockton East WD receives up to 10 TAF/year of New Melones supply when the end-of-February New Melones storage plus March through September forecasted reservoir inflow is greater than 2.5 million AF (MAF; the 10 TAF is linearly reduced to zero when the storage plus inflow forecast is less than 2.5 MAF but greater than 2.0 MAF). Remaining demands after Stanislaus Basin imports are met first through the New Hogan supplies (described previously) and then through groundwater pumping.

Distribution Losses Protocol

All Stanislaus River imports to the Calaveras River Basin have an assumed distribution system loss of 5 percent, based on guidance provided by water users within the basin. This 5 percent loss is applied to Oakdale ID/South San Joaquin ID sales to Stockton East WD and CVP contract water from New Melones Reservoir.

Return Flow Protocol

Return flows from agricultural lands within Stockton East WD are assumed to be 10 cfs during irrigation months. These spills flow to the San Joaquin River at the Stanislaus confluence. The district's M&I return flows are set to be 30 percent of the total M&I delivery and are delivered to the Calaveras River.

Other Related Information

In actual operations, Stockton East WD attempts to reach desired storage levels on December 1 each year. However, CALSIM II uses September carryover storage targets for New Hogan Reservoir. Due to the variation in fall precipitation, the use of December storage targets results in unrealistic simulation results. The end-of-September targets are established to achieve desired storage levels for December 1.

Central San Joaquin Water Conservation District

Water Supply Availability Protocol

Central San Joaquin WCD is supplied surface water from New Melones Reservoir. In CALSIM II, the annual New Melones delivery to the district is determined each March based on end-of-February storage in New Melones reservoir plus March through September forecasted inflow. A portion of this

delivery flows to the Stockton East WD M&I system, while the remainder is delivered to Central San Joaquin WCD. The model assumes that Stockton East WD deliveries from New Melones are limited to 10 TAF/year and that all water delivered to Stockton East WD from New Melones is used for M&I purposes. Central San Joaquin WCD deliveries will vary up to the allocation provided under the New Melones IPO (up to 80 TAF/year) depending on New Melones storage plus inflow.

An investigation of surface water flow data for Central San Joaquin WCD identified Littlejohns Creek as the only major naturally-occurring source of surface water within the district. Littlejohns Creek flows provide another source of surface water for the district's demands.

Delivery Protocol

Diversions from Littlejohns Creek are only limited by the stream's flow and the district's demand. Littlejohns Creek flows are sometimes sufficient to meet the diversion requirement within a given month; however, because high stream flows typically occur in non-irrigating months, Littlejohns Creek is not a reliable source of water for the district.

Stanislaus River diversions for Central San Joaquin WCD occur at Goodwin Dam. The district diverts up to its annual allocation as determined by the New Melones storage plus inflow forecast on the demand pattern shown in Table 7-16.

Table 7-16: Central San Joaquin WCD Monthly Delivery Pattern (percent)

Year Type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
All Years	0.0	0.0	0.0	0.0	0.0	0.0	15.0	15.0	15.0	20.0	20.0	15.0

When Littlejohns Creek flows and New Melones supplies are not sufficient to meet the diversion requirement, groundwater pumping makes up the deficiency.

Distribution Losses Protocol

All Stanislaus River imports to the Calaveras River Basin have an assumed distribution system loss of 5 percent. This assumption is consistent with guidance provided by water users within the basin.

Return Flow Protocol

As modeled, the district's delivery is completely depleted from the system and therefore does not return water to the stream network.

Lower San Joaquin River

Non-District Riparian Lands on the East Bank of the San Joaquin River from the Merced River to the Tuolumne River

The non-district riparian demand area adjacent to the San Joaquin River extending north from the confluence of the Merced River to the confluence of the Tuolumne

River relies on San Joaquin River diversions to satisfy irrigation requirements. This area is bounded by Turlock ID on the east and the San Joaquin River on the west.

Water Supply Availability Protocol

Non-district riparian diverters on the east bank of the San Joaquin River between the Merced River and Tuolumne Rivers use San Joaquin River water to meet agricultural demands. There is no protocol in CALSIM II to determine or reduce the availability of San Joaquin River water for their use.

Delivery Protocol

River diversions are made until the demand is satisfied.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving this non-district riparian demand area are returned to the San Joaquin River between Newman and Maze.

Non-District Riparian Lands on the East Bank of the San Joaquin River from the Tuolumne River to the Stanislaus River

The non-district riparian demand area adjacent to the San Joaquin River extending from the confluence of the Tuolumne to the confluence of the Stanislaus relies on San Joaquin River diversions to satisfy irrigation requirements. This area is bounded by Modesto ID on the east and the San Joaquin River on the west.

Water Supply Availability Protocol

Non-district riparian diverters on the east bank of the San Joaquin River between the Tuolumne and Stanislaus Rivers use both San Joaquin River water and return flows from Modesto and Oakdale Irrigation Districts to meet agricultural demands. There is no protocol in CALSIM II to determine or reduce the availability of San Joaquin River water for their use.

Delivery Protocol

Return flows from Modesto and Oakdale Irrigation Districts are the first water sources for meeting the area's demand. These return flows are incidental,

however, and may not significantly contribute to the diversion requirement. San Joaquin River diversions are made until the remaining demand is satisfied, or until the 50 cfs constraint is reached. Additional demand is met through groundwater pumping.

Distribution Losses Protocol

CALSIM II does not have an explicit assumption or protocol for defining distribution system losses for this area.

Return Flow Protocol

Return flows are calculated using an assumed 75 percent surface water irrigation efficiency. The calculation for non-district return flow is:

$$\textit{Return Flow} = \textit{Surface water delivery} * [1 - (1 + NRL) * IE]$$

Where NRL is the non-recoverable loss (10%) and IE is the irrigation efficiency (75%). There are no return flows associated with groundwater deliveries.

Flows leaving this non-district riparian demand area are returned to the San Joaquin River above the Stanislaus River confluence.

Non-District Lands on the East Bank of the San Joaquin River Downstream of the Stanislaus River

The non-district demand area adjacent to the San Joaquin River extending north from the confluence of the Stanislaus River relies on San Joaquin River diversions to satisfy irrigation requirements. This area is bounded by South San Joaquin ID on the east and the San Joaquin River on the west.

This demand area and its corresponding land use based operations have not yet been integrated in CALSIM II. A simplified depiction of the area's diversions is used as a surrogate operation until a more complete representation is incorporated in the model.

Water Supply Availability Protocol

Non-district riparian diverters on the east bank of the San Joaquin River downstream of the Stanislaus River use San Joaquin River water to meet agricultural demands. There is no protocol in CALSIM II to determine or reduce the availability of San Joaquin River water for these diverters.

Delivery Protocol

Riparian deliveries are made until demand is satisfied; there are no other operational criteria to constrain this area's river diversions.

Distribution Losses Protocol

There are no distribution losses for this diversion.

Return Flow Protocol

The non-district San Joaquin River riparian diversion north of the Stanislaus River confluence is modeled as a system depletion and therefore does not return water to the stream network.

8. West Side Operations

Unlike the east side of the San Joaquin Valley, west side water deliveries are not tied to a diversion requirement. Surface water deliveries are made to west side water users according to contractual obligations. On the east side, when surface supplies are not adequate to meet the diversion requirement, the remaining demand is assumed to be met through groundwater pumping. If, on the west side, surface supplies are inadequate to meet the contract allocation amount, deliveries are reduced and shortages are identified; groundwater does not constitute another water source for west side entities.

Section 8 describes the protocols that CALSIM II uses to determine San Joaquin Basin west side operations, including water supply availability, delivery, distribution/conveyance loss, and return flow protocols. Only the operations that potentially affect flow and water quality in the San Joaquin River at Vernalis (i.e., operations that are hydraulically connected to the river) are included in this description.

Mendota Pool

Gravelly Ford, located downstream of Friant Dam, is a sandy and gravelly section of the San Joaquin River that is subject to high losses of river flow. The section of the San Joaquin River between Gravelly Ford and the Mendota Pool, a reach of approximately 17 miles, is generally dry except when releases are made from Friant Dam for flood control.

During flood control operations, water that passes Gravelly Ford and exceeds demands at Mendota Pool is diverted from the San Joaquin River to the Chowchilla Bypass. When flow in the Chowchilla Bypass reaches its capacity of 6,500 cfs, remaining water in the San Joaquin River flows into the Mendota Pool. The Chowchilla Bypass runs northwest, intercepts flows in the Fresno River, and discharges to the Chowchilla River.

The East Side Bypass begins at the Chowchilla River and runs northwesterly to rejoin the San Joaquin River above Fremont Ford. Together, the Chowchilla and East Side Bypasses intercept flows of the San Joaquin, Fresno, and Chowchilla Rivers, and other lesser east side San Joaquin River tributaries, to provide flood protection for downstream agricultural lands. These bypasses are located in highly permeable soils, and much of the water recharges groundwater.

Flows in the San Joaquin River that are not diverted to the Chowchilla Bypass enter the Mendota Pool. The Mendota Pool was formed in 1871 by the

construction of Mendota Dam on the San Joaquin River by water rights holders, and is the point at which the San Joaquin River turns northward. The Mendota Pool has a capacity of approximately 50,000 AF and serves as a forebay for diversions. The Delta-Mendota Canal, which conveys CVP water from the Delta to Exchange Contractors, terminates at the Mendota Pool. Water also enters Mendota Pool from the south, via Fresno Slough (sometimes referred to as James Bypass), which conveys overflows from the Kings River in the Tulare Lake Basin to the San Joaquin River. Reclamation uses a portion of the flow in Fresno Slough to supply water to the Mendota Wildlife Management Area.

Water that reaches the Mendota Pool from the San Joaquin River and Kings River offset required deliveries from the Delta-Mendota Canal.

Central Valley Project Exchange Contractors

Water Supply Availability Protocol

The annual CVP contract amount for Exchange Contractors is 840,000 AF. CALSIM II splits the contract demand between two locations, at Mendota Pool and on the lower Delta-Mendota Canal prior to the pool. The majority of the contract demand is represented at Mendota Pool and constitutes 700,000 AF (see Section 3, page 49). The total amount of exchange water is subject to reduction based on the CALSIM II CVP South-of-Delta allocation procedure. Reductions to these exchange contracts only occur during Shasta critical years[11] , and the maximum reduction in a given year is 23 percent of the total contract amount.

Delivery Protocol

Delta-Mendota Canal deliveries to Mendota Pool are diverted by Exchange Contractors on the delivery pattern shown in Table 8-1.

Table 8-1: Exchange Contractors' Diversion Pattern from Mendota Pool (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
7.0	2.3	1.0	1.0	2.5	8.0	8.0	11.0	14.5	17.0	16.7	11.0

Distribution Losses Protocol

Central Valley Project conveyance losses are not tied directly to individual contract deliveries. These losses are in addition to contractual and other obligations. CALSIM II applies a static annual loss of 101,500 AF that accounts for all Delta-Mendota Canal deliveries from O'Neill Forebay to Mendota Pool. Annual losses are distributed on the monthly delivery pattern shown in Table 8-2.

Table 8-2: Monthly Distribution of Lower Delta-Mendota Canal Annual Project Losses (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep

[11] A Shasta critical year is a year in which the "full natural inflow to Shasta Lake for the current water year...is equal to or less than 3.2 MAF; or the total accumulated actual deficiencies below 4 MAF in the immediately prior water year (each of which had inflows of less than 4 MAF), together with the forecasted deficiency for the current water year, exceed 800,000 acre-feet" (from *1992 Long-Term Central Valley Project Operations and Criteria Plan,* p 77).

3.8	2.7	2.8	3.7	5.5	5.6	7.5	11.0	16.6	19.0	15.8	6.0

Return Flow Protocol

There are essentially two types of return flow from Mendota Pool Exchange Contractors, agricultural drainage and VAMP releases. VAMP contributions from the Exchange Contractors are determined according to the criteria defined in Section 6 (page 78) above. These releases are made during April and May and enter the San Joaquin River through the combined Mud and Salt Sough representation.

Returns associated with agricultural drainage are depicted in CALSIM II by multiplying the amount of water delivered in a month (minus VAMP releases) by an assumed return flow factor for the month. The monthly return flow factors for Mendota Pool Exchange Contractors are shown in Table 8-3 below.

Table 8-3: Monthly Return Flow as a Percent of Monthly Delivery (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
7	7	20	20	20	7	7	7	7	7	7	7

Mendota Pool Exchange Contractors drainage returns are split between two locations. The majority of the flow enters the San Joaquin River through the combined Mud and Salt Slough representation and represents 93 percent of the Exchange Contractors' returns. The remaining seven percent of the flow enters the San Joaquin River at Newman.

Central Valley Project Agricultural Contractors

Water Supply Availability Protocol

The CALSIM II total CVP agricultural contract demand at (or near) Mendota Pool amounts to nearly 105,500 AF. Allocations to these contractors are determined through the CALSIM II CVP South-of-Delta allocation procedures. CVP Agricultural contracts are subject to 100 percent reduction based on water supply availability.

Delivery Protocol

CVP agricultural contract holders at Mendota Pool divert their annual allocation on the monthly schedule shown in Table 8-4.

Table 8-4: CVP Agricultural Contractors' Diversion Pattern from Mendota Pool (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
4.0	2.0	2.0	3.0	10.3	6.0	7.0	10.7	14.5	17.5	16.0	7.0

Distribution Losses Protocol

As described above (page 125), CVP conveyance losses do not constitute a reduction in deliveries to CVP contractors. Losses associated with conveying water in the Delta-Mendota Canal to the Mendota Pool are in addition to

contractual obligations and are estimated to be 101,500 AF annually, distributed on the pattern shown in Table 8-2.

Return Flow Protocol

CALSIM II determines San Joaquin River return flows (agricultural drainage) from west side CVP agricultural contractors at Mendota Pool by disaggregating deliveries according to individual contract amounts and then assigning a monthly return flow factor for each individual contractor. Table 8-5 shows the disaggregation of Mendota Pool agricultural deliveries and the return flow factor associated with each contractor.

Table 8-5: CVP Agricultural Contractors, Contract Amounts, and Return Flow Factors

CVP Contractor	Contract Amount		Monthly Return as a Percent of Monthly Delivery											
	AF	Percent of Total	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep
Westlands WD (incl. Barcellos)	50,000	47.4	7	7	20	20	20	7	7	7	7	7	7	7
Fresno Slough WD	4,000	3.8	7	7	20	20	20	7	7	7	7	7	7	7
James ID	35,300	33.4	7	7	20	20	20	7	7	7	7	7	7	7
Traction Ranch/F&G	2,080	2.0	7	7	20	20	20	7	7	7	7	7	7	7
Tranquility ID	13,800	13.1	7	7	20	20	20	7	7	7	7	7	7	7
M. Huges	70	0.1	7	7	20	20	20	7	7	7	7	7	7	7
R.D. 1606	228	0.2	7	7	20	20	20	7	7	7	7	7	7	7

Each of the contractors listed in Table 8-5 returns water to the San Joaquin River at Mendota Pool.

Central Valley Project Wildlife Refuge Contractors

Water Supply Availability Protocol

Central Valley Project wildlife refuge contractors at Mendota Pool have an aggregate annual contract amount of 94,410 AF. This amount is subject to reduction based on the South-of-Delta allocation procedure in CALSIM II. According to the procedure, in Shasta critical years allocations may be reduced up to 25 percent of the full contract amount; in Shasta non-critical years refuges are entitled to full deliveries.

Delivery Protocol

Wildlife refuge water users make diversions from Mendota Pool on the schedule shown in Table 8-6 below.

Table 8-6: CVP Refuge Diversion Pattern from Mendota Pool (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
21.1	13.4	6.2	4.1	4.0	3.8	5.6	8.3	10.5	4.0	4.7	14.3

Distribution Losses Protocol

Losses associated with conveying water in the Delta-Mendota Canal to the Mendota Pool are in addition to contractual obligations and are estimated to be 101,500 AF annually (see page 125), distributed on the pattern shown in Table 8-2.

Return Flow Protocol

In order to better depict their ponding operations, the return flows from wildlife areas are represented differently than agricultural entities. The total annual return flow from Mendota Pool CVP refuge contractors is assumed to be 61 percent of their annual delivery. This annual volume is distributed on a unique monthly pattern and is shown in Table 8-7.

Table 8-7: Monthly Distribution of Annual Mendota Pool Refuge Returns (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
5.8	15.3	12.4	7.9	13.9	9.4	2.3	5.0	4.5	2.7	1.9	18.9

Mendota Pool refuge returns enter the San Joaquin River through the combined Mud and Salt Sough representation.

Schedule II Water Rights

Water Supply Availability Protocol

Schedule II water rights at Mendota Pool amount to 34,813 AF annually. CALSIM II combines these water rights with the 700,000 AF exchange contracts at Mendota Pool and therefore makes allocations according to the Exchange Contractors' allocation procedures. Delivery reductions up to 23 percent may occur in Shasta critical years, otherwise schedule II water rights holders receive their full entitlement.

Delivery Protocol

Schedule II water rights annual deliveries are made on the same monthly pattern that is used to distribute Mendota Pool Exchange Contractors' allocations over a given year. This pattern is identified in Table 8-1 above.

Distribution Losses Protocol

Losses due to conveying water in the Delta-Mendota Canal to Mendota Pool amount to 101,500 AF. These losses are a cost to the CVP and do not directly affect deliveries to CVP contractors or water rights holders.

Return Flow Protocol

Return flows from water rights holders at Mendota Pool are a result of agricultural drainage. These flows are depicted in CALSIM II by multiplying the delivery in a given month by an assumed return flow factor for the month. The monthly return flow factors for Schedule II water rights are equivalent to those estimated for the Exchange Contractors, which are shown in Table 8-3 above.

Unlike the Exchange Contractors, however, these flows are represented as entering the San Joaquin River at Mendota Pool.

Lower Delta-Mendota Canal

The Delta-Mendota Canal (DMC) extends from Tracy Pumping Plant in the Sacramento-San Joaquin Delta 117 miles to the Mendota Pool. In the context of this document, the "lower" DMC refers to the section of the canal that extends from O'Neill Forebay to Mendota Pool. This section of the DMC conveys water for Mendota Pool diversions (described above under the "Mendota Pool" subheading) and for diversions prior to (north of) the pool, including CVP exchange, agricultural, and refuge contractors.

Central Valley Project Exchange Contractors

Water Supply Availability Protocol

Exchange contracts on the San Joaquin Valley west side amount to 840,000 AF, and of this "demand", 140,000 AF is spatially represented as a DMC diversion prior to Mendota Pool. CALSIM II determines the Exchange Contractors' annual allocation using the CVP South-of-Delta delivery logic, under which the 140,000 AF is reduced in Shasta critical years. During this year type, exchange contracts may be reduced up to 23 percent, otherwise full allocations are made.

Delivery Protocol

Diversions from the Lower DMC are made by Exchange Contractors on the delivery pattern shown in Table 8-1.

Distribution Losses Protocol

CALSIM II depicts all Lower DMC conveyance losses as an aggregate loss at Mendota Pool; there are no additional losses besides those described in the "Mendota Pool" subheading of Section 8. As noted previously, CVP conveyance losses are in addition to contractual obligations and do not constitute a reduction in deliveries to CVP contractors. Also noted above is that annual losses are estimated to be 101,500 AF distributed monthly on the pattern in Table 8-2. This assumption does not change based on hydrologic conditions.

Return Flow Protocol

Lower DMC Exchange Contractors return drainage water to the San Joaquin River at two locations; 93 percent of these flows are assumed to enter the river at the combined Mud and Salt Sough representation and the remaining seven percent at Newman. Flows are estimated by assuming a monthly return flow factor and multiplying it by the monthly delivery amount. Monthly return flow factors for Exchange Contractors are identified in Table 8-8.

Table 8-8: Monthly Return Flow as a Percent of Monthly Delivery (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep

7	7	20	20	20	7	7	7	7	7	7	7

Central Valley Project Agricultural Contractors

Water Supply Availability Protocol

Total CVP agricultural contracts amount to 124,820 AF in the Lower DMC service area. According to the CVP South-of-Delta allocation logic in CALSIM II, reductions of up to 100 percent may occur under certain hydrologic conditions.

Delivery Protocol

Lower DMC agricultural water users divert their annual allocation on the monthly pattern shown in Table 8-9.

Table 8-9: CVP Agricultural Diversion Pattern from the Lower DMC (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
4.0	2.0	2.0	3.0	10.3	6.0	7.0	10.7	14.5	17.5	16.0	7.0

Distribution Losses Protocol

Losses as a result of conveying CVP water through the Lower DMC are represented as a depletion at Mendota Pool. These are static losses that total 101,500 AF annually, and they are in addition to all CVP contract allocations (see Table 8-2 for the monthly distribution of these losses).

Return Flow Protocol

Agricultural water contractors in the Lower DMC area are assumed to have no return flows to the San Joaquin River, although the functionality is set up in CALSIM II to apply a monthly return flow factor to monthly deliveries, which would result in some returns to the San Joaquin River at the combined Mud and Salt Slough representation.

Central Valley Project Wildlife Refuge Contractors

Water Supply Availability Protocol

All wildlife refuge contract demands in the Lower DMC service area are aggregated into a single demand. The total refuge demand for this area is 182,698 AF each year, which is subject to a maximum reduction of 25 percent in Shasta critical years. In all other year-types, wildlife refuges are entitled to their full contract amounts.

Delivery Protocol

Lower DMC refuge contractors make monthly diversions on the pattern described in Table 8-6 above.

Distribution Losses Protocol

Losses resulting from conveying water from O'Neill Forebay to Mendota Pool are represented as a depletion at Mendota Pool. The 101,500 AF annual loss is

independent of refuge deliveries and does not constitute a reduction to these contractors.

Return Flow Protocol

Return flows from wildlife areas are represented differently than agricultural entities. The total annual return flow from Lower DMC refuge contractors is assumed to be 61 percent of their annual delivery. This annual volume is distributed on a unique monthly pattern and is shown in Table 8-7 above. Refuge returns are assumed to enter the San Joaquin River at the combined Mud and Salt Sough representation.

Upper Delta-Mendota Canal

The DMC extends from Tracy Pumping Plant in the Sacramento-San Joaquin Delta 117 miles to the Mendota Pool. As defined within the context of this document, "Upper" DMC refers to the section of the DMC that extends from Tracy Pumping Plant to O'Neill Forebay. The only contract type represented in CALSIM II within this "service area" is agricultural contracts. However, these agricultural contracts are split between two diversion points and are therefore discussed separately as the Upper DMC North and South diversions.

Central Valley Project Agricultural Contractors (North)

Water Supply Availability Protocol

Central Valley Project agricultural contracts in the northern extents of the Upper DMC service area amount to 63,100 AF[12]. These contracts are subject to 100 percent reduction based on the South-of-Delta allocation procedure in CALSIM II.

Delivery Protocol

Annual deliveries to these CVP agricultural contractors are distributed monthly on the pattern in Table 8-10.

Table 8-10: Upper DMC (North) CVP Agricultural Diversion Pattern (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
4.7	1.9	0.9	0.9	1.1	2.6	9.1	13.5	16.1	22.9	17.4	8.9

Distribution Losses Protocol

Central Valley Project conveyance losses are not tied directly to individual contract deliveries. These losses are in addition to contractual and other obligations. CALSIM II applies a static annual loss of 18,500 AF that accounts for all Delta-Mendota Canal deliveries from Tracy Pumping Plant to O'Neill

[12] This value includes the City of Tracy's 10,000 AF M&I contract. Future representations could be improved by separating this contract from the agricultural contracts, which would slightly change allocations and deliveries in this area.

Forebay. Annual losses are distributed on the monthly delivery pattern shown in Table 8-11.

Table 8-11: Monthly Distribution of Upper DMC Annual Project Losses (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
3.8	2.7	2.9	3.7	5.4	5.6	7.5	11.0	16.6	19.0	15.8	6.0

Return Flow Protocol

Agricultural water contractors in the Upper DMC (North) area are assumed to have no return flows to the San Joaquin River, although the functionality is set up in CALSIM II to apply a monthly return flow factor to monthly deliveries, which would result in some returns to the San Joaquin River at the confluence of the Calaveras River.

Central Valley Project Agricultural Contractors (South)

Water Supply Availability Protocol

Central Valley Project agricultural contracts in the southern extents of the Upper DMC service area amount to 215,210 AF[13]. These contracts are subject to 100 percent reduction based on the South-of-Delta allocation procedure in CALSIM II.

Delivery Protocol

Annual deliveries to these CVP agricultural contractors are distributed monthly on the pattern in Table 8-12.

Table 8-12: Upper DMC (South) CVP Agricultural Diversion Pattern (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
3.7	1.0	0.3	0.3	0.6	2.2	9.5	14.4	17.0	24.6	18.1	8.3

Distribution Losses Protocol

Central Valley Project conveyance losses are not tied directly to individual contract deliveries. These losses are in addition to contractual and other obligations. CALSIM II applies a static annual loss of 18,500 AF that accounts for all Delta-Mendota Canal deliveries from Tracy Pumping Plant to O'Neill Forebay. Annual losses are distributed on the monthly delivery pattern shown in Table 8-11 above.

Return Flow Protocol

CALSIM II determines San Joaquin River return flows (agricultural drainage) from Upper DMC (South) CVP agricultural contractors by disaggregating deliveries according to individual contract amounts and then assigning a monthly return flow factor for each individual contractor. Table 8-13 shows the

[13] This value includes Patterson Water District's 6,000 acre-foot water right. Future representations could be improved by separating this contract from the agricultural contracts, which would slightly change allocations and deliveries in this area.

disaggregation of Upper DMC (South) agricultural deliveries and the return flow factor associated with each contractor.

Table 8-13: CVP Agricultural Contractors, Contract Amounts, and Return Flow Factors

CVP Contractor	Contract Amount		Monthly Return as a Percent of Monthly Delivery											
	AF	Percent of Total	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep
Davis WD	5,400	2.5	7	7	20	20	20	7	7	7	7	7	7	7
Del Puerto WD	12,060	5.6	7	7	20	20	20	7	7	7	7	7	7	7
Hospital WD	34,105	15.8	7	7	20	20	20	7	7	7	7	7	7	7
Kern Canyon WD	7,700	3.6	7	7	20	20	20	7	7	7	7	7	7	7
Salado WD	9,130	4.2	7	7	20	20	20	7	7	7	7	7	7	7
Sunflower WD	16,625	7.7	7	7	20	20	20	7	7	7	7	7	7	7
West Stanislaus WD	50,000	23.2	7	7	20	20	20	7	7	7	7	7	7	7
Mustang WD	14,680	6.8	0	0	0	0	0	0	0	0	0	0	0	0
Orestimba WD	15,860	7.4	7	7	20	20	20	7	7	7	7	7	7	7
Patterson WD Water Rights	6,000	2.8	7	7	20	20	20	7	7	7	7	7	7	7
Patterson WD	16,500	7.7	7	7	20	20	20	7	7	7	7	7	7	7
Foothill WD	10,840	5.0	7	7	20	20	20	7	7	7	7	7	7	7
Quinto WD	8,620	4.0	0	0	0	0	0	0	0	0	0	0	0	0
Romero WD	5,190	2.4	0	0	0	0	0	0	0	0	0	0	0	0
Centinella WD	2,500	1.2	0	0	0	0	0	0	0	0	0	0	0	0

Returns from each water user listed in Table 8-13 are assumed to flow into the San Joaquin River at Newman, the Tuolumne River confluence, and/or Vernalis. Table 8-14 shows the percent of each contractor's drainage flow that is returned at each of the three locations.

Table 8-14: Contractor's Returns to Various Locations (percent)

CVP Contractor	Returns to San Joaquin River at:		
	Newman	Tuolumne	Vernalis
Davis WD	100	0	0
Del Puerto WD	0	100	0
Hospital WD	0	0	100
Kern Canyon WD	0	100	0
Salado WD	0	100	0
Sunflower WD	0	100	0
West Stanislaus WD	0	100	0

CVP Contractor	Returns to San Joaquin River at:		
	Newman	Tuolumne	Vernalis
Mustang WD	n/a	n/a	n/a
Orestimba WD	100	0	0
Patterson WD Water Rights	0	100	0
Patterson WD	0	100	0
Foothill WD	100	0	0
Quinto WD	n/a	n/a	n/a
Romero WD	n/a	n/a	n/a
Centinella WD	n/a	n/a	n/a

San Joaquin River Main Stem Riparian Diversions

San Joaquin River west bank riparian diversions are aggregated in CALSIM II at two diversion points, the Merced River confluence and the Tuolumne River confluence. The diversion at the Merced River confluence represents all west bank riparian diversions between the Merced and Tuolumne Rivers, and the diversion at the Tuolumne River represents all diversions between the Tuolumne and Stanislaus Rivers.

San Joaquin River West Bank Riparian Diverters (from the Merced River to the Tuolumne River)

Water Supply Availability Protocol

CALSIM II does not have a specific protocol to reduce water availability for San Joaquin River west bank riparian diversions between the Merced and Tuolumne Rivers. Water supplies to these diverters are only limited by demand.

Delivery Protocol

River diversions are made until the demand is satisfied. There are no assumed conveyance limits that would reduce deliveries to these diverters.

Distribution Losses Protocol

There is no explicit assumption or protocol in CALSIM II for defining distribution losses associated with west bank diversions.

Return Flow Protocol

Return flows from west bank riparian diversions are calculated by multiplying a return flow factor by the monthly diversion. The monthly return flow factors for this area that are used in the model are shown in Table 8-15 below.

Table 8-15: Monthly Return Flow Factors (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
30	30	30	30	30	30	30	30	30	30	30	30

All returns are assumed to flow back to the San Joaquin River near the Tuolumne River confluence.

San Joaquin River West Bank Riparian Diverters (from the Tuolumne River to the Stanislaus River)

Water Supply Availability Protocol

CALSIM II does not have a specific protocol to reduce water availability for San Joaquin River west bank riparian diversions between the Tuolumne and Stanislaus Rivers. Water supplies to these diverters are only limited by demand.

Delivery Protocol

River diversions are made until the demand is satisfied. There are no assumed conveyance limits that would reduce deliveries to these diverters.

Distribution Losses Protocol

There is no explicit assumption or protocol in CALSIM II for defining distribution losses associated with west bank diversions.

Return Flow Protocol

Return flows from west bank riparian diversions are calculated by multiplying a return flow factor by the monthly diversion. The monthly return flow factors for this area that are used in the model are shown in Table 8-16 below.

Table 8-16: Monthly Return Flow Factors (percent)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
30	30	30	30	30	30	30	30	30	30	30	30

All returns are assumed to flow back to the San Joaquin River near the Stanislaus River confluence.

9. Water Quality

Surface water quality in the San Joaquin River Basin is affected by several factors, including natural runoff, tributary inflow, and agricultural and wildlife area return flows. Water quality in the San Joaquin River varies considerably along the stream's length. Water above Millerton Lake and downstream towards Mendota Pool is generally of very high quality. The reach from Gravelly Ford to Mendota Pool (about 17 miles) is frequently dry, except during flood control releases because all water released from Millerton Lake is diverted upstream to satisfy water rights agreements, or percolates to groundwater.

During the irrigation season, most of the water released from Mendota Pool to the San Joaquin River is imported from the Delta via the Delta-Mendota Canal, and generally has higher concentrations of total dissolved solids (TDS) than water in the upper reaches of the San Joaquin River. Most of the water released from the Mendota Pool to the San Joaquin River is diverted at or above Sack Dam for agricultural uses. Between Sack Dam and the confluence with Salt Slough, the San Joaquin River is often dry. From Salt Slough to Fremont Ford, most of the flow in the San Joaquin River is derived from irrigation and wildlife area returns carried by Salt and Mud sloughs. This reach typically has the poorest water quality of any reach of the river.

As the San Joaquin River progresses downstream from Fremont Ford, water quality generally improves at successive confluences, specifically at those with the Merced, Tuolumne, and Stanislaus Rivers.

Previous versions of CALSIM II used a form of the "Kratzer Formula" to indicate salinity (TDS, converted to EC) in the San Joaquin River above the Stanislaus confluence. However, new planning questions related to source-specific water quality management in the San Joaquin River Basin have necessitated an improved CALSIM II representation of the Vernalis salinity estimation. In conjunction with this east side hydrology refinement effort, Reclamation's response has been to introduce mass-balance routing capabilities in CALSIM II through development of the San Joaquin River Water Quality Module version 1.00 (WQ Module ver1.00). The module disaggregates the Vernalis salinity estimate (i.e., flow rate multiplied by salt concentration) into source components from Lander Avenue to Vernalis. It also provides a modeling framework that can be updated with new source information as knowledge of the Basin progresses (from DRAFT--San Joaquin River Water Quality Module version 1.00 for CALSIM II, 16 December 2004). A complete description of the new water quality module is found in Attachment 2 of this document.

10. Historical Comparison

Unique to CALSIM II, the operations of the San Joaquin Basin depicted by CALSIM II can be reviewed from a validation perspective. While the operations of the Sacramento River Basin facilities have been extremely dynamic in terms of regulatory and operational objectives and extremely flexible in terms of using supplies between reservoir systems, the San Joaquin Basin projects are functionally quite independent of each other and have had relatively constant operational objectives for several if not decades of years. This relatively stable history of operations allows the CALSIM II simulation of operations to be compared to historical operations. A comparison of these two circumstances is described in this section.

Friant Division

The water delivery function is integral to the development of the benchmark operation for the Friant Division. Most comparable are modeled and recorded diversions after 1961. Prior to 1961, Friant water user facilities were not completely built, and many of the facilities in the Tulare Lake Basin were incomplete.

While at times noticeable differences occur between historical and simulated annual delivery and river release volumes, the differences are reconciled in many instances and are largely due to the inability of the model to reflect discretionary and intermittent actions, such as flood management and canal maintenance.

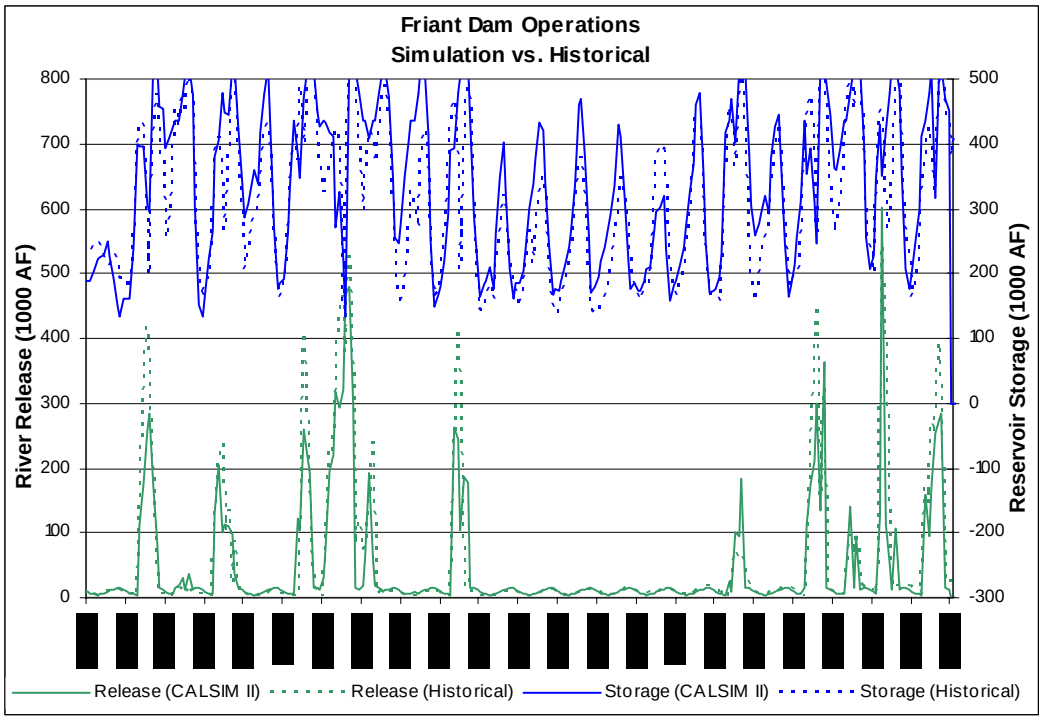


Figure 10-1: Millerton Lake Storage and Total Friant Dam River Release

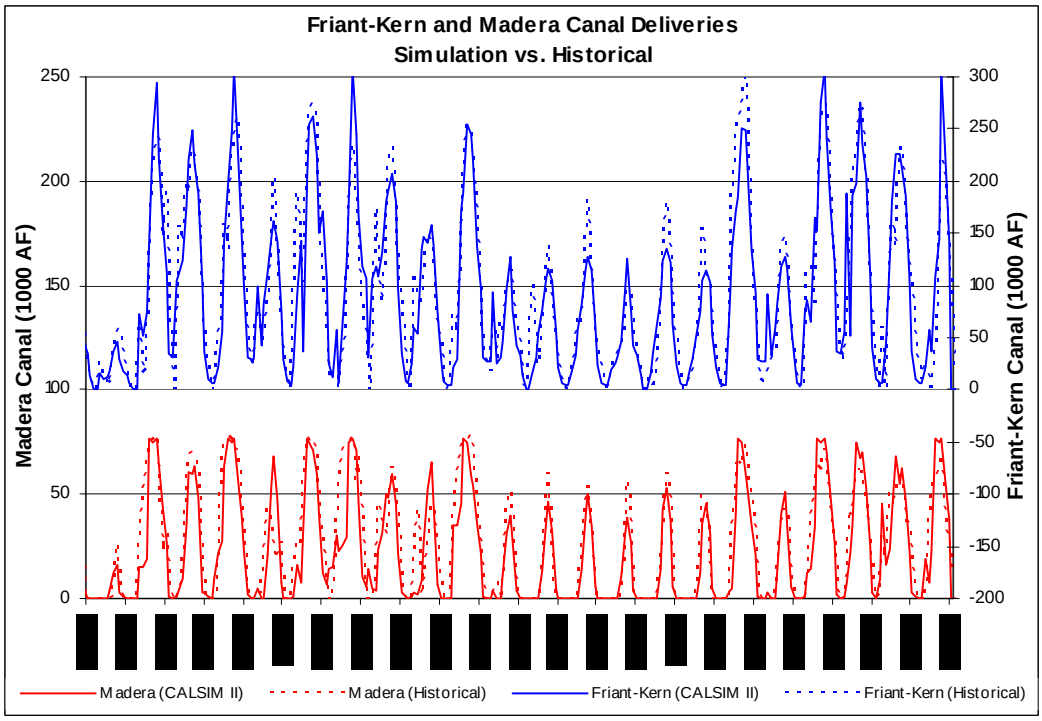


Figure 10-2: Friant-Kern and Madera Canal Diversions

Fresno River

The operation of Hensley Lake (Hidden Dam) began in 1976. The operation is coordinated with available supply from Friant Dam to satisfy water supply needs of Madera ID. The simulation compares very well to the historical operation, particularly when considering the integrated operation of the reservoir.

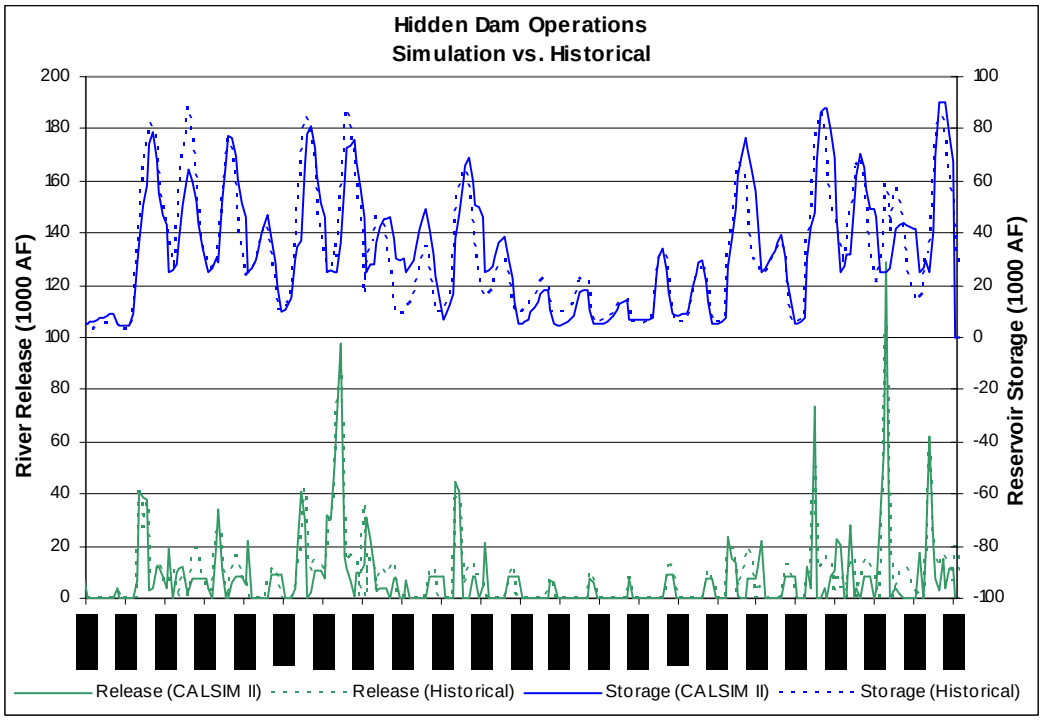


Figure 10-3: Hensley Lake Storage and River Release

Chowchilla River

The operation of Eastman Lake (Buchanan Dam) began in 1976. The operation is coordinated with available supply from Friant Dam to satisfy water supply needs of Chowchilla WD. The simulation compares reasonably well to the historical operation, particularly when considering the integrated operation of the reservoir and changes in the historical operating criteria.

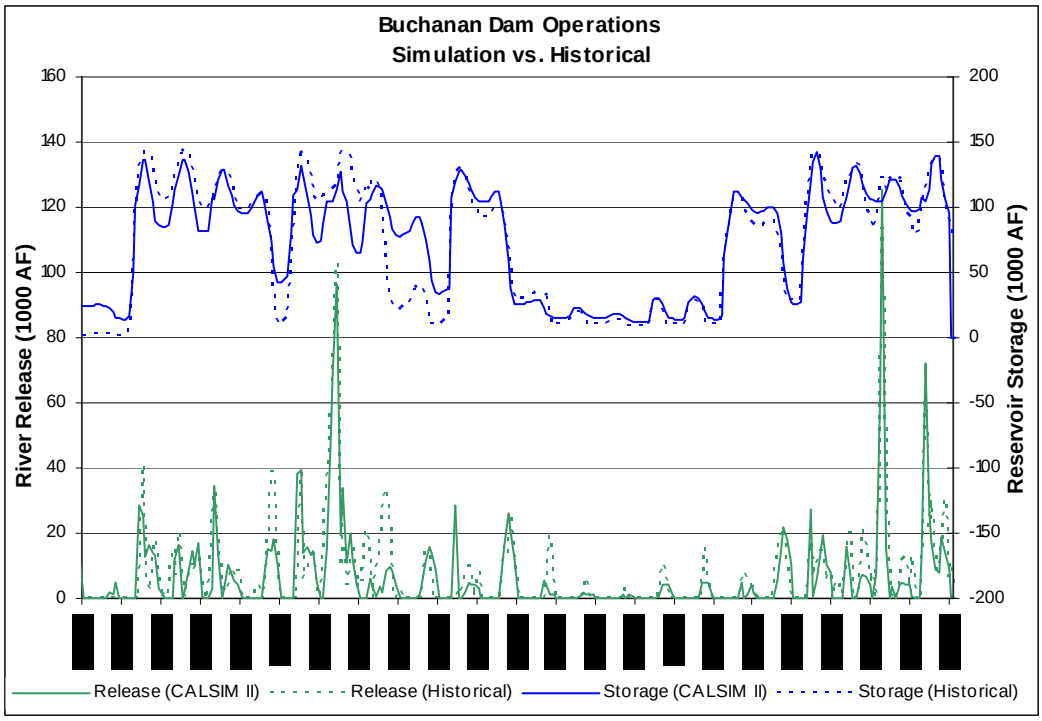


Figure 10-4: Eastman Lake Storage and River Release

Merced River

The operation of New Exchequer and Merced ID diversions compare very well to the historical operation. Deviations from the historical operation occur due to maintenance of the reservoir.

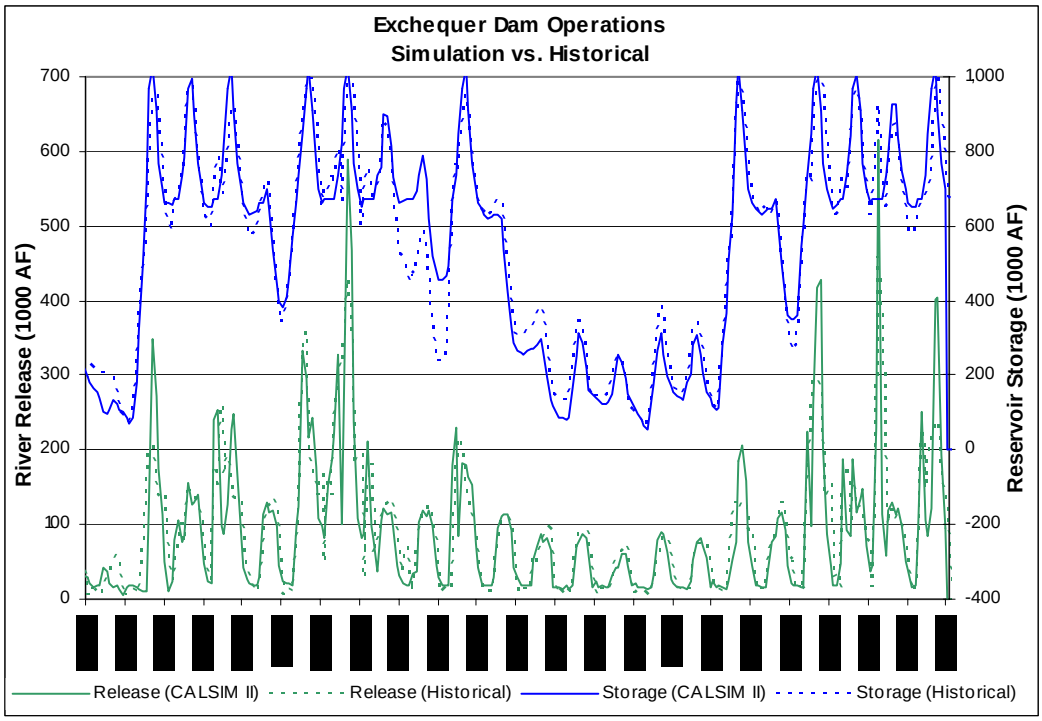


Figure 10-5: Lake McClure Storage and Total Release

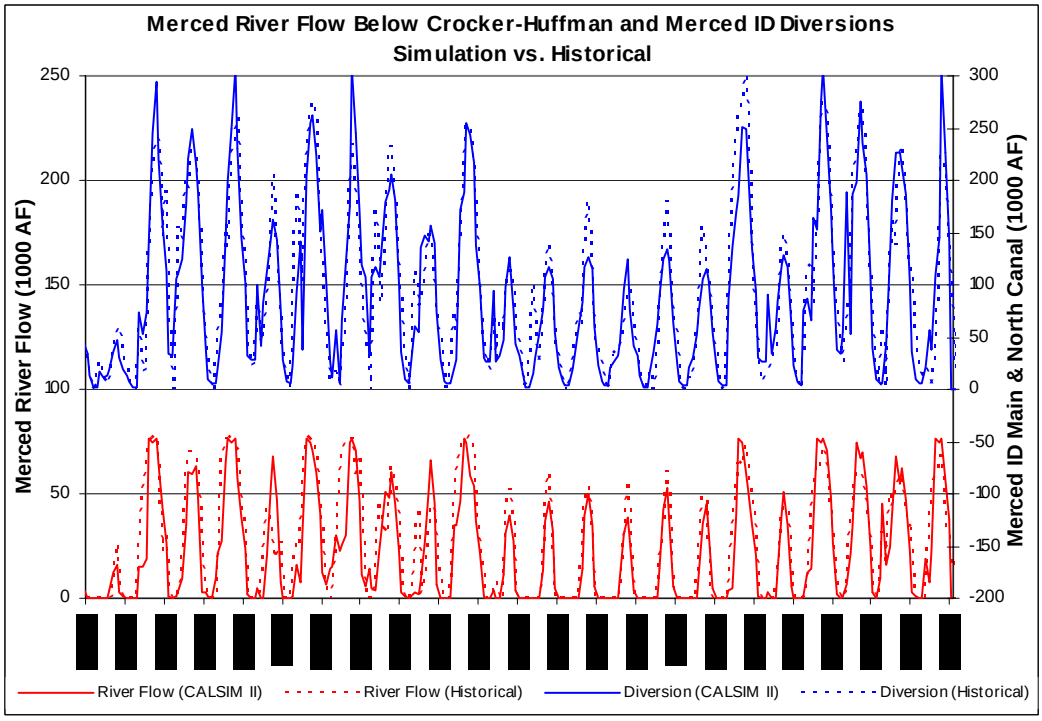


Figure 10-6: Merced ID Diversion and Merced River Flow

Tuolumne River

The following graphics depict the simulated and historical operation of the New Don Pedro Project. The simulation of operations as depicted by reservoir storage and canal diversions tracks well with the historical operation. As with other systems, a drought sequence similar to the 1987 through 1992 had not been experienced previously. Water delivery decisions were developed annually, without certainty as to the length of the drought, and in reaction to local concerns including the use of groundwater as an alternative to surface supplies.

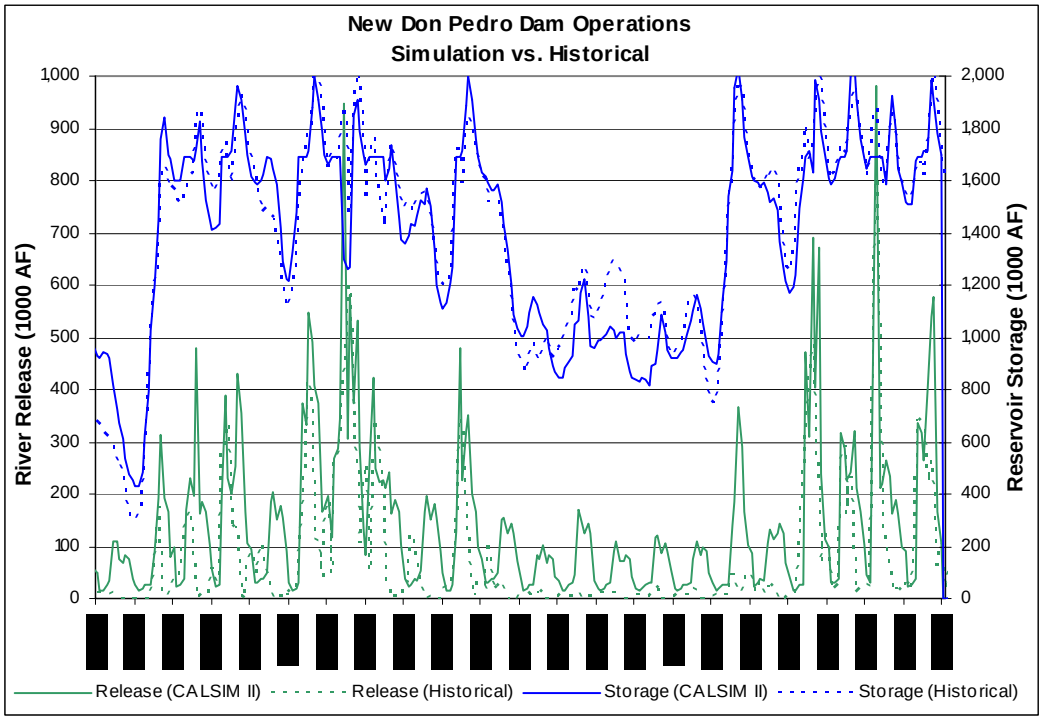


Figure 10-7: New Don Pedro Storage and River Release

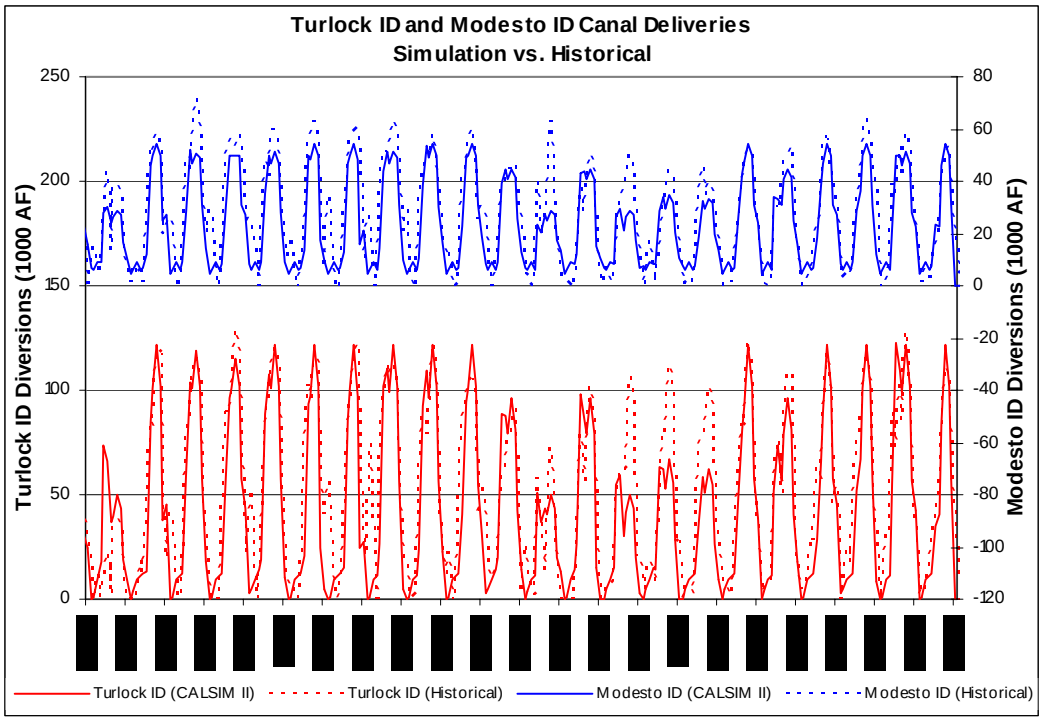


Figure 10-8: Turlock ID and Modesto ID Diversions

Stanislaus River

Simulated Stanislaus River operations and diversions track well with historical operations and diversions (see Figure 10-9 and Figure 10-10). The closeness of the simulation results to the actual recorded operation is somewhat coincidental in recognition of the change in operational objectives that have occurred at New Melones in recent history. The constraints upon diversions to the South San Joaquin ID and Oakdale ID have not changed over time, and their simulation is considered consistent with historical operations.

An additional effort was performed for New Melones that validated the CALSIM II logic for consistency with the operation of the IPO allocation procedures. Due to the numerous changes in hydrology and operations within CALSIM II, including a revised result for water quality and flow upstream of the Stanislaus River confluence, new results of CALSIM II (in terms of a New Melones operation) could not be directly compared with previous planning studies (including the STANMOD studies used to develop the IPO).

To validate the consistency between IPO procedures used in CALSIM II and STANMOD, the revised depiction of the San Joaquin River above the confluence of the Stanislaus River and below Goodwin Dam was replaced in CALSIM II with the flow and quality results (from SANJASM and STANMOD) that were used during the development of the IPO. Other assumptions used in the original IPO studies such as the assumed full diversion of Agreement water by the South

San Joaquin ID and Oakdale ID were also forced into the CALSIM II logic. The result of the effort proved the consistency of the CALSIM II logic to the procedures of the IPO with an almost-exact match in results.

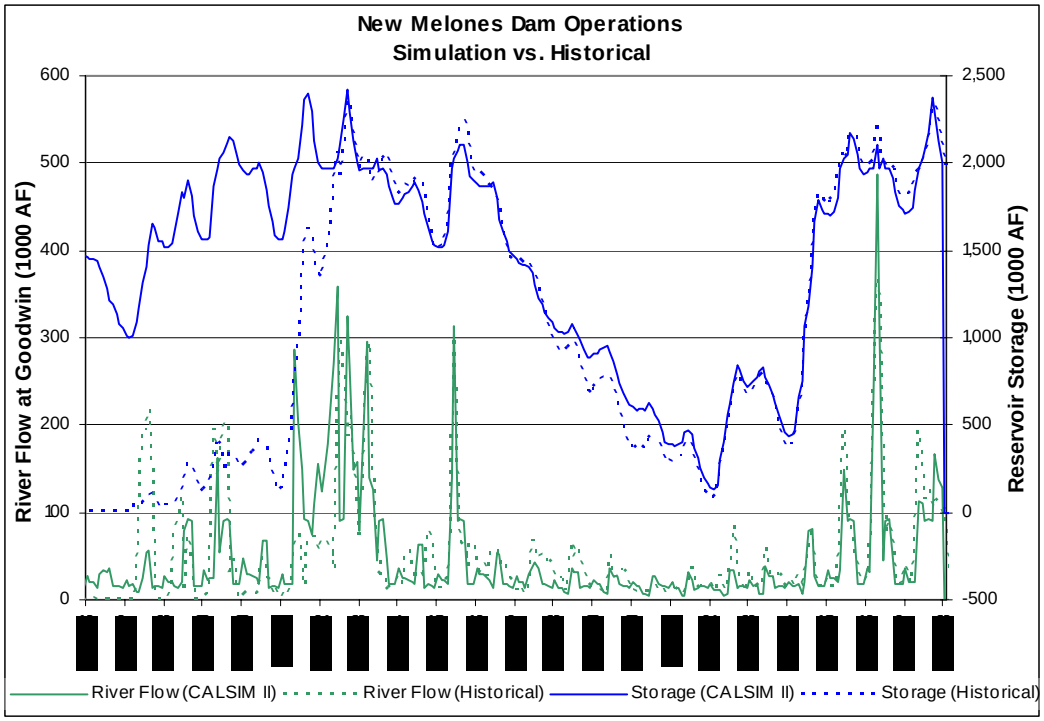


Figure 10-9: New Melones Storage and Stanislaus River Flow at Goodwin Dam

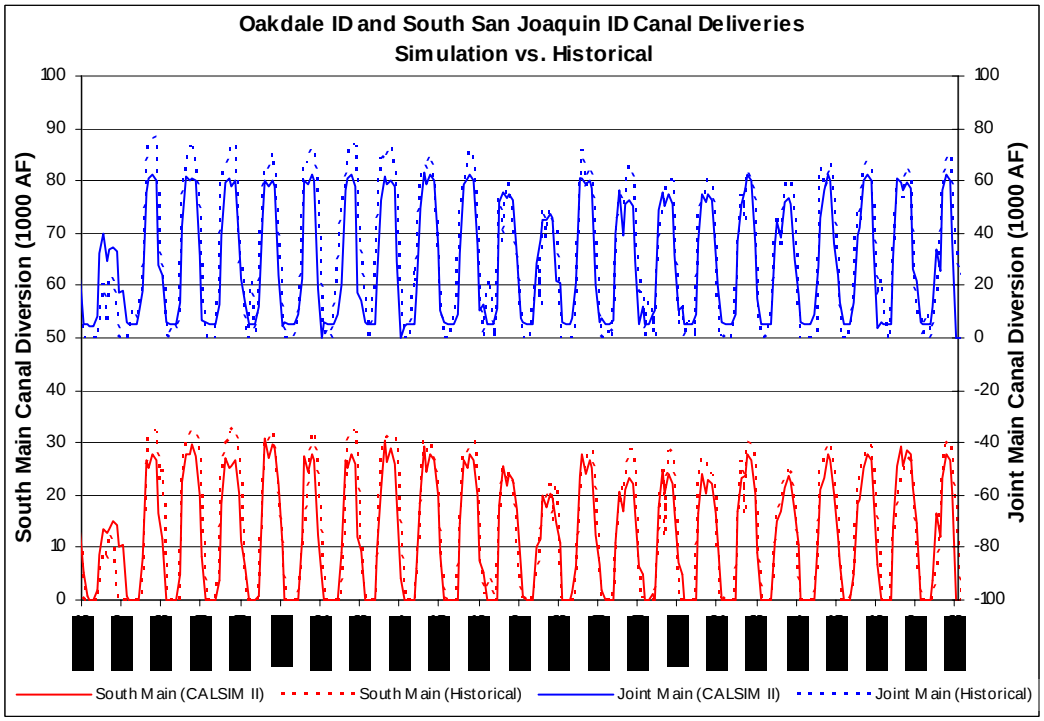


Figure 10-10: South Main and Joint Main Canal Diversions

Calaveras River

The following chart compares the historical New Hogan operation to the CALSIM II simulation. The actual operation of New Hogan has changed over time, due in part to increases in demands, facility improvements, and use of supply from the Stanislaus River. The model compares reasonably well to historical operations. The main difference is the drawdown of Hew Hogan early in drought sequences. CALSIM II tends to maintain higher storage levels than has occurred in the past.

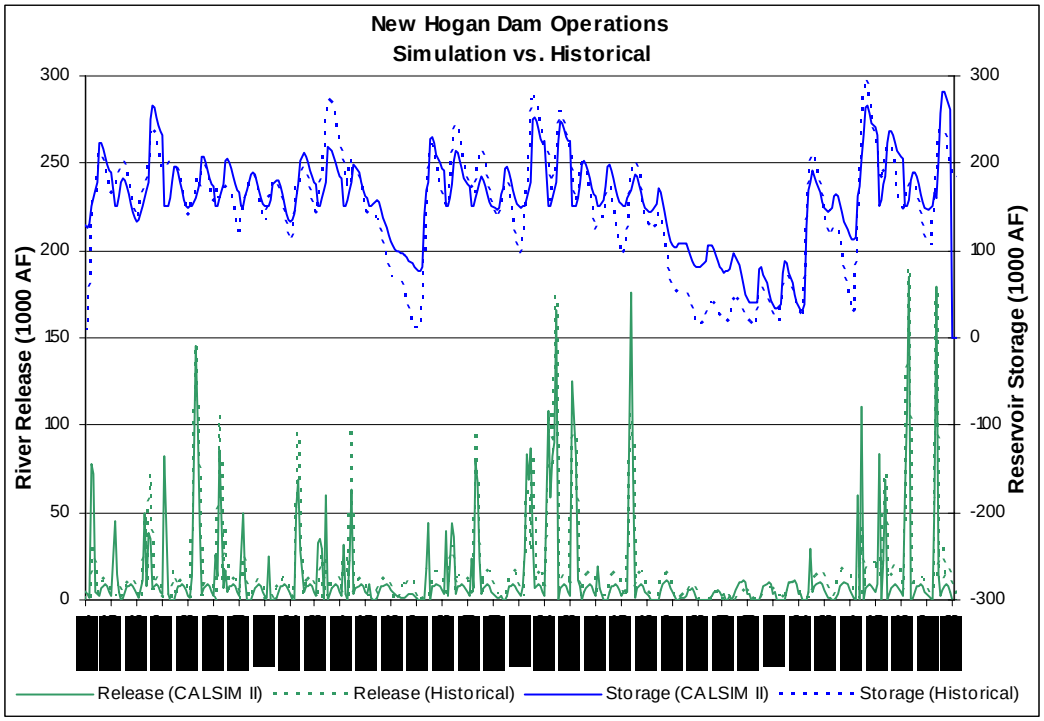


Figure 10-11: New Hogan Storage and Total Release

San Joaquin River Main Stem

The following chart compares the annual historical and simulated flow at Vernalis. Historical flows are adjusted to include high flows that bypassed the Vernalis gage.

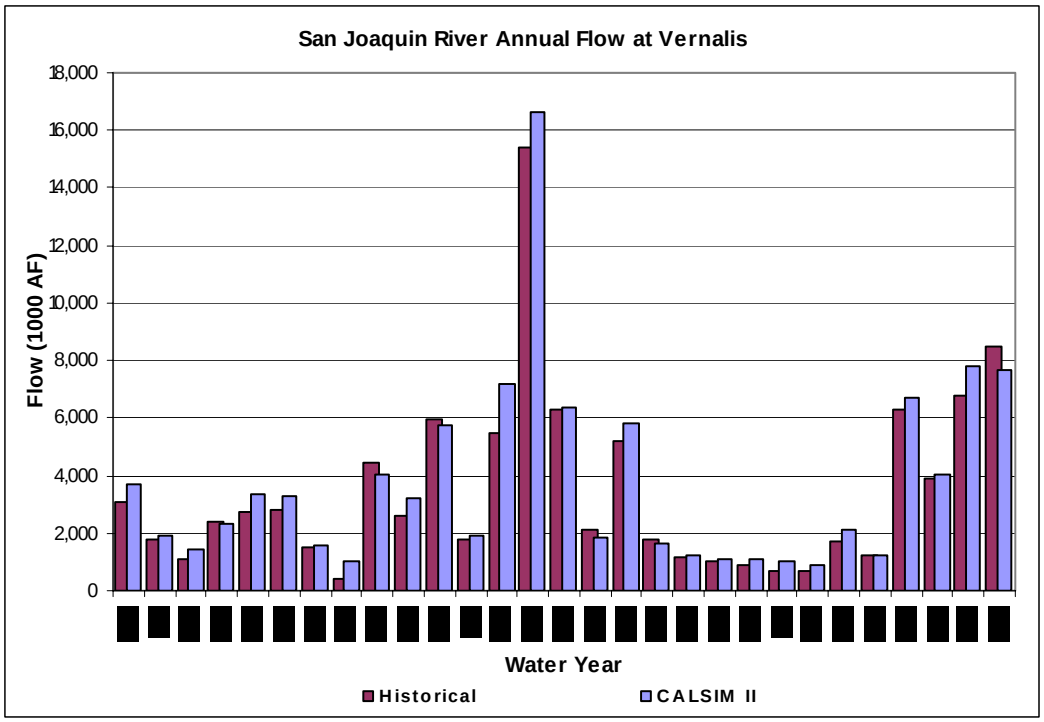


Figure 10-12: Annual San Joaquin River Flow Volume at Vernalis

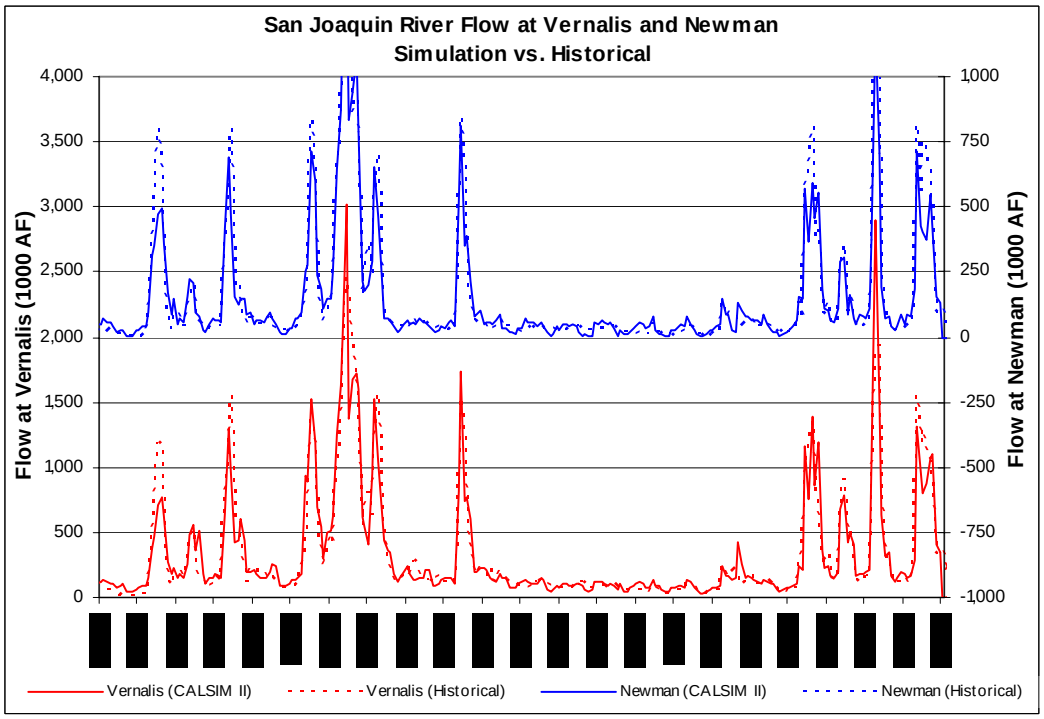


Figure 10-13: San Joaquin River Flow Volume at Vernalis and Newman

11. Acknowledgments

The development of this version of the CALSIM II depiction of the San Joaquin River Basin required the cooperation, efforts and insight of many individuals and the acquisition and review of numerous documents. Many districts and entities within the San Joaquin River Basin provided records and dialog that assisted with developing many of the procedures and data included in CALSIM II. Personal contact was made with the following entities:

- Madera Irrigation District
- Chowchilla Water District
- Merced Irrigation District
- Turlock Irrigation District
- Modesto Irrigation District
- Oakdale Irrigation District
- South San Joaquin Irrigation District
- Stockton East Water District
- The San Joaquin River Exchange Contractors

The efforts and work product of other entities and investigations also contributed to the development of this CALSIM II version, including the Upper San Joaquin River Basin Storage Investigation, Delta Mendota Canal San Luis Water Authority, and the Friant Water Users Association.

Also contributing to the effort over a number of years were the planning staffs of the Department of Water Resources and Reclamation, and the operations staff of Reclamation.

12. Reference Tools

Numerous electronic files support the development of the data used in CALSIM II for the depiction of hydrology and operations for the San Joaquin River Basin. These files accompany this documentation and are described by the following listing and file structure.

Supporting_Files

Land_Use.xls

This MS Excel spreadsheet contains land use information that was developed from GIS coverage. The information is processed within the spreadsheet to determine the land use within each demand area in the San Joaquin River Basin east side. The spreadsheet results are directly input to the CU model. East side M&I demands are also developed within this spreadsheet.

Madera_flood.xls

This MS Excel spreadsheet contains data used to develop rules for routing flood flows from Friant Dam through the Madera Canal to the Fresno River.

Merced_min.xls

This MS Excel spreadsheet contains minimum flow requirements for the Merced River.

SOD_CVP_demands.xls

This MS Excel spreadsheet contains CVP demands south of the Delta that are used in CALSIM II. Linkage between demands and San Joaquin west side returns are defined in the spreadsheet.

SJR_input.xls

This MS Excel spreadsheet contains all of the San Joaquin River Basin time series inputs to CALSIM II.

SJR_Schematic.xls

This MS Excel spreadsheet contains a schematic of the San Joaquin River Basin as represented by CALSIM II nodes and arcs.

Accretions

This directory contains Microsoft Excel (MS Excel) spreadsheets used to estimate San Joaquin River Basin accretions for river reaches simulated in CALSIM II.

Calaveras_acc-dep.xls

MS Excel spreadsheet used to calculate Calaveras River accretions from New Hogan to Bellota.

Chowchilla.xls

MS Excel spreadsheet used to estimate Chowchilla River seepage losses, water supply available to Chowchilla WD, and inflow to Eastman Lake.

Fresno.xls

MS Excel spreadsheet used to estimate Fresno River seepage losses, water supply available to Madera ID, and inflow to Hensley Lake.

Merced.xls

MS Excel spreadsheet used to estimate Merced River accretions from Exchequer Dam to Crocker-Huffman Dam, Crocker-Huffman Dam to Cressey, and Cressey to Stevinson. This spreadsheet includes estimated inflow to Lake McClure.

SJR_USfromMerced.xls

MS Excel spreadsheet used to estimate accretions for a region of the San Joaquin River Basin upstream from the San Joaquin River confluence with the Merced River. This upstream boundary of this region is the San Joaquin River below Friant Dam, Fresno River below Hidden Dam, Chowchilla River below Buchanan Dam, and Mendota Pool.

Stanislaus.xls

MS Excel spreadsheet used to estimate Stanislaus River accretions from New Melones Dam to Tulloch Reservoir, from Tulloch Reservoir to Goodwin Dam, and from Goodwin Dam to Ripon.

Tuolumne.xls

MS Excel spreadsheet used to estimate Tuolumne River accretions from LaGrange Dam to Modesto.

SJR_Mainstem

This directory contains MS Excel spreadsheets used to estimate San Joaquin River main stem accretions.

SJR_mainstem_div.xls

MS Excel spreadsheet used to estimate San Joaquin River main stem diversions from the west bank of the river.

SJR_main.xls

MS Excel spreadsheet used to estimate San Joaquin River main stem accretions. A mass-balance is performed between the San Joaquin River

at Vernalis, the San Joaquin River at Newman, the Stanislaus River at Ripon, and the Tuolumne River at Modesto. Accretions calculated using regression results from *Mainstem_regression.xls* are incorporated to bring the accretions to a projected level of development.

Accretion_636_639.xls

MS Excel spreadsheet used to allocate San Joaquin River accretions to upstream and downstream of Maze Boulevard.

Mainstem_regression.xls

MS Excel spreadsheet used to perform regression analysis to bring San Joaquin River accretions to projected level of development and remove obvious gage errors.

Oristimba_DelPuerto.xls

MS Excel spreadsheet containing historical and estimated flows from Oristimba and Del Puerto Creeks entering the San Joaquin River main stem.

Regression_032604.xls

Memorandum on the methods used to perform the San Joaquin River main stem accretions regression analysis (MS Word file).

SJR_present

This directory contains presentation (and supporting) files on the development of the San Joaquin Valley depiction in CALSIM II.

sjr.ppt

MS PowerPoint presentation on the development of the San Joaquin River Basin in CALSIM II.

sjr_HO.xls

MS PowerPoint presentation on the development of the San Joaquin River Basin in CALSIM II, formatted for printing handouts.

Land Use Aggregation.pdf

This Adobe Acrobat file contains an image of the San Joaquin Valley demand area boundaries.

Land use with Aggregation Areas.pdf

This Adobe Acrobat file contains an image of the San Joaquin Valley demand area boundaries and corresponding land use.

Water Districts

This directory contains MS Excel spreadsheets used to perform water budgets for the main irrigation and water districts in the east side of the San Joaquin Basin. Results of the calculations performed in these spreadsheets are input to CALSIM II through lookup tables, time series DSS data, and WRESL code. River specific information is also included.

Madera_budget.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for Madera ID.

Chow_budget.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for Chowchilla WD.

Merced_budget.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for Merced ID.

Turlock Balance.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for Turlock ID. Also included are data relating to New Don Pedro inflow, flood control storage, and minimum LaGrange Dam releases.

Modesto Balance.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for Modesto ID.

OID South Balance.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for Oakdale ID south of the Stanislaus River.

SSJID_OID North Balance.xls

MS Excel spreadsheet containing water budget information to develop CALSIM II inputs for South San Joaquin ID and Oakdale ID north of the Stanislaus River.

CU_model-CUAW

cu.exe

This file is an executable version of DWR's CU model.

dsa49a

cuinput

CU model input file for DSA 49A.

dsa49b

This sub-directory contains CU input files for demand areas within DSA 49B.

Modesto

cuinput

CU model input file for Modesto ID.

OID_north

cuinput

CU model input file for Oakdale ID north of the Stanislaus River.

OID_south

cuinput

CU model input file for Oakdale ID south of the Stanislaus River.

SJR_blw_stan

cuinput

CU model input file for non-district lands east of and adjacent to the San Joaquin River downstream of the confluence with the Stanislaus River (i.e., north of the confluence.

SJR_tuol-stan

cuinput

CU model input file for non-district lands east of and adjacent to the San Joaquin River between the Tuolumne and Stanislaus Rivers.

SSJ

cuinput

CU model input file for South San Joaquin ID.

Stan_R

cuinput

CU model input file for non-district lands adjacent to the Stanislaus River.

dsa49c

This sub-directory contains CU input files for demand areas within DSA 49C.

209

cuinput

CU model input file for non-district lands east of Turlock ID (DAU 209).

SJR_merc-Tuol

cuinput

CU model input file for non-district lands east of and adjacent to the San Joaquin River between the Merced and Tuolumne Rivers.

tuol_R

cuinput

CU model input file for non-district lands adjacent to the Tuolumne River.

Turlock

cuinput

CU model input file for Turlock ID.

dsa49d

This sub-directory contains CU input files for demand areas within DSA 49D.

211

cuinput

CU model input file for non-district lands east of Merced ID (DAU 211).

212

cuinput

CU model input file for non-district lands west of Merced ID (DAU 212).

214

cuinput

CU model input file for non-district lands east of Madera ID (DAU 214).

215

cuinput

CU model input file for non-district lands west of Madera ID (DAU 215).

Chow

cuinput

CU model input file for Chowchilla WD.

Madera

cuinput

CU model input file for Madera ID.

Merced

cuinput

CU model input file for Merced ID.

Merced_R

cuinput

CU model input file for non-district lands adjacent to the Merced River.

DWR_CU_Model

This sub-directory contains the DWR CU model, including source code and tools to compile the source code using the Lahey FORTRAN compiler. The following files are contained within this sub-directory.

AMTEMP.BAT
AUTOMAKE.DEP
automake.fig
AUTOMAKE.RSP
cu.exe
Cu.for