Sacramento Water Allocation Model

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and

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Abbreviations and Acronyms

AFRP	Anadromous Fish Restoration Program
ANN	Artificial Neural Network
Bay-Delta Plan	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
BDCP	Bay Delta Conservation Plan
BiOp	Biological Opinion
BoM	beginning-of-month
CA	California Aqueduct
CaSIL	California Spatial Information Library
CCTL	Central Coast and Tulare basin
CDEC	California Data Exchange Center
CDFW	California Department of Fish and Wildlife, formerly Department of Fish and Game
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
CM	canal mile
COA	Coordinated Operations Agreement
CSD	Community Service District
CSA	Community Service Area
csv	comma-separated values
CUP	Consumptive Use Program
CVP	Central Valley Project
CVPA	Central Valley Planning Area model
CVPIA	Central Valley Project Improvement Act
CWD	Community Water District
DAU	Detailed Analysis Unit
DCD	Delta Channel Depletion
DETAW	Delta Evapotranspiration of Applied Water
DI	Demand Index
DLL	Dynamic-Link Library
DSIWM	Division of Statewide Integrated Water Management, Department of Water Resources
DSM2	Delta Simulation Model 2
DU	Demand Unit
DWR	California Department of Water Resources
DXC	Delta Cross Channel

EBMUD	East Bay Municipal Utility District
EC	electrical conductivity
EROS	Earth Resources Observation and Science
ET	evapotranspiration
eWRIMS	Electronic Water Rights Information Management System
FAO	Food and Agricultural Organization
FC&WCD	Flood Control and Water Conservation District
FERC	Federal Energy Regulatory Commission
FMS	Flow Management Standard
FNF	full natural flow
FRI	Four Reservoir Index
FRSA	Feather River Service Area
GIS	geographic information system
H&S	Health and Safety
HOR	Head of the Old River
HUC	hydrologic unit code
IBU	in-basin use
ICA	irrigated crop acreage
IDC	Irrigation and Drainage Company
IFII	Impaired Folsom Inflow Index
IFR	instream flow requirement
ITP	Incidental Take Permit
JSA	Joint Settlement Agreement
LP	linear programming
M&I	Municipal and Industrial
MAF	million acre-feet
MFP	Middle Fork Project
MFR	Minimum Flow Requirement
mgd	million gallons per day
MILP	Mixed Integer Linear Programming
MOA	memorandum of agreement
MRDO	minimum required Delta outflow
MW	megawatts
MWC	Mutual Water Company
NASA	National Aeronautics and Space Administration
NDOI	Net Delta Outflow Index
NED	National Elevation Dataset
NHD	National Hydrography Dataset
NLCD	National Land Cover Database

NMFS	National Marine Fisheries Service
NOD	north of Delta
NRCS	Natural Resources Conservation Service
NTU	nephelometric turbidity unit
NWR	National Wildlife Refuge
OCAP	Operation Criteria and Plan
OMR	Old and Middle River
PAE	potential application efficiency
PCWA	Placer County Water Agency
PEST	parameter estimation
PG&E	Pacific Gas and Electric
PPT	parts per thousand
PUD	Public Utility District
PWSS	Public Water System Statistics
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RM	river mile
RMSE	root mean square error
RPA	Reasonable and Prudent Alternative
SacWAM	Sacramento Water Allocation Model
SBA	South Bay Aqueduct
SCS	Soil Conservation Service
SEI	Stockholm Environment Institute
SIMETAW	Simulation of Evapotranspiration of Applied Water
SMSCG	Suisun Marsh Salinity Control Gates
SMUD	Sacramento Municipal Utility District
SOD	south of Delta
SR	surface runoff and return
SRI	Sacramento River Index
SWP	California State Water Project
SWRCB	State Water Resources Control Board
TAF	thousand acre-feet
TUCP	Temporary Urgency Change Petition
UARP	Upper American River Project
UDC	user-defined constraint
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWFE	unstored water available for export
UWMP	Urban Water Management Plan

WA	Water Agency
WBA	Water Budget Area
WCD	Water Conservation District
WD	Water District
WEAP	Water Evaluation and Planning system
WMA	Wildlife Management Area
WPCF	Water Pollution Control Facility
WPCP	Water Pollution Control Plant
WSI	Water Supply Index
WTP	Water Treatment Plant
WUA	Water Users Association
WWTP	Wastewater Treatment Plant
WYT	water year type
X2	Location of the 2 parts per thousand salinity contour (isohaline), one meter above the bottom of the estuary, as measured in kilometers upstream from the Golden Gate Bridge

1 Overview

1.1 Introduction

In 2013, the Stockholm Environment Institute (SEI) contracted with the State Water Resources Control Board (State Water Board) through ICF International to develop a Water Evaluation and Planning system (WEAP) model for use in the update of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The State Water Board's water quality control planning process for approving amendments to the Bay-Delta Plan must ensure the reasonable protection of beneficial uses, which requires balancing competing priorities for water, including municipal and industrial (M&I) use, agricultural use, fish and wildlife, and other environmental use. The State Water Board's process will include an analysis of the effects of any changed flow objectives on the environment in the watersheds in which Delta flows originate, including the Delta, and in areas in which Delta water is used. The planning process will also include an analysis of the economic impacts that could result from changed flow objectives.

This report describes the development of the Sacramento Water Allocation Model (SacWAM) used to support the State Water Board's efforts. SacWAM provides simulated flows on a monthly time step to inform a comparative environmental analysis of potential alterntatives to the Bay-Delta Plan. Monthly time step output from SacWAM is used to estimate the changes in reservoir storage, streamflows, and water supply resulting from potential Bay-Delta Plan modifications.

In 2016, the Delta Science Program (DSP) facilitated an independent scientific review (ISR) of SacWAM to assure transparency and confirm the adequacy of SacWAM to simulate flows that will be used in a comparative analysis of alternatives related to updates of the Bay-Delta Plan, and as part of the Delta Science Program's mission to provide the best possible unbiased scientific information to inform water and environmental decision-making in the Bay-Delta system. The DSP held an ISR peer review panel workshop on October 19, 2016, and provided a review report to the State Water Board on December 19, 2016, titled 'Independent Peer Review of the Sacramento Water Allocation Model (SacWAM). The report contained detailed recommendations for model improvements and suggestions for meeting with local agencies to obtain information to improve SacWAM's representation of the water resources system.

In response to recommendations of the Peer Review panel, the SacWAM development team met with local agencies and undertook additional model refinement to improve the representation of hydrology, water control facilities, and water management in SacWAM. SacWAM model version 1.05 was released in October 2017 which incorporated many refinements suggested by the peer review panel, for example, the simulation period was extended from September 2009 through September 2015, additional climate data was incorporated, and the groundwater representation was modified. Further model development occurred in 2018 and 2019 which incorporated updates to upper watershed hydrology and operations, and CVP and SWP operations based on updates related to the development of CalSim 3 by DWR, Reclamation and their consultants. SacWAM model version 1.2 was released in April 2019 which incorporated these updates. In November of 2019, SacWAM model version 2019.11.22 was released followed with a public presentation in December 2019. SacWAM 2019.11.22 included draft scenarios of the Voluntary Agreement, 45 and 55 percent of unimpaired flow. Since 2019, SacWAM updates have been related to updated regulations such as the 2019 Biological Opinions by the US Fish and Wildlife Service and the National Marine Fisheries Service, the California Department of Fish and Wildlife 2020 Incidental Take Permit (CDFW, 2020), and refining model logic to support the simulation of a Voluntary Agreement alternative. More information on these regulatory assumptions can be found in the environmental documents developed by the State Water Board to support its Bay-Delta planning efforts.

The SacWAM domain is shown in Figure 1-1. The model represents the Sacramento River Hydrologic Region, the Trinity River watershed above the Lewiston gauge (USGS 11525500), and the northern part of the San Joaquin River Hydrologic Region downstream from the gauge at Vernalis (USGS 11303500). The model includes the entire Sacramento-San Joaquin Delta (Delta), and the Delta Eastside streams comprising the Cosumnes, Mokelumne, and Calaveras rivers. SacWAM also includes the Delta-Mendota Canal, California Aqueduct, and San Luis Reservoir. Flows in the San Joaquin River entering the SacWAM model domain at Vernalis are specified based a CalSim 3 simulation by Stantec in 2022. SacWAM represents the water resources within the model domain using a comprehensive approach in which hydrology, water infrastructure, and water management are all contained within the simulation model.

The model was designed to satisfy needs of the State Water Board as it develops an updated Bay-Delta Plan. Model requirements include:

- Period of simulation comprising water years 1922 – 2015.
- A monthly time step.[1]
- Simulation of unimpaired flows.
- Simulation of stream flows throughout the Sacramento and Delta Eastside Tributary Watersheds.
- Simulation of stream flows at United States Geological Survey (USGS) and California Department of Water Resources (DWR) gauges located on the Sacramento River.
- Simulation of Delta inflow, net Delta outflow, and flows within the south Delta.
- Simulation of major water infrastructure and storage regulation.
- Simulation of water allocations, diversions, and return flows on the valley floor.
- Simulation of groundwater pumping.
- Simulation of stream-aquifer interaction.
- Tracking of changes to groundwater storage through mass-balance accounting.

By necessity, SacWAM simplifies the depiction of stream flows by aggregating surface water diversions, return flows, and groundwater inflows to the stream network. Figure 1-2 and Figure 1-3 show the points of interest to the State Water Board where flow is accurately simulated in SacWAM, despite these spatial simplifications.

[1] Crop water demands and rainfall-runoff are determined using a daily time step.

Most reservoirs with storage of greater than 50,000 acre-feet and inter-basin transfers exceeding 15,000 acre-feet per year are represented in SacWAM.[2] Major reservoir operations including those for Trinity, Whiskeytown, Shasta, Oroville, and Folsom are simulated based on their multi-purpose to meet flood control, water supply, and environmental water requirements. For minor reservoirs, storage regulation is simulated using a mix of rule curves based on hydrologic indices and average monthly historical values. For reregulating reservoirs and diversion structures, storage is typically held constant.

Model representation of the valley includes all major water diversions, canals, weirs, and flood bypasses. Agricultural water demands are represented using 20 crop types and the average irrigated acreage for 1998 – 2007. Crop water use is calculated using a daily dual crop coefficient approach (Allen et al., 1998). Urban water demands, divided into indoor and outdoor water use, are based on historical purveyor production data for 2006 – 2010 for major cities and towns and are based on population data for smaller communities. Wildlife refuges represent permanently and seasonally flooded wetlands. Associated water demands are calculated in a manner simulated to irrigated agricultural lands.

Operations of the federal Central Valley Project (CVP) and State Water Project (SWP) significantly affect river and channel flows within much of the model domain. Aspects of the CVP and SWP operations simulated in SacWAM include, but are not limited to:

- Instream flow requirements (IFRs) on the Trinity, Sacramento, Feather, and American rivers and Clear Creek.[3]
- Water Right Decision 1641 (D-1641) Delta flow requirements and Delta export restrictions[4]
- D-1641 water quality requirements.
- National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) 2019 Biological Opinion (BiOp).
- CVP-SWP 2018 Coordinated Operations Agreement (COA).
- Calfiornia Department of Fish and Wildlife (CDFW) 2020 Incidental Take Permit (ITP).
- CVP and SWP water service contracts and settlement agreements.

The model also retains the capability of excluding the 2020 ITP as well as modeling the 2008 USFWS and 2009 NMFS BiOps and 1986 COA. Additionally, SacWAM includes regulatory requirements, such as minimum and maximum reservoir levels and instream flow requirements that affect local reservoir

[2] The exception to this general rule is the watershed above Shasta Dam. This watershed contains PG&E facilities on the McCloud and Pit rivers. Lake McCloud has a capacity of 53 TAF. Big Sage Reservoir, owned by Hot Spring Valley ID, has a capacity of 77 TAF.

[3] Instream flow requirements modeled include both regulatory flow requirements and target flows that may be needed to achieve cold-water temperature targets downstream from reservoirs.

[4] D-1641 (SWRCB, 2001) implements the flow and water quality objectives of the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary and assigns responsibility to DWR and Reclamation for meeting these objectives.

operations and surface water diversions. Many of these flow requirements are specified in Federal Energy Regulatory Commission (FERC) licenses for hydropower projects in the upper watersheds.

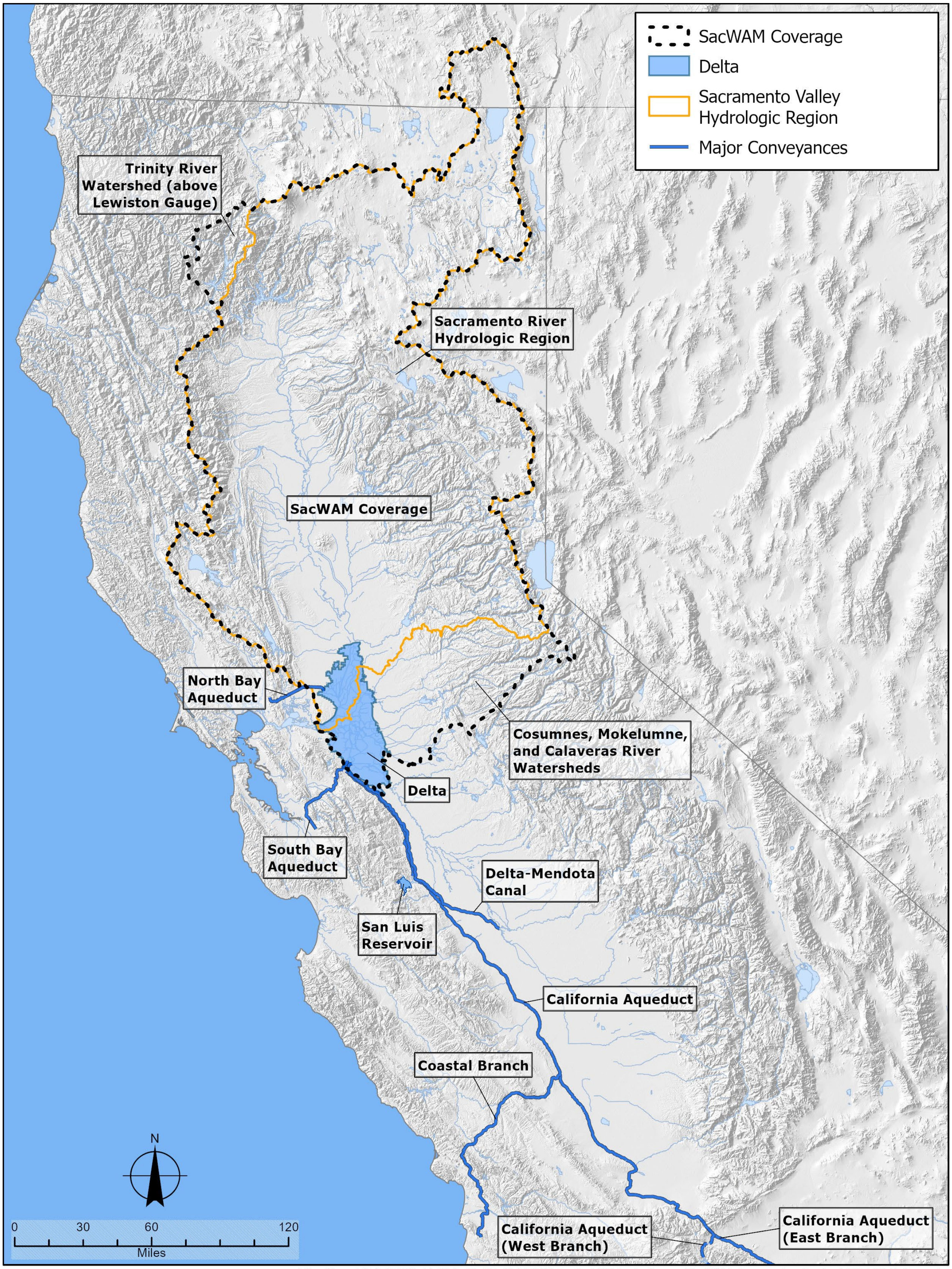

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Figure 1-1. Sacramento Water Allocation Model Domain

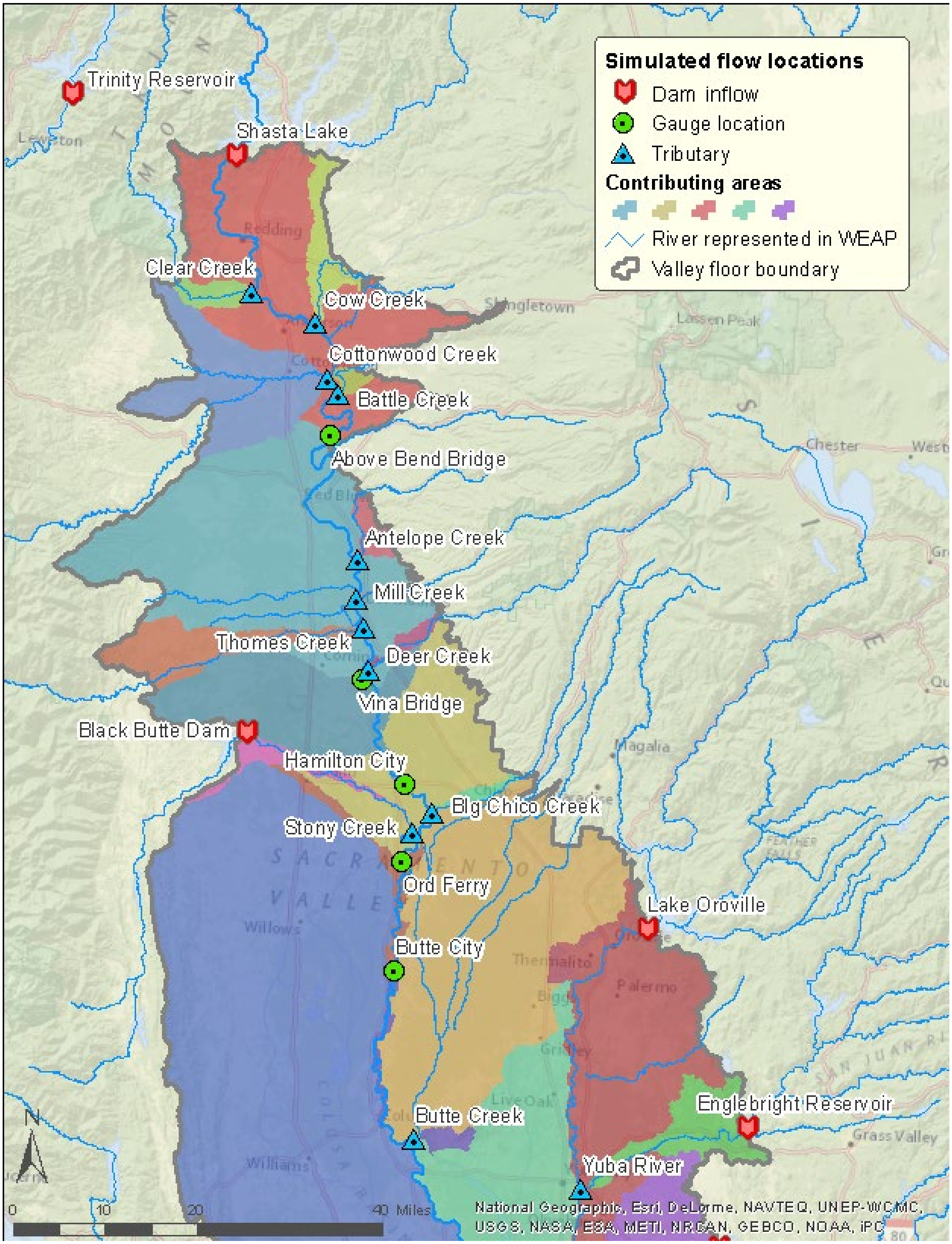

Figure 1-2. Simulated Flow Locations (North)

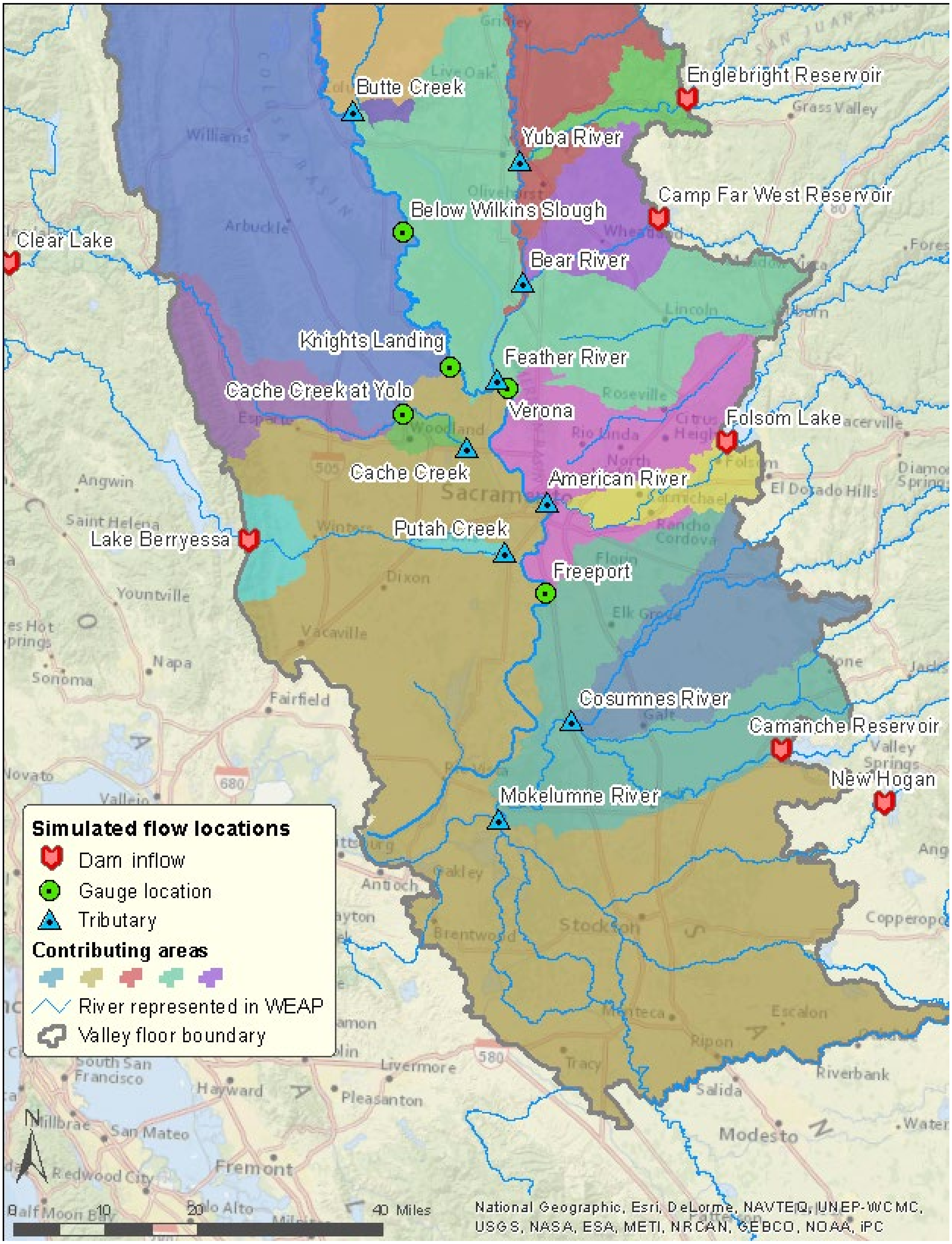

Figure 1-3. Simulated Flow Locations (South)

1.2 Organization and Contents of this Document

This report describes the methods and assumptions used to develop the SacWAM application within the WEAP software that are primarily contained in WEAP's 'Data View'. After the first three introductory chapters, chapter titles correspond to the six major categories found in the Data View "tree" in the WEAP software, and chapter subsection titles match the branch names used in SacWAM. This organizational structure simplifies finding relevant information as a model user navigates through SacWAM. Chapters include information on the representation of the valley floor demands and hydrology, the upper watersheds, and the operations rules for the water management infrastructure. The contents of each chapter are as follows:

Chapter 1, Overview, provides general background and describes the purpose of SacWAM and this document.

Chapter 2, Water Evaluation and Planning System, describes the WEAP software used to develop SacWAM.

Chapter 3, Schematic and Model Domain, describes development of the SacWAM schematic, constructed using WEAP's internal water resources objects.

Chapter 4, Demand Sites and Catchments – Valley Floor and Delta, explains the aggregation of water users into demand units, describes simulation of water demands and water use, and model calibration for the valley floor domain.

Chapter 5, Demand Sites and Catchments – Upper Watersheds, describes the representation of the mountain and foothill watersheds that surround the valley floor, and the calibration of WEAP's internal hydrology model to simulate climate-driven snow accumulation and melt and rainfall-runoff processes.

Chapter 6, Supply and Resources, describes the parameterization of SacWAM's water resources objects using built-in object properties.

Chapter 7, Other Assumptions, describes model input parameters and variables that supplement data attached to WEAP's built-in object properties. These inputs are unique to the SacWAM application.

Chapter 8, User-Defined Linear Programming Constraints, describes complex operating rules that supplement those automatically developed by WEAP from properties of the built-in water resources objects. These constraints are unique to the SacWAM application.

Chapter 9, Key Assumptions, lists model settings that control the mode of simulation.

Chapter 10, Model Calibration, summarizes the calibration of runoff from catchment objects and stream-groundwater interactions and refers readers to Appendices A and B for more detailed discussion of the calibration.

Chapter 11, Model Use and Limitations, discusses appropriate use of SacWAM, lists current model limitations, and makes recommendations for using and interpreting model results.

Chapter 12, References, presents sources cited in this report.

Appendix A, Sacramento Valley Floor and Delta Calibration, discusses the calibration of various aspects of the hydrologic system on the Sacramento Valley floor. Validation results of stream flows, water deliveries, and CVP and SWP operations are also presented.

As described above, parameterization of the model is documented in Chapters 1 to 9 using the same headings found in the WEAP software data tree. The purpose is to help the user navigate the model. For example, if there is a question regarding the *Maximum Flow Volume* on a transmission link on the valley floor, a description of how this parameter was derived can be found by navigating through the table of contents to the valley floor parameterization section (Chapter 6) and following the headings as seen in the WEAP data tree *(Supply and Resources\Transmission links\Linking Rules\Maximum Flow Volume*). Phrases in *italics* in the documentation are model parameters and variables and branches with sub-branches separated by a backslash ('\'). File pathways in the model and documentation directories also use backslashes but are not in italics.

Data and information used to develop SacWAM are contained in a directory structure on a file system that can be provided upon request from the State Water Board. These data and information include:

- **Geographic Information System (GIS) data:** used to develop the schematic and define watershed parameters.
- **Climate data:** used to populate WEAP's watershed objects.
- **Spreadsheets:** contain reservoir storage capacity, groundwater, surface streamflow, urban, and agricultural data used to develop the hydrology and water demand parameters.
- **References:** copies of data references (in pdf format), primarily water demand data.

These data and information are referenced in the document using three methods. The first method is the inclusion of 'File Location Information' tables found throughout the document. The second method is through standard referencing techniques; supporting documents, journal articles, and reports are cited in the text. Data sources are provided in digital form within the directory structure under 'References' except for data sources that are readily available on the internet (typically government-sponsored data repositories) that are simply referenced by their web page address. The third reference method is for supporting GIS or spreadsheet-based data. This type of data is referenced in the text using an alias in **bold** font. These aliases or referenced names are then listed in tables located throughout the document that also provide the actual name for the file and its location in the directory structure. For example, a GIS shapefile that contains a map of river miles is referred in the text as '**river miles**.' In Table 3-5, the alias of referenced named 'river miles' is associated with the shapefile sac_val_stream_miles.shp located in GIS\Hydrology. Table 3-5 provides file information relating to the SacWAM Data and Information DVD for the datasets referenced in Chapter 3.

1.3 WEAP Software

The WEAP software has been under development by SEI for nearly 20 years. The software provides a comprehensive suite of tools for simulating water resources systems including rainfall-runoff hydrology, water resources infrastructure, agricultural, urban, and environmental demands, and the ability to apply complex operating rules and constraints to the water allocation problem. The water allocation problem is solved using linear programming (LP) defined by user-specified demand priorities, water supply preferences, and user-defined constraints (UDCs). The software is well documented and has a well-developed training tutorial provided on the WEAP21 website. Through an arrangement with DWR, the software is provided without charge to all California public agencies. Comprehensive information on the software and download links are available at www.weap21.org.

1.4 Acknowledgements

The SacWAM development team has benefited from information provided by various water agencies and their consultants relating to local project operations within the SacWAM domain. In particular, we would like to acknowledge support from the California Department of Water Resources, Modeling Support Office.

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2 Water Evaluation and Planning System

The text of this chapter first appeared in various chapters of the California Water Plan, Update 2013 document on WEAP (Joyce et al., 2010). Minor edits have been made for consistency with the rest of this document.

This Chapter presents an overview of the WEAP modeling environment that provided the framework for developing the Statewide Hydrologic Region model and Central Valley Planning Area model (CVPA), which were used by DWR to support the California Water Plan, Update 2013, and SacWAM. Focus is given to WEAP's scenario analysis capabilities, water allocation logic, and hydrologic calculations.

2.1 General Description

The WEAP system is a comprehensive, fully integrated river basin analysis tool. It is a simulation model that includes a robust and flexible representation of water demands from different sectors, and the ability to program operating rules for infrastructure elements such as reservoirs, canals, and hydropower projects (Purkey and Huber-Lee, 2006; Purkey et al., 2007; Yates, Purkey et al., 2005; Yates, Sieber et al., 2005; Yates et al., 2008; and Yates et al., 2009). Additionally, it has watershed snow accumulation, snowmelt, and rainfall-runoff modeling capabilities that allow all portions of the water infrastructure and demand to be dynamically nested within the underlying hydrological processes. This functionality allows the modeler to analyze how specific configurations of infrastructure, operating rules, and operational priorities will affect water uses as diverse as instream flows, irrigated agriculture, and municipal water supply under the umbrella of input weather data and physical watershed conditions.

The WEAP software is organized into five 'views', as follows:

- **Schematic View**, in which the spatial layout of the model domain is created, edited, and viewed.
- **Data View**, consisting of a hierarchical tree that organizes modeling data into six major categories: Key Assumptions, Demand Sites and Catchments, Hydrology, Supply and Resources, Water Quality, Other Assumptions, and User-Defined LP Constraints.
- **Results View**, which allows detailed and flexible display of all model outputs in customizable charts and tables. Multiple modeling scenarios can be concurrently displayed. It includes a 'Favorites' option that saves useful charts, including chart formatting.
- **Scenario Explorer View**, in which results or data across many scenarios can be grouped together to help show the relative impacts of multiple scenarios.
- **Notes View**, a word processing tool for making notes or documenting aspects of the modeling input and analysis.

Information on navigating and using the WEAP 'views' can be found in the following documents, which are available at www.weap21.org:

- WEAP Water Evaluation and Planning System User Guide for WEAP 2015, August 2015.

- WEAP Water Evaluation and Planning System Tutorial, August 2016.

2.2 WEAP Approach

The development of all WEAP applications follows a standard approach, as illustrated in Figure 2-1. The first step in this approach is the study definition, wherein the spatial extent and system components of the area of interest are defined and the time horizon of the analysis is set. The user subsequently defines system components (e.g., rivers, agricultural and urban demands) and the network configuration connecting these components. Following the study definition, the 'current accounts' are defined, which is a baseline representation of the system – including existing operating rules to manage both supplies and demands. The current accounts serve as the point of departure for developing scenarios, which characterize alternative sets of future assumptions pertaining to regulations, infrastructure, water demands, and water supplies. Finally, the scenarios are evaluated regarding water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables. In this context, scenarios represent evaluations of water management alternatives under uncertain future conditions. The steps in the analytical sequence are described in greater detail in the following sections.

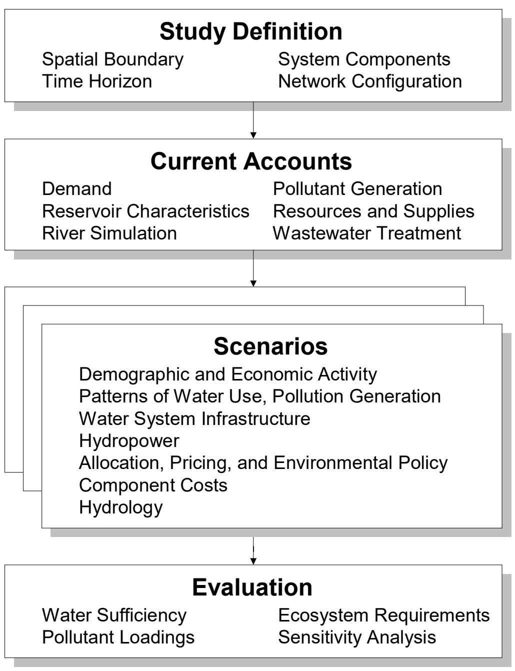


Figure 2-1. Components of a WEAP Application

2.3 Study Definition

Evaluating the implications of storage regulation, streamflows, and diversions along a river, and how the water resources are managed, requires consideration of the entire land area that contributes flow to the river, i.e., the river basin. Within WEAP, it is necessary to set the spatial scope of the analysis by defining the boundaries of the river basin. Within these boundaries, there are smaller rivers and streams (or tributaries) that flow into the main river of interest. Because these tributaries determine the distribution of water throughout the whole basin, it is also necessary to divide the study area into subbasins, or catchments, such that the spatial variability of stream flows can be characterized.

2.3.1 Current Accounts

Current accounts represent the definition of the water system as it currently exists. In SacWAM this baseline scenario is called “Existing.” Current accounts include specification of supply and demand infrastructure (e.g., reservoirs, pipelines, treatment plants). Establishing current accounts also requires the user to calibrate system data and assumptions to mimic the observed operation of the system. This calibration process mayinclude setting parameters for defined catchments so that WEAP can simulate snowmelt and rainfall-runoff using input climate data (i.e., temperature and precipitation), and estimate evaporative water demand in the delineated basins. For details on calibration in SacWAM, see Appendices A and B.

2.3.2 Scenarios

At the heart of WEAP is the concept of scenario analysis. Scenarios are story lines of how a future system might evolve over time. The scenarios can address a broad range of ‘what if’ questions. In this manner, the implications of changes to the system can be evaluated, and subsequently how policy and/or technical interventions may mitigate these changes. For example, WEAP may be used to evaluate the water supply and demand changes for a range of future changes in demography, land use, and climate. In the case of SacWAM, the model will be used to study various in stream flow requirement scenarios and their impacts on water storage, water availability, and stream flows.

2.3.3 Evaluation

Once the performance of a set of response packages has been simulated within the context of future scenarios, the response packages can be compared relative to key metrics. Typically, these metrics relate to water supply reliability, water allocation equity, ecosystem sustainability and cost. However, any number of performance metrics can be defined and quantified within WEAP.

2.4 WEAP Water Allocation

Two user-defined priority systems are used to determine allocations of water supplies to meet demands (modeled as demand sites and as catchment objects for irrigation), instream flow requirements, and for filling (or draining) reservoirs. These are: (1) demand priorities, and (2) supply preferences.

A demand priority is attached to a demand site, catchment, reservoir, or flow requirement, and may range from 1 to 99, with 1 being the highest priority and 99 the lowest.[5] Demand sites can share the same priority, which is useful in representing a system of water rights, where water users are defined by their water entitlement and/or seniority. In cases of water shortage, higher priority users are satisfied as fully as possible before lower priority users are considered. If priorities are the same, shortage will be shared equally (as a percentage of their water demands).

When demand sites or catchments are connected to more than one supply source, supply preferences determine the order of withdrawal. Like demand priorities, supply preferences are assigned a value

[5] Beginning with WEAP version 2018.0105, the upper limit on the demand priority has been expanded from the default of 99 to 999,999,999.

between 1 and 99, with lower numbers indicating preferred water sources. The assignment of these preferences usually reflects economic, environmental, historical, legal, and/or political realities. Several water sources may be available when a preferred water source is insufficient to satisfy all of an area's water demands. WEAP treats additional sources as supplemental supplies and will draw from these sources only after it encounters a shortage or a capacity constraint (expressed as either a maximum flow volume or a maximum percent of demand) associated with a preferred water source.

WEAP's allocation routine uses demand priorities and supply preferences to balance water supplies and demands. To do this, WEAP must assess the available water supplies each time step. While total supplies may be sufficient to meet all the demands within the system, it is often the case that operational considerations prevent the release of water to do so. These rules are usually intended to preserve water in times of shortage so that long-term delivery reliability is maximized for the highest priority water users (often indoor urban demands). WEAP can represent this controlled release of stored water using its built-in reservoir routines.

WEAP uses generic reservoir objects, which divide storage into four zones, or pools, as illustrated in Figure 2-2. These include, from top to bottom, the flood-control zone, conservation zone, buffer zone, and inactive zone. The conservation and buffer pools together constitute a reservoir's active storage. WEAP always evacuates the flood-control zone, so that the volume of water in a reservoir cannot exceed the top of the conservation pool. The size of each of these pools can change throughout the year per regulatory requirements, such as flood control rule curves.

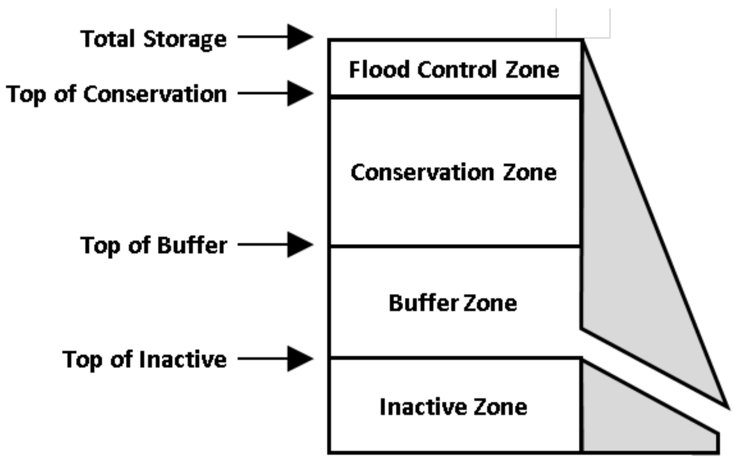


Figure 2-2. WEAP Reservoir Zones

WEAP allows reservoirs to release water from the conservation pool to meet downstream requirements in full. Once the reservoir storage level drops into the buffer pool, the release is restricted according to the buffer coefficient, to conserve the reservoir's dwindling supplies. The buffer coefficient is the fraction of the water in the buffer zone available each month for release. Thus, a coefficient close to 1.0 will cause demands to be met more fully, while rapidly emptying the buffer zone. A coefficient close to zero will leave demands unmet while preserving the storage in the buffer zone. Alternatively, the conservation zone and buffer zone may be assigned different priorities to represent changing priorities as storage reserves dwindle. Water in the inactive pool is not available for allocation, although under extreme conditions evaporation may draw the reservoir below the top of the inactive pool.

2.5 WEAP Hydrology

The hydrology module in WEAP is spatially continuous, with a study area configured as a contiguous set of catchments that cover the entire extent of the represented river basin. This continuous representation of the river basin is overlaid with a water management network of rivers, canals, reservoirs, demand centers, aquifers, and other features (Yates, Purkey et al., 2005; Yates, Sieber et al., 2005). Each catchment is fractionally subdivided into a unique set of independent land-use or land-cover classes that lack detail regarding their exact location within the catchment, but which sum to 100 percent of the catchment's area. A unique climate data set of precipitation, temperature, relative humidity, and wind speed is uniformly prescribed across each catchment. For details on how catchments were developed for SacWAM, refer toChapter 1 and Chapter 5.

In the SacWAM application, hydrological processes are represented using two different approaches. In the mountainous upper watersheds, the *Soil Moisture* method is used to represent rainfall-runoff processes. This method was used in the upper watersheds due to its ability to simulate snow accumulation and melt processes and its relatively small set of input parameters. On the Sacramento Valley floor, the *MABIA* method is used to represent agricultural crops and irrigation management. This method was designed for the simulation of irrigated agriculture and allows the model user to specify several irrigation related parameters.

The Soil Moisture method is one-dimensional, quasi-physical water balance model that depicts the hydrologic response of each fractional area within a catchment and partitions water into surface runoff, infiltration, evapotranspiration (ET), interflow, percolation, and baseflow components. Values from each fractional area (fa) within the catchment are then summed to represent the lumped hydrologic response for all land cover classes, with surface runoff, interflow, and baseflow being linked to a river element; deep percolation being linked to a groundwater element where prescribed; and ET being lost from the system.

The hydrologic response of each catchment is depicted by a 'two-bucket' water balance model as shown in Figure 2-3. The model tracks soil water storage, in the upper bucket, z_{fa}, and in the lower bucket, Z. Effective precipitation, P_e, and applied water, AW, are partitioned into evapotranspiration (ET), surface runoff/return flow, interflow, percolation and baseflow. Effective precipitation is the combination of direct precipitation (P_{obs}) and snowmelt (which is controlled by the temperatures at which snow freezes, T_s, and melts, T_l). Soil water storage in the shallow soil profile (or upper bucket) is tracked within each fractional area, fa, and is influenced by the following parameters: a plant/crop coefficient (kc_{fa}); a conceptual runoff resistance factor (RRF_{fa}); water holding capacity (WC_{fa}); hydraulic conductivity (HC_{fa}); upper and lower soil water irrigation thresholds (U_{fa} and L_{fa}); and a partitioning fraction, f, which determines whether water moves horizontally or vertically. Percolation from each of these fractional areas contributes to soil water storage (Z) in the deep soil zone (or lower bucket) and is influenced by the following parameters: water holding capacity (WC_{fa}), hydraulic conductivity (HC_{fa}), and the partitioning fraction, f.

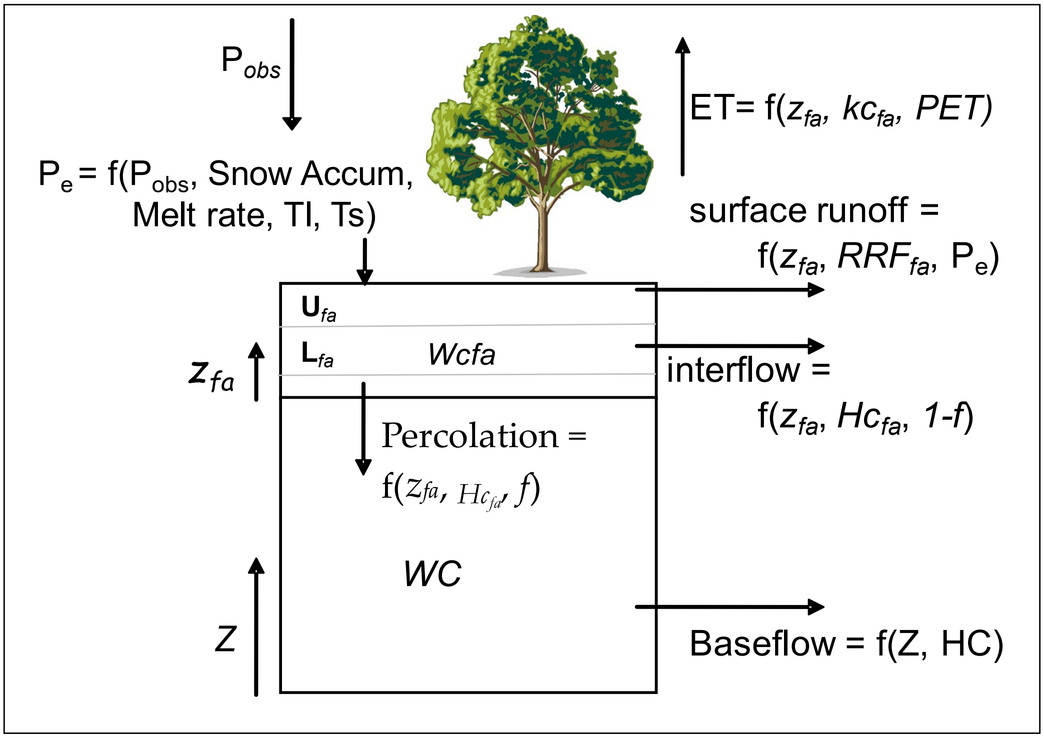


Figure 2-3. Two-Bucket Soil Moisture Method Model

The MABIA method is a daily simulation of transpiration, evaporation, irrigation requirements and scheduling, crop growth and yields, and includes modules for estimating reference evapotranspiration and soil water capacity. It was derived from the MABIA suite of software tools, developed at the Institut National Agronomique de Tunisie by Dr. Ali Sahli and Mohamed Jabloun. More information about MABIA is available at http://mabia-agrosoftware.co. The algorithms and descriptions contained here are for the combined MABIA-WEAP calculation procedure.

The MABIA method is a one-dimensional water balance model that simulates the hydrological response for each land class/crop type within a catchment and partitions rainfall (P) into surface runoff (SR), infiltration (I), evapotranspiration (E and T), and deep percolation (DP), as illustrated in Figure 2-4. For the calculation of evapotranspiration, MABIA uses the dual Kc method, as described in FAO Irrigation and Drainage Paper No. 56 (Allen et al., 1998), whereby the Kc value is divided into a basal crop coefficient, Kcb, and a separate component, Ke, representing evaporation from a shallow soil surface layer. The basal crop coefficient represents ET when the soil surface is dry but sufficient root zone moisture is present to support full transpiration. The MABIA method also provides parameters for the user to specify irrigation efficiency and effective rainfall. The method can be used to model both agricultural crops as well as non-agricultural land classes, such as forests and grasslands.

Although the time step for MABIA is daily, the time step for the rest of the WEAP analysis does not need to be daily. For each WEAP time step (e.g., monthly), MABIA would run for every day in that time step and aggregate its results (evaporation, transpiration, irrigation requirements, runoff, and infiltration) to that time step. For example, in January, MABIA would run from January 1 to 31, and sum up its results as January totals, including the supply requirement for irrigation. WEAP would then solve its supply allocations, using this monthly irrigation requirement from the MABIA catchments. In the case where the supply delivered to the catchments was less than the requirement, MABIA would rerun its daily simulation, this time using only the reduced amount of irrigation to determine actual evaporation, transpiration, irrigation requirements, runoff, and infiltration.

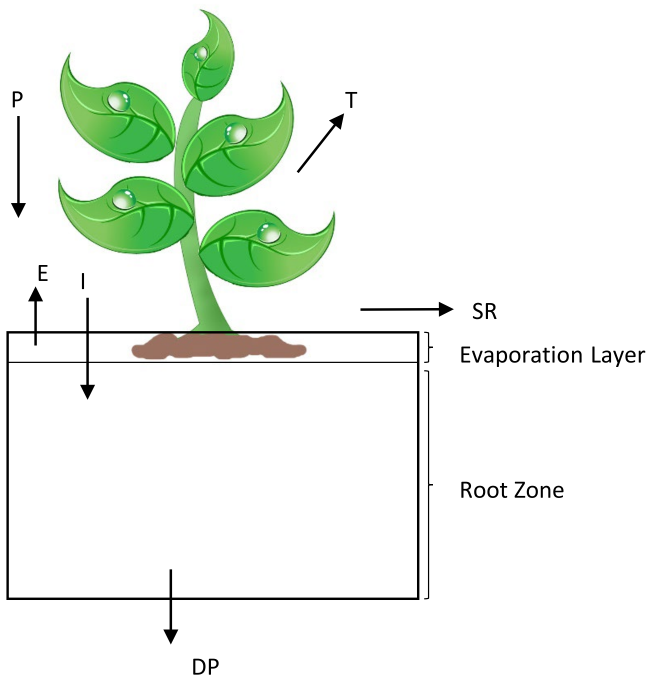


Figure 2-4. MABIA Soil Moisture Model

2.6 WEAP Solution Methodology

At each time step, WEAP first computes the horizontal and vertical fluxes using the catchment objects, which it passes to each river and groundwater object. Next, water allocations are made for the given time step by passing constraints related to the characteristics of reservoirs and the distribution network, environmental regulations, and the priorities and preferences assigned to demand sites to a linear programming optimization routine that maximizes demand 'satisfaction' to the greatest extent possible (Yates, Sieber et al., 2005). All flows are assumed to occur instantaneously; thus, demand sites can withdraw water from the river, use some of the water consumptively, and optionally return the remainder to a receiving water body in the same time step. As constrained by the network topology, the model can also allocate water to meet any demand in the system, without regard to travel time. Thus, the model time step should be at least the length of the water residence time within the study area.

A form of linear programming known as mixed integer programming (MILP) is used to solve the water allocation problem whose objective is to maximize satisfaction of demand, subject to supply preferences, demand site priorities, mass balances, and other constraints. The problem is iteratively solved within each time step by sequentially considering the ranking of the demand priorities and supply preferences. The approach has some attributes of a more traditional dynamic programming algorithm, where the model is solved in sequence based on the knowledge of values derived from the previous variables and equations. Individual demand sites, reservoirs, and in-stream flow requirements are assigned a unique priority number, which are integers that range from 1 (highest priority) to 99 (lowest priority). Those entities with a Priority 1 ranking are members of Equity Group 1, those with a Priority 2 ranking are members of Equity Group 2, and so on. The MILP constraint set is written to supply an equal percentage of water to the members of each Equity Group. This is done by adding to the MILP for each demand site:

- A percent coverage variable, i.e., the percent of the total demand satisfied at a given time step.
- An equity constraint that equally satisfies all demands within each Equity Group in terms of percentage of satisfied demand.
- A coverage constraint, which ensure the appropriate amount of water supplied to a demand site or the meeting of an instream flow requirement.

The MILP is solved at least once for each Equity Group that maximizes coverage to demand sites within that Equity Group. When solving for Priority 1, WEAP will suspend (in the MILP) allocations to demands with Priority 2 and lower. Then, after Priority 1 allocations have been made that ensure equity among all Priority 1 members, Priority 2 demands are activated (but 3 and lower are still not set). Like demand priorities, supply preferences apply an integer ranking scheme to define which sources will supply a single demand site. Often, irrigation districts and municipalities will rely on multiple sources to meet their demands, so there is a need for a mechanism in the allocation scheme to handle these choices. To achieve this effect in the allocation algorithm, each supply to the same demand site is assigned a preference rank, and within the given priority, the MILP algorithm iterates across each supply preference to maximize coverage at each demand site. In addition, the user can constrain the flow through any transmission link to a maximum volume or a percent of demand, to reflect physical (e.g., pipe or pump capacities) or contractual limits, or preferences on mixing of supplies. These constraints, if they exist, are added to the MILP.

Upon solution of the MILP, the shadow prices on the equity constraints are examined and if non-zero for a demand site, then the water supplied for this demand site is optimal for the current constraint set. The supply set from the optimal solution of the current MILP, its equity constraint removed, and the LP is solved again for the current Equity Group and the equity constraints re-examined. This is repeated until the equity constraint for each demand site returns a positive shadow price, and their supplies set.

The MILP then iterates across the supply preferences, and this too is repeated until all the demand sites have an assigned water supply for the given Equity Group. The algorithm then proceeds to the next Equity Group. Once all Equity Groups are solved at the current time step, the algorithm proceeds to the next time step where time dependent demands and constraints are updated, and the procedure repeats.

3 Schematic and Model Domain

The SacWAM schematic provides a geographically based, high-resolution representation of water supplies in the mountain and foothill watersheds, and water demands and water use on the valley floor and Delta. This chapter provides an overview of WEAP's schematic objects, physical features that are included in the SacWAM schematic, and SacWAM schematic construction. This chapter discusses physical elements of the model and the model's geographic extent. Operational logic and simulation details are described in later chapters.

3.1 Overview

The development of all WEAP applications follows a standard approach. The first step in this approach is the *Study Definition*, wherein the spatial extent and system components of the area of interest are defined and the time horizon of the analysis is set. Subsequently, *System Components* (e.g., rivers, reservoirs, agricultural and urban demands) and the network configuration connecting these components are defined. Following the *Study Definition*, the model's *Current Accounts* are defined, which represent the system under existing conditions – including operating rules to manage both water supplies and water demands. The *Current Accounts* serve as the point of departure for developing scenarios, which characterize alternative sets of assumptions pertaining to policies, regulatory requirements, and water infrastructure.

3.1.1 Study Definition

The SacWAM domain, described in Section 1.1 and presented in Figure 1-1, includes the Sacramento River Hydrologic Region and northern part of the San Joaquin River Hydrologic Region.[6] Within this domain, SacWAM considers two types of watersheds. The first type, known as 'upper' watersheds, includes the foothill and mountain watersheds of the Trinity/Cascade, Sierra Nevada, and Coast Ranges. These watersheds are characterized by complex topography, steep slopes, shallow soils, and limited aquifer systems. Upper watersheds are relatively undeveloped and are primarily a mix of forest, pasture, and small, scattered communities. The second type of watershed, known as 'valley floor' watersheds, are located between the upper watersheds and the Delta. In contrast to the upper watersheds, the valley floor watersheds have been extensively developed over time, are highly managed, and are composed of rich agricultural lands, wildlife refuges and wetlands, and urban areas. Valley watersheds overlay the deep alluvial Sacramento Groundwater Basin and parts of the San Joaquin Groundwater Basin.

No single source of information has been used to construct the divide between upper and valley floor watersheds. Elevation is an imprecise indicator because of valley grades and the presence of terraces

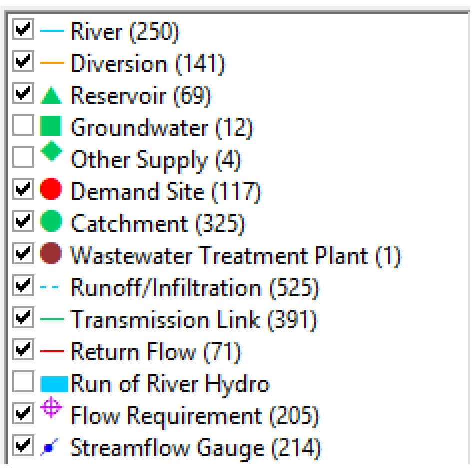
[6] The United States is divided and sub-divided into successively smaller hydrologic units that are classified in to four levels: regions, subregions, accounting units, and cataloging units. The hydrologic units are arranged within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system. The Central Valley consists of subregions 1802 (aka Sacramento River Hydrologic Region), 1804 (aka San Joaquin River Hydrologic Region), and 1803 (aka Tulare Lake Hydrologic Region).

and side valleys. In general, the borders of the valley floor are defined where alluvial soils merge with bedrock features. SacWAM defines the boundary of the valley watersheds according to stream gauge locations and foothill dams, where historical streamflows are known. This flow-based boundary is typically located slightly upslope from the Sacramento and San Joaquin groundwater basin boundaries.

GIS shapefiles used in the construction of the model are stored within the SacWAM data directory and can be displayed in the model's schematic view to orient the model user. File location information for these shapefiles and other files mentioned in this section is presented in Table 3-5. The shapefiles provide visual cues in understanding and interpreting the SacWAM schematic. An example of these shapefiles is presented in Figure 3-1.

3.1.2 System Components

The SacWAM schematic is built using WEAP's system components that define the water supply system and the water demands. The WEAP palette of components is shown below. The following sections describe each component as it is used in SacWAM.



3.2 Rivers and Diversions

Schematic construction began with defining rivers, canals, and other waterways. Shapefiles were used to identify and trace hydrologic features that were added to the schematic. Shapefiles of **river miles** (RMs) and **canal miles** (CMs), developed using aerial imagery, were subsequently used to identify points of diversion, as well as the location of other water control infrastructure.

3.2.1 River Arcs

River arcs represent rivers, streams, and other natural channels. Blue arcs are used to represent natural waterways in the SacWAM schematic and are listed in Table 3-1. SacWAM represents the Trinity River upstream from Lewiston (USGS gauge 11525500), the entire Sacramento River, Feather River, and American River, and the San Joaquin River downstream from Vernalis (USGS gauge 11303500). Additionally, the model represents streams identified by the State Water Board that will form part of Phase IV of the Bay-Delta Plan update.

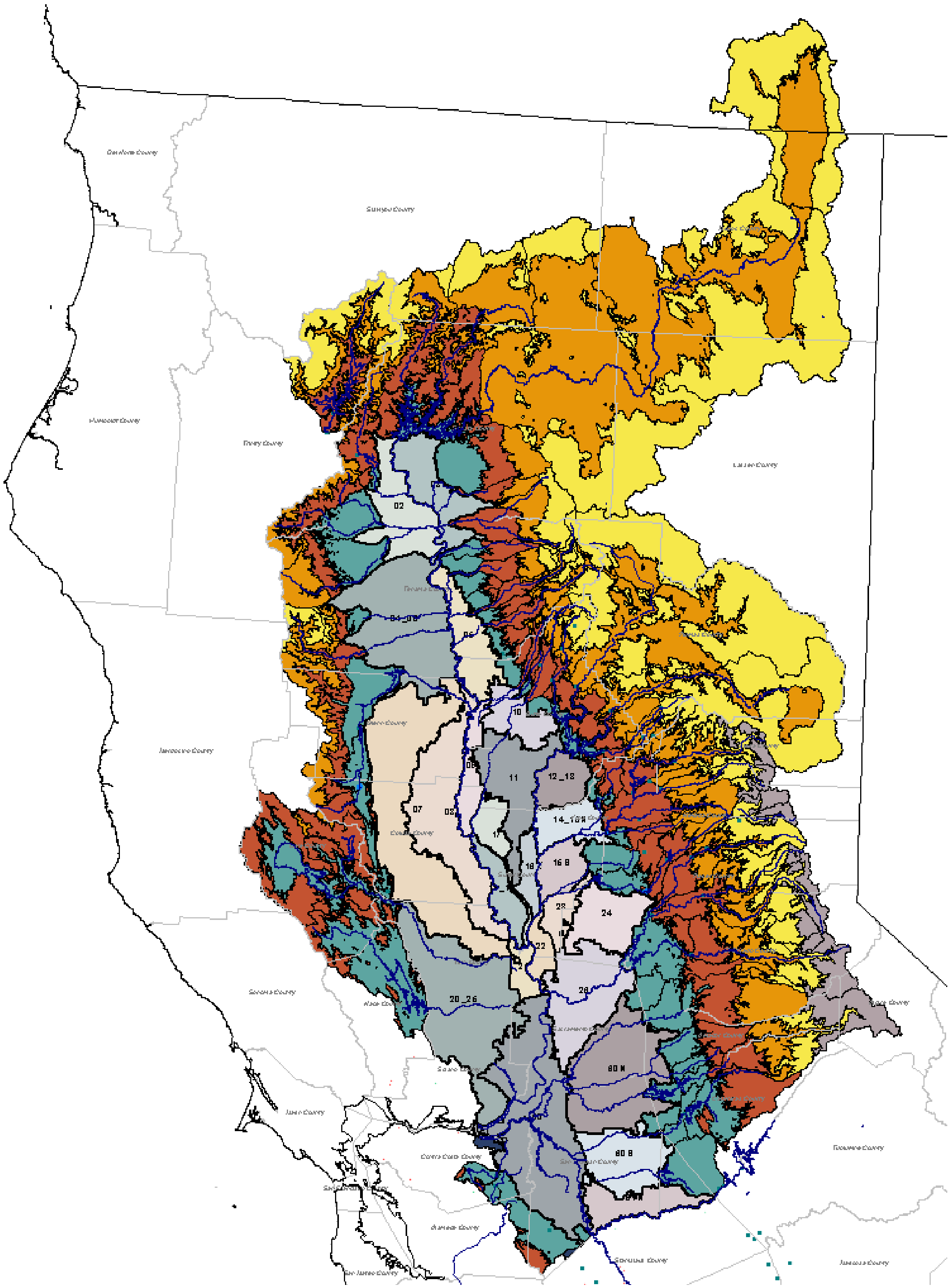


Figure 3-1. SacWAM GIS Layers

Table 3-1. Natural Rivers, Channels, and Waterways Represented in SacWAM

Name	Name	Name
American River	Gerle Creek	North Fork of North Fork American River
Antelope Creek	Grizzly Creek	Old and Middle River
Auburn Ravine	Hamilton Branch	OMR Reverse Flow
Battle Creek	Head of Old River	Oregon Creek
Bear Creek	Honcut Creek	Paynes Creek
Bear River	Indian Creek	Pilot Creek
Bear River (Mokelumne Watershed)	Indian Slough Eastward	Pit and Upper Sacramento River
Big Chico Creek	Indian Slough Westward	Putah Creek
Big Grizzly Creek	Jackson Creek	QWest
Brush Creek	James Bypass inflow to Mendota Pool	Rock Creek
Bucks Creek	Kellogg Creek	Rubicon River
Butt Creek	Little Chico Creek	Sacramento River
Butte Creek	Little Dry Creek	San Joaquin River below Vernalis
Cache Creek	Little Last Chance Creek	San Joaquin River to Mendota Pool
Cache Slough	Little Rubicon River	Secret Ravine
Calaveras River	Little Stony Creek	Silver Creek
Camp Creek	Littlejohns Creek	Silver Fork American River
Canyon Creek	Long Canyon Creek	Slate Creek
Caples Creek	Lost Creek	Sly Creek
Clear Creek	Marsh Creek	Sly Park Creek
Cole Creek	McCloud River	South Fork American River
Cosumnes River	McClure Creek	South Fork Calaveras River
Cottonwood Creek	Middle Fork American River	South Fork Cosumnes River
Cow Creek	Middle Fork Cosumnes River	South Fork Cottonwood Creek
Deer Creek (Sacramento River tributary)	Middle Fork Feather River	South Fork Feather River
Deer Creek (Yuba watershed)	Middle Fork Mokelumne River	South Fork Mokelumne River
Dry and Hutchinson Creeks	Middle Yuba River	South Fork Rubicon River
Dry Creek (Natomas Drain tributary)	Mill Creek	South Fork Silver Creek
Dry Creek (Mokelumne watershed)	Mokelumne River	South Yuba River
Dry Creek (Yuba watershed)	North and South Fork Canyon Creek	Stony Creek
Duncan Creek	North Fork American River	Thomes Creek
Echo Creek	North Fork Cache Creek	Tiger Creek
Elder Creek	North Fork Calaveras River	Trinity River
Fall River	North Fork Cosumnes River	Upper Pit River
Feather River below Oroville	North Fork Feather River	West Branch Feather River
Fordyce Creek	North Fork Mokelumne River	Wolf Creek
French Dry Creek	North Fork Middle Fork American River	Yuba River
Georgiana Slough		

WEAP places restrictions on river arcs that in certain instances prevents the arcs from being used to represent natural channels. First, flow in a river arc must be unidirectional, from upstream to downstream. Second, river arcs may flow into other river arcs as tributaries but may not divide into two or more river arcs as distributaries. Therefore, the following diversion (orange) arcs are used to represent natural channel flows in SacWAM.

- **Head of Old River** diversion arc: Represents flow from the San Joaquin River to Old River near the City of Tracy.
- **Indian Slough Eastward** and **Indian Slough Westward** diversion arcs: Represent bidirectional flow in a Delta channel linking the San Joaquin River and Old River. Its inclusion in the model is important for correctly simulating regulatory flow compliance for the Old and Middle rivers. Flows through Indian Slough bypass the Old River flow compliance location, thus south Delta water diversions have a less than 1-to-1 effect on gauged Old and Middle River reverse flows.
- **Georgiana Slough** diversion arc: Represents the Delta channel linking the Sacramento and Mokelumne rivers. A diversion arc is also used to represent the Delta Cross Channel, which is categorized as an artificial channel.
- **Qwest** diversion arc: Represents the net westward flow of the San Joaquin River at Jersey Point averaged over a tidal cycle. In SacWAM, it represents reverse flows, which may occur when Delta diversions and agricultural demands in the south and central Delta exceed the inflow into the central Delta. Qwest is further described in Section 8.9.2.
- **OMR Reverse Flow** diversion arc: Represents the total flow from north to south in the Old and Middle River. Reverse flows may occur when the combined CVP and SWP export pumping exceeds flows at the Head of the Old River.

The reaches of the Old and Middle rivers (OMR) between the intake to Jones Pumping Plant and the confluence with the San Joaquin River are represented by two parallel river arcs. Flow is north to south in one arc (reverse flow) and south to north in the other arc (positive flow).

Similarly, the San Joaquin River downstream from the mouth of the Mokelumne River is represented by two parallel river arcs. Flow is west to east in one arc (reverse flow) and east to west in the other arc (positive flow).

3.2.2 Diversion Arcs

Diversion arcs typically represent manmade conveyance facilities, including canals, pipelines, tunnels, and hydropower penstocks. They are represented by orange arcs in the SacWAM schematic and are listed in Table 3-2.

Table 3-2. Conveyance Facilities Represented in SacWAM

Facility	Facility	Facility
Auburn Tunnel	Electra Tunnel	Palermo Canal
BDCP Tunnels	Folsom South Canal	Pardee to Amador
Bear River Canal	Freeport Intertie	PCWA Buying Point YB 136
Belden Tunnel	Freeport Pumping Plant	Poe Tunnel
Bella Vista Pipeline	Fremont Weir	Power Canal
Bowman Spaulding Conduit	French Meadows Hell Hole Tunnel	Prattville Tunnel
Brush Creek Tunnel	Georgetown Divide Ditch	Putah South Canal
Buck Grizzly Tunnel	Georgiana Slough	Ralston Tunnel
Buck Loon Tunnel	Gerle Canal	Richvale Canal
Bucks Creek Powerhouse	Glenn-Colusa Canal	Robbs Peak Tunnel
Butte Slough	Hamilton Branch Powerhouse	Rock Creek Tunnel
Butte Slough Outfall Gates	Hell Hole Tunnel	Rock Slough Intake
California Aqueduct	Jaybird Conduit	Rubicon Rockbound Tunnel
California Aqueduct East and West Branches	Jenkinson Lake Camino Conduit	Sacramento Weir
Camino Conduit	Joint Board Canal	San Luis Canal
Camp Creek Diversion Tunnel	Jones Fork Tunnel	Slate Creek Tunnel
Camptonville Tunnel	Kelly Ridge Powerhouse	South Bay Aqueduct
Caribou Powerhouses 1 and 2	Knights Landing Ridge Cut	South Canal
Chalk Bluff Canal	Lake Valley Canal	South Fork Tunnel
Chicago Park Flume	Lohman Ridge Tunnel	South Sutter WD Main Canal
Clear Creek Tunnel	Long Canyon Creek Diversion Tunnel	South Yuba Canal and Wasteway
Colgate Powerhouse	Loon Lake Powerplant	Spring Creek Conduit
Colusa Basin Drain	Los Vaqueros Pipeline	Sutter Bypass
Colusa Weir	Los Vaqueros to Transfer[1]	SWP San Luis Fill
Combie Ophir Canal	Lower Bear River Tunnel	TCC to GCC Intertie
Constant Head Orifice	Lower Boardman Canal	Tehama-Colusa Canal
Contra Costa Canal	M and T 3Bs Goose Lake	Tiger Creek Conduit
Cox Spill	Milton Bowman Tunnel	Tiger Creek Powerhouse
Cresta Tunnel	Miners Ranch Canal	Tisdale Weir
Delta Cross Channel	Miocene Canal	Toadtown Canal
Delta-Mendota Canal	Mokelumne Aqueduct	Transfer to Los Vaqueros[1]
DMC_CA Intertie	Mokelumne Los Vaqueros Intertie	Union Valley Powerhouse
Drum Canal	Moulton Weir	Upper Bear River Tunnel
Duncan Creek Tunnel	Natomas Cross Canal	West Point Powerhouse
Dutch Flat Flume	Natomas East Main Drain	Western Canal
Dutch Flat Powerhouse No. 1	North Bay Aqueduct	White Rock Tunnel
EBMUD Intertie (Freeport)	Oak Flat Powerhouses	Wise Canal
Echo Lake Conduit	Old River Pipeline	Wise Lower Boardman Intertie
El Dorado Akin Powerhouse	Oxbow Powerhouse	Yolo Bypass
El Dorado Canal		

Note:
[1] The Los Vaqueros Transfer Pipeline is a bidirectional facility that connects Contra Costa Water District's Transfer Station to Los Vaqueros Reservoir. The pipeline is used to both fill the reservoir and withdraw water from storage. In SacWAM, this single pipeline is represented using two diversion arcs. An integer variable prevents both filling and release within the same time step.

Key:
BDCP=Bay-Delta Conservation Plan, CA=California Aqueduct, DMC=Delta-Mendota Canal, EBMUD=East Bay Municipal Utility District, GCC=Glenn-Colusa Canal, OMR=Old and Middle River, SWP=State Water Project, TCC=Tehama-Colusa Canal.

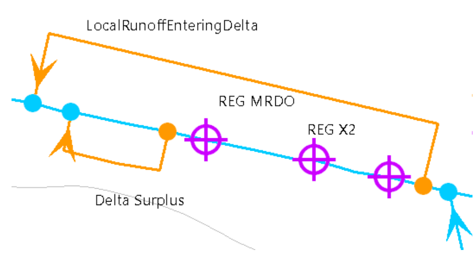
Additional to the diversions listed in Table 3-2, the SacWAM schematic includes diversion arcs to represent other aspects of the Sacramento Valley and Delta water system. These diversions include:

- **Canal Losses**: diversion arcs representing seepage from canals to groundwater or loss by evaporation. Canal loss arcs (and the seepage loss) include those for the Bear River Canal (7%), Chalk Bluff Canal (12.5%), Lower Boardman Canal (12%), and Putah South Canal (8%).[7]
- **Water Treatment Plant Intakes**: diversion arcs representing water treatment plants that serve multiple DUs (WEAP does not contain an object for water treatment plants). These are described in Section 3.10.
- **Bias Corrections**: Outflows from the river system to correct for bias in the SacWAM hydrology. These include flow adjustments at the Bend Bridge and Butte City gauges on the Sacramento River (*Headflow Adjustment Bend Bridge Outflow* and *Headflow Adjustment Butte City Outflow*). SacWAM also includes inflow adjustments at these locations using river arcs. Flow adjustments are only made during high-flow events.
- **Delta Depletions**: SacWAM includes the option of using preprocessed time series data to represent net channel depletions within the Delta. As part of this option, the model includes seven accretion arcs (represented using river objects) and seven depletion arcs (represented using diversion objects). These are labelled 'Delta Depletion X' (where X is a number).
- **Stream Losses**: SacWAM includes a depletion on the American River immediately upstream from Folsom Lake to represent evaporative losses from the upper watershed.
- **Consumptive Use**: SacWAM includes a depletion on the Feather River immediately upstream from Lake Oroville to represent irrigation consumptive losses from the upper watershed.

3.2.2.1 Delta Outflow

The SacWAM representation of net Delta outflow, shown below, is conceptual in nature and divides the tidally averaged freshwater outflow into three components: required Delta outflow; surplus Delta outflow; and outflow from local runoff entering the Delta. These components are described below.

3.2.2.1.1 Total Delta Outflow



Total Delta outflow is the flow in the Sacramento River arc immediately downstream from the confluence with the San Joaquin River, as indicated by the blue node bottom right.

3.2.2.1.2 Local Runoff Entering Delta

Lands adjacent to, but lying outside of the Delta, may contribute a significant volume of Delta inflow following heavy rainfall. This inflow is not included in the

[7] Canal losses for the Bear River Canal and Chalk Bluff Canal are based on the 1963 Consolidated Contract between Nevada Irrigation District and Pacific Gas and Electric Company. Canal losses for the lower Boardman Canal are based on the Yuba-Bear ResSim model developed for Nevada ID 2011 license application, FERC Project No. 2266. Canal losses for the Putah South Canal are from the Integrated Regional Water Management Plan and Startegic Plan (SCWA, 2005).

D-1641 index of Delta inflow, nor is it part of the Delta mass balance for determining D-1641 Delta outflow standards. In SacWAM, this portion of flow is conveyed through the diversion arc *LocalRunoffEnteringDelta* and is not available for meeting existing regulatory Delta outflow requirements as indicated by WEAP's IFR objects (*MRDO*, *X2*). Figure 3-2 shows ungauged runoff entering the Delta.

3.2.2.1.3 Required Delta Outflow

Required Delta outflow, represented by the Sacramento River arc downstream from the *Delta Surplus* diversion arc, is the tidally averaged freshwater outflow required to meet regulatory requirements.

3.2.2.1.4 Surplus Delta Outflow

Surplus Delta outflow, represented by flow through the orange diversion arc labeled 'Delta Surplus', is the Delta outflow (less the local runoff entering the Delta) that is over and above the flow needed to meet regulatory requirements.

3.2.2.2 California Aqueduct

SacWAM represents the California Aqueduct, stretching from Clifton Court Forebay to its division in to the West and East Branches. To simplify simulation of CVP and SWP joint-use facilities south of the Delta, the CVP and SWP conveyance infrastructure has been artificially separated into two distinct systems. The capacity of the California Aqueduct–Delta-Mendota Canal Intertie is set to zero and the capacity of the Delta-Mendota Canal is modeled as 4,600 cfs along its entire reach.[8] The CVP share of the joint-reach is modeled as a separate canal diverting from the Delta-Mendota Canal downstream from O'Neill Pumping Plant and San Luis Reservoir.

3.2.2.2.1 Delta-Mendota Canal

SacWAM represents the 117-mile-long Delta-Mendota Canal from the Jones Pumping Plant to the Mendota Pool. To represent CVP south-of-Delta demands, the SacWAM schematic includes the reach of the San Joaquin River from Mendota Dam to Sack Dam and inflows from the James Bypass and the San Joaquin River below the Chowchilla Bifurcation Structure.

3.2.2.2.2 O'Neill and Gianelli Pumping Generating Plants

In SacWAM, the CVP and SWP shares of San Luis Reservoir are represented as two distinct reservoirs for water accounting purposes. WEAP contains no objects for offstream reservoirs; reservoir objects must be located on a river arc. Therefore, SacWAM uses two artificial rivers to locate the CVP and SWP shares of San Luis Reservoir, as shown below.

[8] The purpose of the Intertie is to improve Delta-Mendota Canal conveyance and to improve operational flexibility for operations, maintenance, and emergency activities. The Delta-Mendota Canal capacity upstream from the O'Neill Forebay and the pumping capacity at O'Neill Pumping Plant is about 4,200 cfs. Before the Intertie was built, pumping at Jones Pumping Plant could only exceed 4,200 cfs if deliveries were made to contractors located upstream from the O'Neill Pumping Plant.

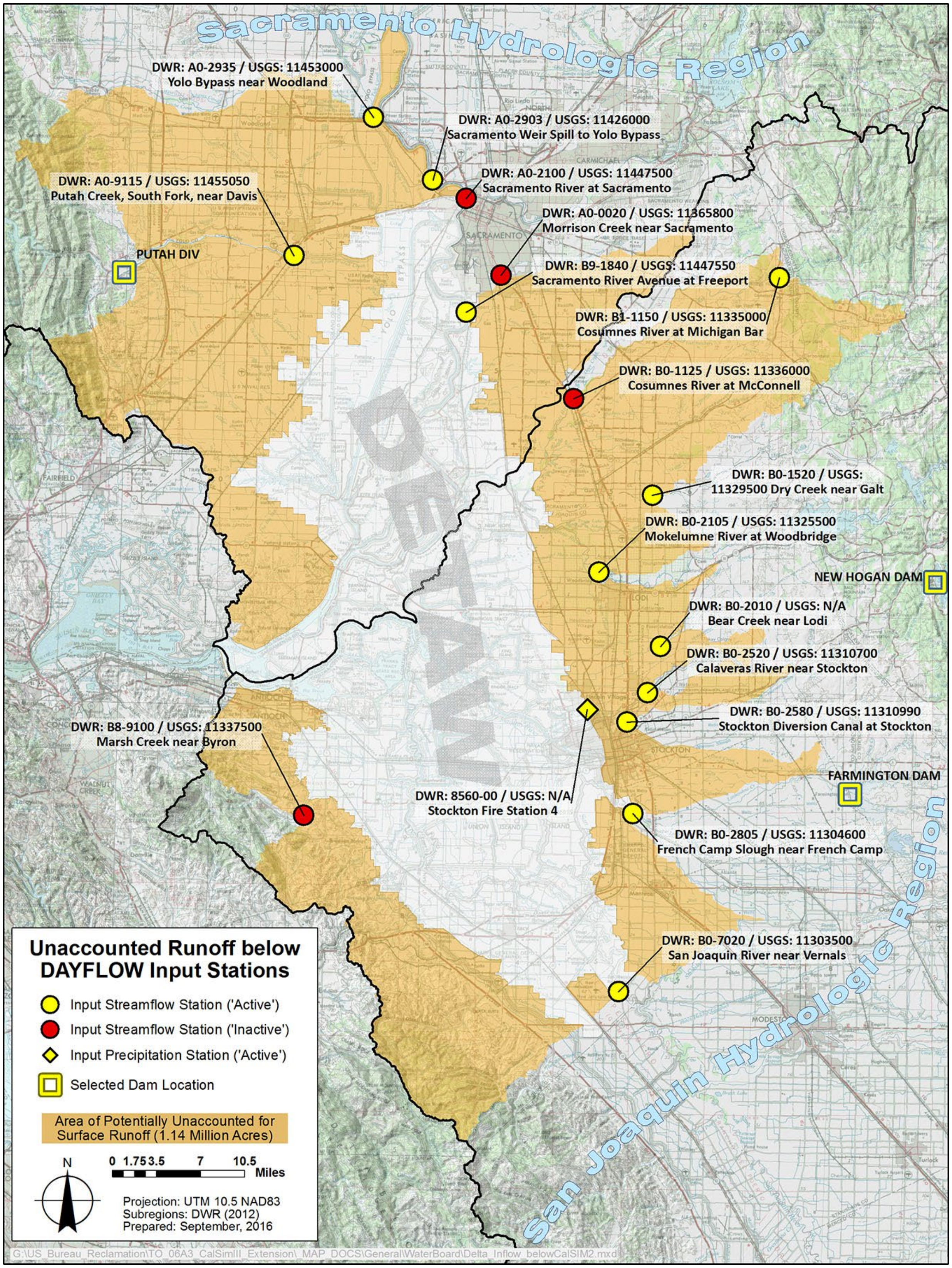
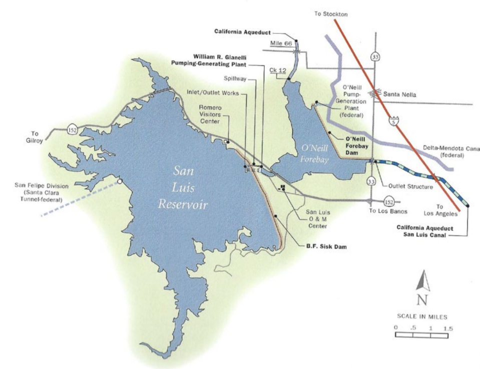


Figure 3-2. Ungauged Runoff Entering the Delta

The O`Neill Pump-Generating Plant consists of an intake channel leading off the Delta-Mendota Canal and six pump-generating units. Normally these units operate to lift water into the O`Neill Forebay. From there, CVP water flows through the joint-reach or is lifted into San Luis Reservoir by the Gianelli Pump-Generating Plant. Water released from the reservoir generates power as it passes back through the Gianelli Pump- Generating Plant. CVP water may subsequently flow back to the Delta-Mendota Canal through the O`Neill Pump-Generating Plant or flow through the Joint Reach of the California Aqueduct for delivery to CVP contractors.



Simulation of the CVP and SWP shares of San Luis Reservoir requires multiple arcs linking the California Aqueduct and Delta-Mendota Canal to the two simulated reservoirs. One set of arcs represents flow of CVP water from the O'Neill Pumping Plant and the Gianelli Pumping Plant to fill the reservoir and the release of CVP water back to the Joint-Reach (represented as two separate canals) or Delta-Mendota Canal. A similar pair of arcs represents the flow of SWP water through the Gianelli Pump-Generating Plant either to fill or drain the reservoir. The additional arc labelled 'CVP JPOD' represents wheeling of CVP water through Banks Pumping Plant and storage of this water in San Luis Reservoir.

3.3 Reservoirs

SacWAM represents all major water supply reservoirs within the model domain that have a storage capacity greater than 50,000 acre-feet. SacWAM also represents reservoirs used for hydropower in cases where their storage regulation significantly affects seasonal river flows downstream. Additionally, smaller reservoirs are included in the schematic to help orient the model user or to define points of diversion, for example, Lewiston Reservoir on the Trinity River provides a forebay for diversions to the Sacramento Valley through the Clear Creek Tunnel. Table 3 - lists the reservoirs contained in SacWAM, and river on which the reservoir is located. For more information on reservoir parameters and operational logic, see Section 6.1.2.

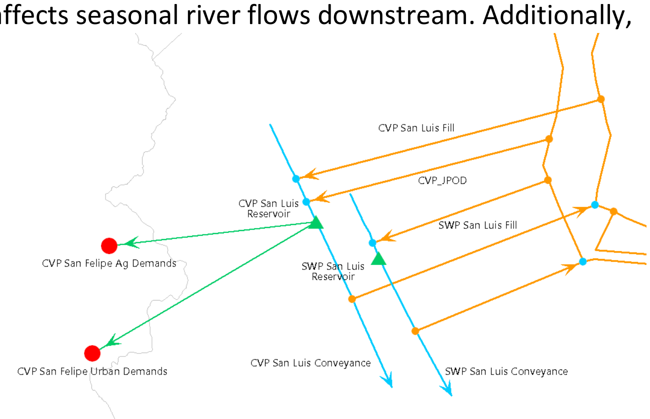


Table 3-3. Lakes and Reservoirs Represented in SacWAM

SacWAM River	Reservoir/Lake	SacWAM River	Reservoir/Lake
American River	Folsom Lake	North Fork Feather River	Belden Reservoir
American River	Lake Natoma	North Fork Feather River	Cresta Reservoir
Bear River	Camp Far West	North Fork Feather River	Lake Almanor
Bear River	Lake Combie	North Fork Feather River	Poe Reservoir
Bear River	Rollins Reservoir	North Fork Feather River	Rock Creek Reservoir
Bear River (Mokelumne)	Lower Bear	North Fork Mokelumne River	Salt Springs Reservoir
Big Grizzly Creek	Lake Davis	North Fork of NF American	Lake Valley Reservoir
Bucks Creek	Bucks Lake	Offstream	CVP San Luis Reservoir
Butt Creek	Butt Valley Reservoir	Offstream	SWP San Luis Reservoir
Cache Creek	Clear Lake	Old and Middle River	Clifton Court Forebay
Calaveras River	New Hogan Reservoir	Pilot Creek	Stumpy Meadows Reservoir
Canyon Creek	Bowman Lake	Power Canal	Thermalito Afterbay
Caples Creek	Caples Lake	Putah Creek	Lake Berryessa
Clear Creek	Whiskeytown Reservoir	Rubicon River	Hell Hole Reservoir
Deer Creek (Yuba)	Scotts Flat Reservoir	Rubicon River	Rubicon Lake
Feather River	Lake Oroville	Sacramento River	Keswick Reservoir
Fordyce Creek	Lake Fordyce	Sacramento River	Shasta Lake
French Dry Creek	Merle Collins Reservoir	Silver Creek	Camino Reservoir
Gerle Creek	Gerle Creek Reservoir	Silver Creek	Junction Reservoir
Gerle Creek	Loon Lake	Silver Creek	Union Valley Reservoir
Hamilton Branch	Mountain Meadows Reservoir	Silver Fork American	Silver Lake
Indian Creek	Antelope Reservoir	Sly Park Creek	Jenkinson Lake
Jackson Creek	Lake Amador	South Fork American River	Chili Bar Reservoir
Kellogg Creek	Los Vaqueros Reservoir	South Fork American River	Slab Creek Reservoir
Little Last Chance Creek	Frenchman Lake	South Fork Feather River	Little Grass Valley Reservoir
Little Rubicon River	Buck Island Reservoir	South Fork Silver Creek	Ice House Reservoir
Little Stony Creek	East Park Reservoir	South Fork Yuba River	Lake Spaulding
Littlejohns Creek	Farmington Reservoir	Stony Creek	Black Butte Reservoir
Lost Creek	Sly Creek Reservoir	Stony Creek	Stony Gorge Reservoir
Middle Fork American River	French Meadows	Trinity River	Lewiston Lake
Middle Yuba River	Jackson Meadows Reservoir	Trinity River	Trinity Lake
Mokelumne Aqueduct	EBMUD Terminal Reservoirs	West Branch Feather River	Philbrook Round Valley
Mokelumne River	Camanche Reservoir	Yuba River	Englebright Reservoir
Mokelumne River	Pardee Reservoir	Yuba River	New Bullards Bar Reservoir
North Fork Cache Creek	Indian Valley Reservoir		

3.4 Groundwater

Ten groundwater basins are simulated in SacWAM using WEAP groundwater objects. The horizontal extents of the basins are shown in Figure 3-3. The basins are aggregated from Bulletin 118 Groundwater Basins (DWR, 2014a) as shown in Table 3-4. The **Bulletin 118 GW basins** shapefile was used to create the SacWAM **groundwater basins** shapefile.

Inflows and outflows to and from the groundwater basins include: (1) deep percolation from demand unit catchment objects, (2) return flows from urban demand sites, (3) seepage losses on surface water distribution systems, (4) interaction with the stream network through the *Groundwater Inflow* and

Groundwater Outflow parameters on stream reaches, and (5) groundwater pumping to meet catchments and demand site water demands.

In the SacWAM schematic, vertical recharge from catchment objects to the groundwater basins are shown by dashed blue runoff/infiltration arcs, return flows from demand sites are indicated by red arcs, and groundwater pumping is represented by green transmission links. Other groundwater flow components, though simulated, are not represented in the schematic. Displaying all the groundwater arcs crowds the schematic and these arcs are typically inactivated for display purposes.

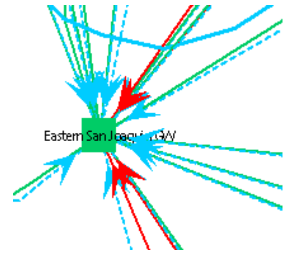


Table 3-4. Relationship between SacWAM Groundwater Objects and Bulletin 118 Basins

SacWAM Groundwater Basin	Bulletin 118 Basins3
Redding	South Battle Creek, Bowman, Rosewood, Anderson, Enterprise, Millville
Red Bluff Corning	Bend, Antelope, Dye Creek, Corning, Red Bluff, Vina, Los Molinos
Colusa	Colusa
Butte	East Butte, West Butte
Sutter Yuba	North Yuba, South Yuba, Sutter
Yolo Solano1	Yolo, Solano
American1	North American, South American
Cosumnes	Cosumnes
Eastern San Joaquin1	Eastern San Joaquin
Delta1	Not represented
Suisun2	Suisun-Fairfield

Notes:
[1] Parts of Yolo Solano, American, and Eastern San Joaquin are represented as part of the Delta groundwater object. The boundaries of the Delta groundwater object coincide with the Delta boundaries.
[2] Only a small portion of the Suisun-Fairfield groundwater basin is represented in SacWAM.
[3] California's Groundwater, Update 2003. Bulletin 118. California Department of Water Resources, Sacramento, California

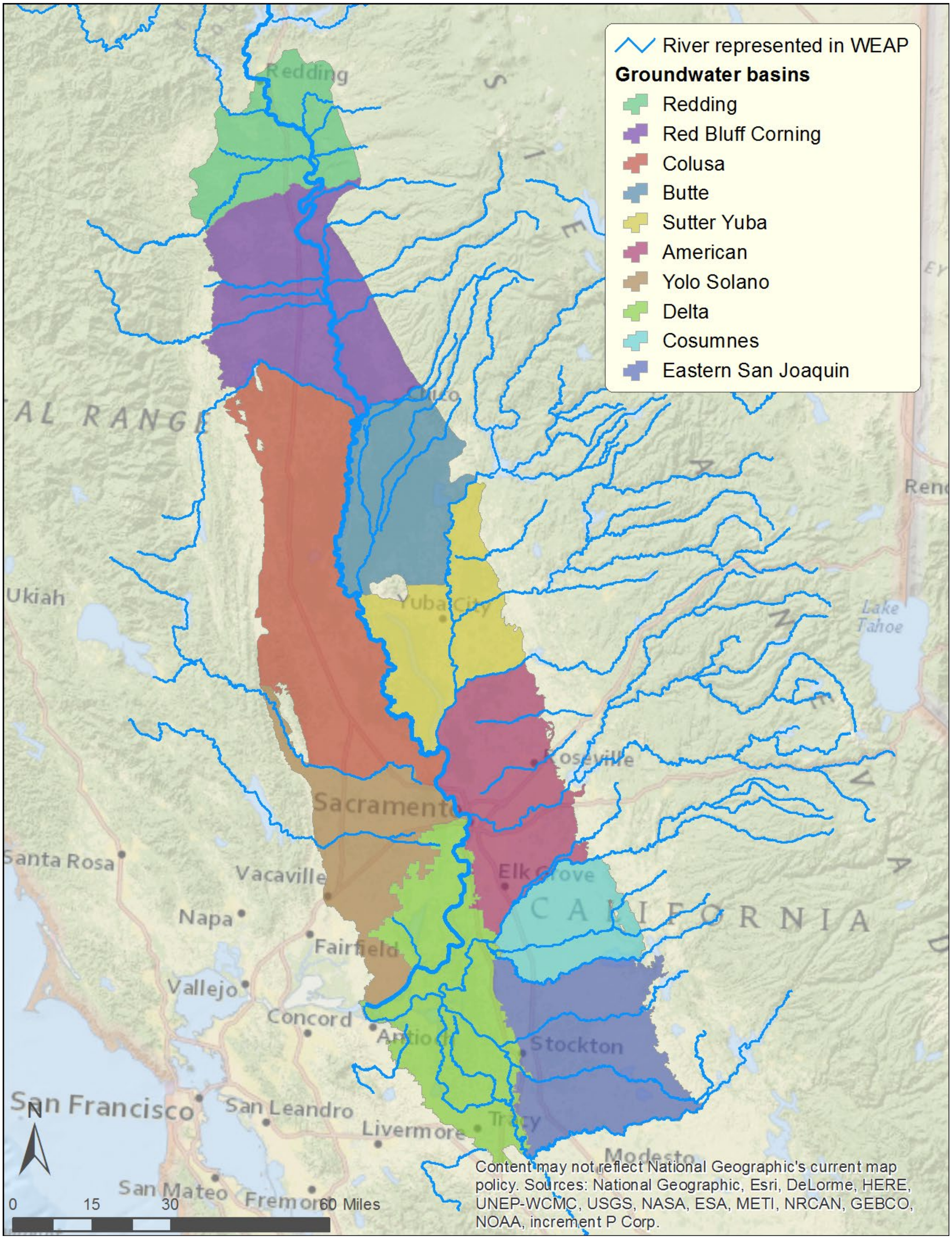
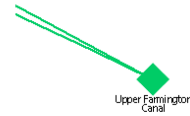


Figure 3-3. Groundwater Basins

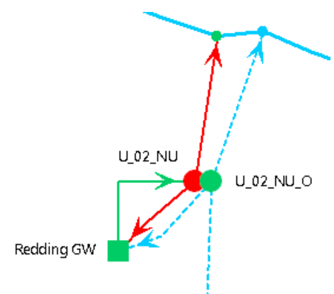
3.5 Other Supplies

The use of the WEAP 'Other Supply' object in SacWAM is limited to the San Joaquin Valley. These objects provide water to lands on the southern boundary of the model domain located between the Calaveras and Stanislaus rivers, east of the San Joaquin River. Four Other Supply objects represent: (1) CVP water that is diverted from the Stanislaus River into the Upper Farmington Canal for delivery to Central San Joaquin WCD and Stockton East WD; (2) water diverted into the South San Joaquin Main Canal for delivery to South San Joaquin ID, Oakdale ID, and the South San Joaquuin ID water treatment plant; (3) water diverted by riparian and appropriative water right holders on the right bank of the Stanislaus River; (4) riparian and appropriative water right holders on the right bank of the San Joaquin River between the Stanisaus River and Vernalis.



3.6 Demand Sites

WEAP's demand sites are used to represent: (1) urban water demands; and (2) deliveries to water users located outside the model domain (e.g., CVP and SWP south-of-Delta contractors). Within the model domain, rainfall-runoff and deep percolation from urban lands is represented using a WEAP catchment object associated with each urban demand site. In the example shown to the left, the urban demand site is U_02_NU and the associated catchment object for simulating runoff is U_02_NU_O (the suffix _O denoting outdoor). Urban demand sites are discussed in Chapter 4 and are listed in Table 4-3.



3.7 Catchments

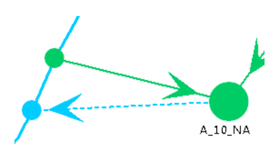
The valley floor domain in SacWAM is divided into smaller geographic regions known as **Water Budget Areas** (WBAs). Within each WBA, catchment objects were added to the schematic to represent groups of water users on the valley floor, known as demand units (DUs). These are described in detail in Sections 4.1.1 and 4.1.2.

The spatial extents of WBAs and DUs determined the catchment placement in the SacWAM model-building process. Because there may be multiple non-contiguous polygons associated with a single DU a DU's catchment placement in the model is only accurate within its WBA boundary.

3.8 Runoff/Infiltration

3.8.1 Surface Runoff and Return Flows

Surface runoff is represented in SacWAM with a runoff link from a catchment object to a surface water body (dashed blue line). In some cases, runoff is distributed to multiple receiving surface water bodies. The percentage of runoff that contributes to each return location (**surface returns** file) is entered in the *Supply and Resources\Runoff and Infiltration\Demand Unit\Inflows and Outflows\Surface Runoff*



Fraction branch of the data tree. For information on how surface water runoff and return flow locations were determined for SacWAM DUs, see Sections 6.5 (return flow) and 6.7 (runoff).

3.9 Transmission Links

Transmission links connect water supplies to water demands, represented in WEAP by 'Demand Site' objects and 'Catchment' objects. Points of diversion for CVP and SWP contractors were identified using a variety of sources, including CVP contract documents[9] (Reclamation, 2013a), SWP Handbook (DWR, 1992), and Delta-Mendota Canal Structures report (Reclamation 1986). Non-Project[10] points of diversion were identified using a combination of the State Water Board Electronic Water Rights Information Management System (eWRIMS) database (SWRCB, 2014), Bulletin 23 (DWR, 1924-1962) and Bulletin 130 (DWR, 1963-1975, 1988) data, and aerial imagery. SacWAM's surface water diversions are summarized in Table 6-19, Table 6-20, and Table 6-21. These tables provide a list of all DUs and associated surface water diversions and river mile, where applicable.

3.9.1 Central Valley Project Deliveries

Under the terms of its authorization, the CVP provides water to: Sacramento River water right settlement contractors (settlement contractors) in the Sacramento Valley; San Joaquin River exchange contractors (exchange contractors) and water right holders in the San Joaquin Valley; agricultural and municipal and industrial (M&I) water service contractors in both the Sacramento and San Joaquin valleys; and wildlife refuges both north and south of the Delta. CVP deliveries to contractors in the Sacramento Valley are listed inTable 6-19, Table 6-20, and Table 6-21.

3.9.1.1 Settlement Contractors

Sacramento River settlement contractors include individuals and districts who had established water rights on the Sacramento River before the construction of Shasta Dam. If these water rights were fully exercised, it would compromise operation of the CVP and the project's ability to make water available to its water service contractors. Thus, Congress directed Reclamation to negotiate settlement agreements. In 1964, Reclamation entered into long-term settlement contracts with senior water right holders, both districts and individuals, to divert certain natural flows of the Sacramento River (base supply) and also provide a contractual entitlement to additional water supplies during the summer months from CVP yield (project water). The original term of these contracts was 40 years and gave 146 settlement contractors the right to divert approximately 2.2 million acre-feet (MAF) from the Sacramento River in

[9] Reclamation's long-term water service contracts for CVP diverters give exact locations of surface water diversions by RM for each contractor that diverts from the Sacramento River. SacWAM river miles were defined from recent aerial imagery. In contrast, CVP contract miles are based on the historical path of the river. Consequently, CVP contract miles have been adjusted to SacWAM RMs.

[10] SacWAM development has gained from the huge amount of work undertaken by DWR and Reclamation in the development of CalSim II and CalSim 3.0. The principal purpose of CalSim II is for conducting planning studies relating to the operation of the CVP and SWP. As such, the model is CVP/SWP centric. 'Project' demands refer to water demands of CVP and SWP contractors. 'Non-Project' water demands are those associated with local water agencies and individulas who do not receive CVP or SWP water. SacWAM uses this same distinction between 'project' and 'non-project' entities and water demands.

most years, and approximately 1.65 MAF during Shasta Lake 'critical years.'[11] Reclamation renewed the majority of the settlement contracts in 2005. Annual contract quantities range from 4 acre-feet to 825,000 acre-feet. The 20 largest settlement contracts account for approximately 95 percent of the total contracted amount.

In SacWAM, the settlement contractors are represented by two urban DUs for the City of Redding (U_02_SU, U_03_SU), and 11 agricultural DUs (A_02_SA, A_03_SA, A_08_SA1, A_08_SA2, A_08_SA3, A_09_SA1, A_09_SA2, A_18_19_SA, A_21_SA, A_22_SA1, A_22_SA2). Points of diversion are based on information contained in Reclamation's long-term water contracts. CVP contract miles were converted to SacWAM river miles.[12]

3.9.1.2 Water Service Contractors

CVP water service contracts are agreements between Reclamation and water districts and water agencies for purchase of CVP project water. Reclamation signed its first water service contracts in 1964. Most of these contracts were for the delivery of project water for a 40-year period. Many of the water service contracts were renewed in 2005. In SacWAM, water service contractors are represented by 10 urban DUs (U_02_PU, U_03_PU, U_26_PU1, U_26_PU2, U_26_PU3, U_26_PU4, U_26_PU5, U_60N_PU, U_EIDLO_NU, U_CCWD_PU) and 9 agricultural DUs (A_02_PA, A_03_PA, A_04_06_PA1, A_04_06_PA2, A_07_PA, A_08_PA, A_16_PA, A_21_PA, A_60S_PA). Points of diversion are based on information contained in Reclamation's long-term water service contracts and/or aerial imagery.

3.9.1.3 Refuges

Reclamation delivers CVP water to Sacramento NWR, Delevan NWR, and Colusa NWR in the Colusa Basin, and to Gray Lodge WA (through exchange agreements) and Sutter NWR in the Butte and Sutter basins. SacWAM simulates delivery of Level 2 water supplies.[13] Level 4 water supplies (the additional amount of water needed for optimal conditions) are not simulated. Surface water deliveries are limited to the Level 2 contract amount (plus an allowance for conveyance loss) using the *Maximum Flow Volume* property of the transmission link. These volumes are reduced by 25% in Shasta critical years.

3.9.2 State Water Project Deliveries

The SWP operates under long-term contracts with 29 public water agencies. These agencies deliver water to wholesalers, retailers, or deliver water directly to agricultural and M&I water users. Additionally, DWR has signed 'settlement' agreements with senior water right holders on the Feather River to resolve water supply issues associated with the operation of SWP facilities associated with Lake

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[11] Settlement contracts are subject to reduction of contract amounts only in Shasta Lake 'critical' years. In these years, settlement contractors receive 75 percent of their full contract amount.

[12] SacWAM river miles are defined using recent aerial imagery and are measured upstream from the Sacramento San Joaquin River confluence.

[13] Level 2 water supplies include those specifically identified as Level 2 in the Report on Refuge Water Supply Investigations (Reclamation, 1989a). The amount of water diverted to meet these demands at the refuge boundaries will be greater because of loss of water during conveyance. SacWAM assumes a 15% conveyance loss for Sacramento NWR, Delevan, and Colusa NWR, 17.5% loss for Gray Lodge WA, and 10% loss for Sutter NWR.

Oroville and Thermalito Forebay and Afterbay. SacWAM's representation of SWP deliveries are described in the following sections.

3.9.2.1 Feather River Service Area

Three SWP long-term contractors are located north of the Delta: Plumas County Flood Control and Water Conservation District (FC&WCD), Butte County, and the City of Yuba City. Plumas County FC&WCD is located upstream from Lake Oroville in the upper Feather River basin and currently is not represented directly in SacWAM. The City of Yuba City diverts water from the Feather River immediately upstream from the Yuba River confluence with the Feather River at RM 028. Butte County acts as a wholesaler of SWP water to municipal agencies within the county.

For modeling purposes, Butte County's SWP water is available to Thermalito Irrigation District (ID) (U_11_NU1), Cal Water–Oroville (U_12_13_NU1), and the City of Yuba City (U_16_PU). Cal Water–Oroville purchases water from Pacific Gas and Electric (PG&E), which is delivered from the West Branch of the Feather River via the Miocene Canal, and diverts SWP water, under a contract with Butte County, from the Thermalito Power Canal. Thermalito ID holds water rights associated with Concow Reservoir. Under an agreement with the State, the reservoir is kept full during the summer months for fishery purposes. Water released in the fall, winter, and spring is stored in Lake Oroville and re-released in the summer to meet Thermalito ID demands.

DWR has signed settlement agreements with districts in the Feather River Service Area (FRSA) associated with the operation of Lake Oroville. These districts include Western Canal WD, Joint Board WD, Plumas Mutual Water Company (MWC), Garden Highway MWC, Oswald WD, and Tudor MWC. Western Canal WD and the Joint Board WD divert from the Thermalito Afterbay. Points of diversion for other water districts are based on SWP settlement contracts (DWR, 1997a). The FRSA is represented in SacWAM by portions of WBAs 11, 12, and 16.

In addition to water districts, many individual agricultural water users hold water rights senior to the SWP for Feather River water. Data on water entitlements for the Feather River were collected by DWR as part of the Feather River Trial Distribution Program and published in Bulletin 140 (DWR, 1965). The net irrigable area of lands of riparian and appropriative water right holders was estimated to be approximately 30,000 acres. For SacWAM, surface water diversions to these individuals are based on estimates of irrigated riparian lands, beneficial use, and appropriative water rights (Sergent, 2008) and on information published in Bulletin 168 (DWR, 1978).

3.9.2.2 North Bay Aqueduct

The North Bay Aqueduct is part of the SWP, delivering water to Solano County Water Agency (WA) and Napa County FC&WCD, which are both long-term SWP water contractors. Under agreements with Solano County WA, water from the North Bay Aqueduct is delivered to the Cities of Benicia, Fairfield, Vacaville, and Vallejo. The Cities of Dixon, Rio Vista, and Suisun all have contract entitlements to water from the North Bay Aqueduct but currently do not have facilities to receive this supply. Under agreements with Napa County FC&WCD, the Cities of Calistoga, Napa, St. Helena, American Canyon, and the Town of Yountville receive SWP water from an extension of the North Bay Aqueduct. In addition, SWP wheels water through the North Bay Aqueduct to appropriative water right holders.

SacWAM represents the North Bay Aqueduct as a diversion from Cache Slough (Barker Slough is not represented in the model). Points of diversion along the aqueduct are based on data presented in the

SWP Handbook (DWR, 1997a). Except for the City of Vacaville (U_20_25_PU), all deliveries from the North Bay Aqueduct are exports from the model domain. Multiple transmission links to each demand site differentiate between SWP Table A water and Vacaville Permit water. Disaggregating DUs into demands with high and low priorities allows the model to differentiate SWP Article 21 water deliveries from Settlement water deliveries. Article 21 water and Settlement water are assigned a low priority so that deliveries only occur when the Delta is in excess conditions.

3.9.3 Non-Project Deliveries

In the context of SacWAM, non-project diversions are surface water diversions that are not associated with the CVP or SWP. However, non-project diversions include Federal projects other than the CVP.

3.9.3.1 Deliveries from Sacramento River

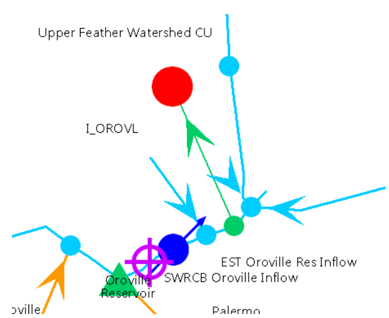
Major diverters of non-project water along the Sacramento River include Llano Seco Rancho (A_09_SA), and the Cities of Sacramento (U_26_NU3) and West Sacramento (U_21_PU). Additionally, Sacramento County WA and East Bay Municipal Utility District (EBMUD) divert non-project water as part of the Freeport Regional Water Project. The Cities of Davis and Woodland (U_20_25_NU) have recently started to divert non-project water as part of the Davis-Woodland Project.

Non-project diversions from the Sacramento River other than those described above are not well defined, and records of their historical diversions are incomplete or unavailable. DWR's county land use surveys (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a) were used to identify land that was contiguous with the Sacramento River, and within three miles of the river centerline. From the county land-use survey information, a subset of these lands was identified as cropland that is irrigated by surface water or mixed surface water and groundwater and lies outside any water districts or irrigation districts. Model transmission links to these non-project agricultural diverters (A_08_NA, A_18_19_NA) represent multiple small diversions.

3.9.3.2 Deliveries from Upper Feather River Watershed

SacWAM represents the major imports and exports of water from the upper Feather River watershed above Lake Oroville. These include the export of water from the West Branch Feather River at the Hendricks Diversion Dam as part of PG&E's DeSabla-Centerville Project (FERC Project No. 803), and the import of water from Slate Creek as part of South Feather Water and Power Agency's South Feather Hydroelectric Project (FERC Project No. 2088). Water diversions for use within the Feather watershed include West Branch Feather River diversion into the Miocene Canal and South Feather Water and Power Agency's diversions into the Oroville-Wyandotte and Miners Ranch canals.

Consumptive water use in the Upper Feather River watershed is represented indirectly using a demand site labelled 'Upper Feather Watershed CU', located immediately upstream from Lake Oroville. To provide consistency with DWR estimates of unimpaired flow at Oroville and the calculation of headflows used in the model, SacWAM assumes a consumptive use demand of 75,000 acre-feet per year. This is in addition to consumptive use associated with Miocene, Hendricks, Forbestown, Bangor, and Palermo canals.



3.9.3.3 Deliveries from Lower Feather River

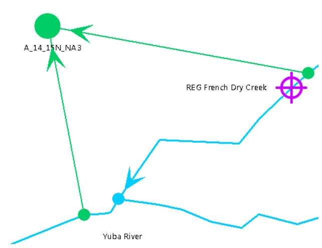
Major diversions from the Feather River below Oroville Dam consist of water right holders who have signed settlement agreements with DWR (see Section 3.9.2.1). In addition, many minor appropriative and riparian water right holders divert water from both the left and right banks of the river. For SacWAM, these minor diversions were determined using diversion data published in Bulletin 168 (DWR, 1978), estimates of irrigated riparian lands and beneficial use, eWRIMS database of appropriative water rights, and from personal communication with DWR (Sergent, 2008).

3.9.3.4 Deliveries from Upper Yuba River Watershed

The Yuba River watershed has been extensively developed for both hydropower generation and water supply. Development in the upper watersheds of the North, Middle and South Yuba rivers and Deer Creek include parts of South Feather Water and Power Agency's South Feather Hydroelectric Project (FERC Project No. 2088), Yuba County WA's Yuba River Development Project (FERC Project No. 2246), Nevada ID's Yuba-Bear Hydroelectric Project (FERC Project No. 2266), PG&E's Drum-Spaulding Project (FERC Project No. 2310), and USACE's Englebright and Daguerre Point dams. SacWAM represents the major diversion and export facilities associated with these projects, including the Slate Creek Tunnel, Lohman and Camptonville tunnels, Milton-Bowman Tunnel, Bowman-Spaulding Conduit, and the South Yuba and Drum canals. Consumptive use within these upper watersheds is represented by two DUs: NIDDC_NA represents Nevada ID's Deer Creek unit and NIDDC_NU represents urban water supplies to Grass Valley and Nevada City.

3.9.3.5 Deliveries from Lower Yuba River

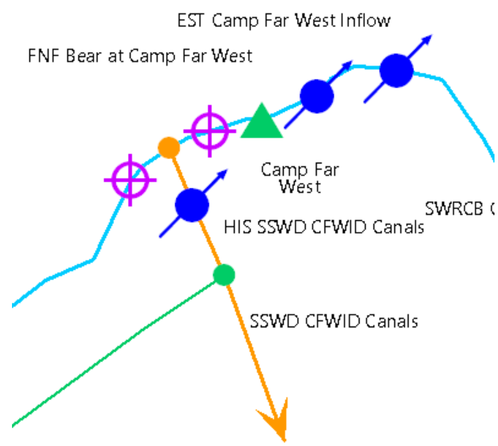
As part of the Yuba River Development Project, Yuba County WA delivers water to its member units at Daguerre Point Dam located at RM 11 on the lower Yuba River. Water is diverted to irrigate lands both north (A_14_15N_NA2) and south (A_15S_NA) of the river. Additionally, Browns Valley ID (A_14_15N_NA3) diverts water at its pumping plant located approximately two miles upstream at RM 13. SacWAM includes three transmission links for these non-project diversions from the lower Yuba River.



Dry Creek joins the Yuba River from the north, approximately two miles upstream from Daguerre Point Dam. Flows in Dry Creek are regulated by Browns Valley ID's operation of Merle Collins Reservoir and Virginia Ranch Dam. The district supplements Yuba River water with diversions from Dry Creek below the dam.

3.9.3.6 Deliveries from Bear River

The Bear River watershed upstream from Camp Far West Reservoir includes storage and diversion facilities owned and operated by Nevada ID, Placer County WA, and PG&E. The SacWAM schematic includes imports to the watershed through PG&E's Drum Canal and Lake Valley Canal and exports to PG&E's Bear River Canal and Placer County WA's Lower Boardman Canal. SacWAM also represents Nevada ID diversions from Lake Combie to the Combie Ophir Canal. Nevada ID service area includes both agricultural (A_NIDBR_NA, A_24_NA1) and urban demands (part of U_24_NU1). Similarly, Placer County WA's service area is represented by a mix of agricultural (A_24_NA2, A_24_NA3) and urban DUs (U_PCWA3_NU, U_24_NU1, U_24_NU2).



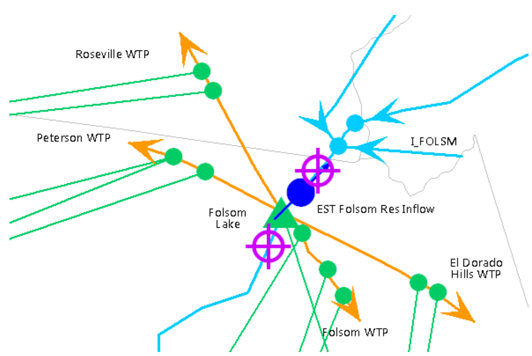
Water is released from Camp Far West Reservoir for irrigation, power generation, and to meet downstream flow requirements. South Sutter WD operates a diversion dam at RM 17, approximately one mile downstream from Camp Far West Dam, to irrigate lands served by Camp Far West ID and South Sutter WD (A_23_NA).

3.9.3.7 Deliveries from Upper American River Watershed

SacWAM represents the upper American River watersheds of the North Fork, Middle Fork, and South Fork. The schematic includes storage regulation and diversions facilities associated with Placer County WA's Middle Fork Project (MFP), PG&E's Drum-Spaulding Project, Sacramento Municipal Utility District's (SMUD) Upper American River Project (UARP), and El Dorado ID's South Fork Project, known as Project 184. Diversions for water supply include those from Pilot Creek to Georgetown Divide PUD (U_GPUD_NU and A_GPUD_NA), Placer County WA's diversion at the Auburn Dam site to meet agricultural (A_24_NA2, A_24_NA3) and urban (U_24_NU2) water demands in its service area, and El Dorado ID's diversion from the El Dorado Canal to its urban service area (U_EIDUP_NU).[14]

3.9.3.8 Deliveries from Lower American River

There are no significant agricultural diversions from Folsom Lake and the lower American River. However, four urban agencies divert water from Folsom Lake (City of Roseville [U_26_PU1], San Juan WD [u_26_PU2], City of Folsom [U_26_PU3], and El Dorado ID [U_EIDLO_NU]).[15] Additionally, Aerojet (U_26_NU5), Folsom State Prison,



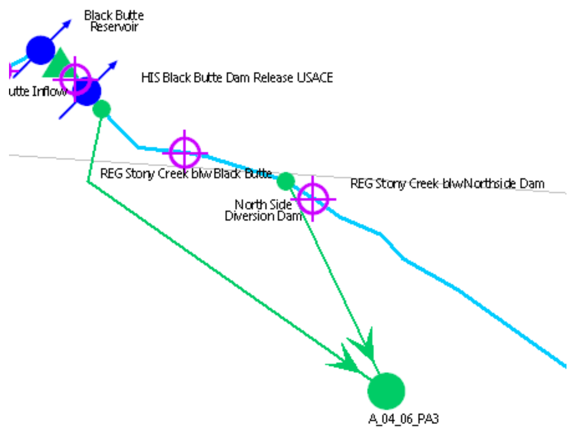
[14] SacWAM divides the El Dorado ID service area into an upland eastern section (U_EIDUp_NU) and a lowland western section (U_EIDLo_NU). The model assumes that water from the El Dorado Forebay supplies only the eastern section of the service area and water from Folsom Lake supply only the western section. Jenkinson Lake provides supplemental water to both sections.

[15] San Juan WD wheels and delivered treated water t Sacramento Suburban WD. San Juan WD also delivers treated water to Orange Vale WC, Citrus Heights WD, and Fair Oaks WD. Water demands for Folsom Prison are aggregated with those for the City of Folsom.

and State Parks receive water from the lake. As part of the CVP, water is diverted from Lake Natoma into the Folsom South Canal. The canal delivers project water to Golden State WA (U_26_PU5), and to SMUD's Rancho Seco Power Plant (U_60N_PU). In the past, the CVP has delivered water to agricultural water districts in the Cosumnes River watershed (A_60N_NA2). Though shown on the schematic, SacWAM delivers no surface water to these districts. On the lower American River, there are diversions to Carmichael WD (U_26_NU2) and City of Sacramento (U_26_NU3). In SacWAM, these diversions are represented by diversion arcs to water treatment plants and transmission links connecting the diversion arc to individual DUs.

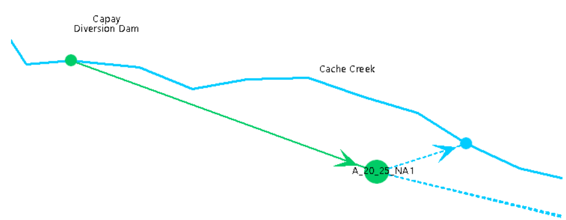
3.9.3.9 Deliveries from Stony Creek

The Orland Project, centered on Stony Creek, is one of the oldest Federal Reclamation projects in the country. Water was delivered to the first farm units at the beginning of the 1910 growing season. The main elements of the project include East Park Dam, Stony Gorge Dam, Rainbow Diversion Dam and East Park Feeder Canal, South Diversion Intake and South Canal, and Northside Diversion Dam and North Canal. Black Butte Dam, constructed by the U.S. Army Corps of Engineers (USACE), is an authorized facility of CVP. The CVP and the Orland Project are separate projects with separate water rights. SacWAM represents a small diversion from East Park Dam to Stony Creek WD (A_SCKWD_NA), and diversions at and below Black Butte Dam to the Orland Water Users (A_04_06_NA1). Though represented in the schematic, SacWAM assumes that there are no deliveries from Stony Creek through the Constant Head Orifice to the Tehama-Colusa Canal.



3.9.3.10 Deliveries from Cache Creek

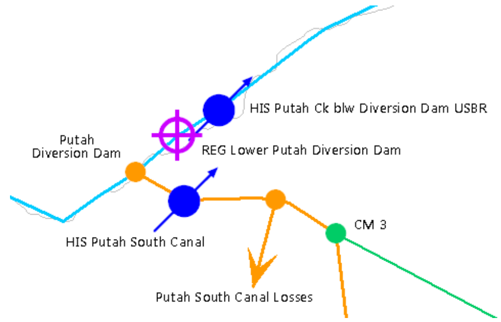
Clear Lake is the dominant feature within the Cache Creek watershed. Releases from the lake for agricultural water supply are supplemented by releases from Indian Valley Reservoir located on the North Fork Cache Creek. SacWAM represents minor withdrawals from Clear Lake to the surrounding communities (U_CLLPT_NU). SacWAM represents all agricultural water use by a single diversion at the Capay Diversion Dam at RM 30, where water is delivered to the Yolo County FC&WCD service area (A_20_25_NA1).



3.9.3.11 Deliveries from Putah Creek

The Solano Project, completed in 1959, was constructed by Reclamation to provide irrigation water to approximately 96,000 acres of land located in Solano County. The project also furnishes M&I water to the major cities of Solano County. Project facilities include Lake Berryessa and Monticello Dam, Putah Diversion Dam, Putah South Canal and canal distribution system, and a small terminal reservoir (Solano County WA, 2011). Water released from Monticello Dam is diverted at the Putah Diversion Dam located approximately six miles downstream. Water is subsequently conveyed to its end users through the

Putah South Canal. In addition to the Solano Project, there are minor diversions in the Putah Creek watershed under both riparian and appropriative water rights. These include diversions by UC Davis from the South Fork of Putah Creek. These minor diversions are not currently represented in SacWAM.



3.9.3.12 Deliveries from Cosumnes River

The Cosumnes River watershed spans across parts of El Dorado, Amador, and Sacramento counties. The upper watershed, east of Highway 49, includes the watersheds of the North, Middle, and South Fork of the Cosumnes River. The upper watershed remains largely unimpaired by development except for the former Sly Park Unit of the CVP, which was transferred to El Dorado ID in 2003. SacWAM represents Jenkinson Lake and Sly Park Dam and associated imports from Camp Creek and exports through the Sly Park-Camino Conduit to the El Dorado ID service area. El Dorado ID diversions into the Crawford Ditch from the North Fork Cosumnes River are not represented. Below the stream gauge at Michigan Bar (USGS 11335000), SacWAM represents a single point of diversion - to the community of Rancho Murieta (U_60N_NU2) at Granlees Dam. There are many small diversions along the lower Cosumnes River. These typically consist of small pumps that divert less than 1 cfs. State Water Board records show there are approximately 133 active water rights permits and licenses, representing an annual entitlement of up to 5,700 acre-feet along the lower Cosumnes River watershed. These diversions are not currently represented in SacWAM.

3.9.3.13 Deliveries from Dry Creek

Dry Creek, located south of the Cosumnes River watershed, joins the Cosumnes River just upstream from the Cosumnes-Mokelumne river confluence. Flows in Dry Creek are partially regulated by Lake Amador, located on Jackson Creek. Under an agreement between Jackson Valley ID and EBMUD, water is diverted from Pardee Reservoir into Lake Amador. SacWAM represents diversions from Lake Amador to supply the irrigation district (A_60N_NA1) but does not represent any other diversions in the Dry Creek watershed.

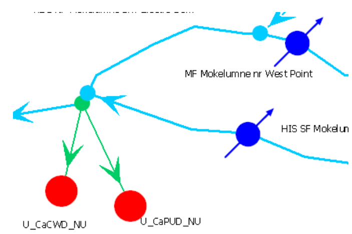
3.9.3.14 Deliveries from Mokelumne River

The Mokelumne River watershed can be divided into upper and lower watersheds by the gauge at Mokelumne Hill (USGS 11319500) located near Highway 49. The upper watershed includes the North Fork, Middle Fork, and South Fork, and 8 miles of the main stem of the Mokelumne River.

3.9.3.14.1 North Fork

PG&E owns and operates the Mokelumne Hydroelectric Project (FERC Project No. 137) on the North Fork Mokelumne River. The project consists of seven storage reservoirs and associated diversions and powerhouses. SacWAM represents only the new larger reservoirs: Lower Bear and Salt Springs. Downstream diversions by Amador Water Agency (U_ AMADR_NU) to serve local communities are located at the Tiger Creek Afterbay and from the Electra Tunnel.

3.9.3.14.2 Middle and South Forks

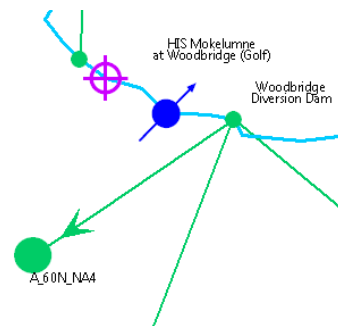


SacWAM represents the Middle Fork and South Mokelumne River as two fixed time series of inflows. The model aggregates diversions by Calaveras County WD and Calaveras PUD to a single point of diversion downstream from the confluence of the two forks. The diversion supplies Mokelumne Hill and other rural communities (U_CaCWD_NU and U_CPU_NUD).

3.9.3.14.3 Main Stem

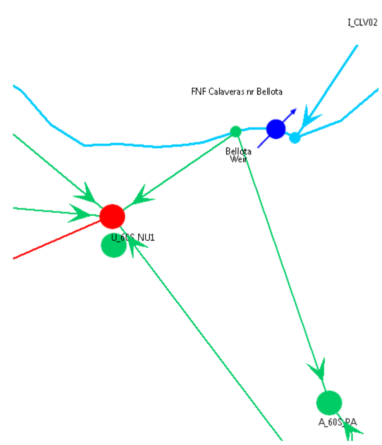
EBMUD owns and operates Pardee and Camanche reservoirs and dams located in the lower watershed on the main stem of the Mokelumne River below the Mokelumne Hill gauge. From Pardee Reservoir, the district diverts water in to the Mokelumne Aqueduct, which is conveyed to its service district in the San Francisco Bay Area. SacWAM simulates diversions to the Mokelumne Aqueduct and water deliveries from Pardee Reservoir to Lake Amador.

Water right holders on the lower Mokelumne River below Camanche Dam include North San Joaquin WCD, Woodbridge ID, and minor riparian and appropriative water right holders. SacWAM represents separate diversions to these entities. Diversions to North San Joaquin WCD (A_60N_NA3) are represented as a single diversion at RM 50. Minor diversions to individual water right holders (A_60N_NA5) are located at two points, upstream and downstream from the Woodbridge Diversion Dam. Lastly, SacWAM represents diversions to Woodbridge ID (A_60N_NA4) and district wholesale agreements with the City of Lodi (U_60N_NU1) and the City of Stockton (U_60S_NU1) using three transmission links located at the diversion dam at RM 35.



3.9.3.15 Deliveries from Calaveras River

The Calaveras River is divided into upper and lower reaches by New Hogan Reservoir and Dam located at RM 45. The reservoir was built by USACE for both water supply and flood control purposes. There is no significant agricultural development above the dam. Approximately 20 miles below the dam, the river bifurcates at the Bellota Weir into Mormon Slough and the old Calaveras River channel. Many irrigation diversions are located along both waterways. Mormon Slough is not represented in SacWAM, and all flows not diverted are assumed to remain in the old river channel.



Water stored in New Hogan Reservoir is shared between Stockton East WD and Calaveras County WD. From New Hogan Dam to Bellota Weir, SacWAM includes only a single diversion - at RM 43 to the unincorporated area of Jenny Lind (U_JLIND). All other diversions are aggregated and represented in the model by two transmission links located at Bellota Weir. The first transmission link supplies irrigation water to Stockton East WD and riparian diverters in Calaveras County (A_60S_PA). The second represents the raw water supply to Stockton East WD's (Dr. J. Waidhofer) water treatment plant that supplies the City of Stockton (U_60S_NU1).

3.9.3.16 Deliveries from Minor Streams and Creeks

Points of diversion for minor tributaries to the Sacramento River were identified from a variety of sources, including the State Water Board eWRIMS database (SWRCB, 2014), annual bulletins published by DWR and its predecessors,[16] and recent aerial imagery. Typically, diversions from minor creeks for agricultural water supply are aggregated to a single point of diversion in SacWAM located at the largest diversion structure, where one exists.

3.9.3.17 Deliveries from the Sacramento-San Joaquin Delta

SacWAM's representation of agricultural water use in the Delta and associated surface water diversions and return flows is conceptual rather than physically based and represents a balance between Delta channel accretions and depletions. Channel accretions result from rainfall-runoff, irrigation drainage, and seepage from Delta islands. Excess water is pumped from Delta islands back into the Delta. Channel depletions primarily consist of irrigation diversions and leach water. Net channel depletions are the difference between total diversions and total drainage or return flows.

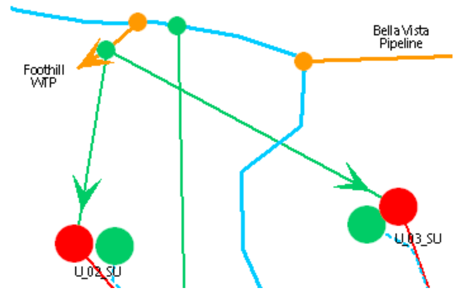
In SacWAM, the Delta is divided into seven Delta subregions. These subregions are illustrated in Figure 3-4 and are identical to regions identified by DWR for modeling CVP and SWP operations in the joint DWR-Reclamation planning model, CalSim. SacWAM incorporates two model options for simulating diversions and return flows to each Delta subregion, as follows:

- For consistency with DWR's planning model CalSim II and the agency's Delta hydrodynamic model DSM2, SacWAM Delta channel diversions and return flows may be read from a CSV file containing monthly time series data developed by DWR for CalSim II/CalSim 3.0.
- SacWAM includes seven watershed objects to represent the Delta subregions with associated transmission links and runoff-infiltration arcs.
- Though use of SacWAM watershed objects may provide a better estimate of crop evapotranspiration and consumptive use, the default option for running SacWAM is to use DWR-based flows to provide consistency with other planning processes.

[16] Bulletin 23, published continuously between 1930 and 1965 (DWR, 1924-1962), contains data for monthly diversions, streamflows, return flows, water use, and salinity in the Sacramento River and San Joaquin watersheds. The series was discontinued in 1965, following the publication of Bulletin 23-62. Bulletin 130 superseded Bulletin 23 and presented hydrologic data in five appendices covering the entire State. The bulletin was published annually from 1963 through 1975 and was last published in 1988 (DWR, 1963-1975, 1988). Bulletin 130 superseded Bulletin 23 and presents hydrologic data in five appendices covering the entire State. The bulletin was published annually from 1963 through 1975 and was last published in 1988 (DWR, 1963-1975, 1988).

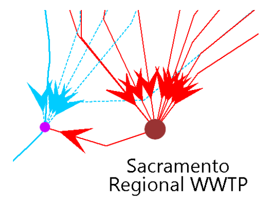
3.10 Water Treatment Plants

The WEAP software does not contain an object for representing water treatment plants. However, SacWAM does represent several water treatment plants indirectly using a combination of diversion arcs and transmission links. The diversion arc represents the river intake to the water treatment plant; the transmission links connect the diversion arc to the urban DU and represent the distribution system downstream from the water treatment plant. Water treatment plants are represented in this manner where they serve more than one DU or use multiple transmission links to the same DU to differentiate between different types of water (e.g., CVP water vs water right water). Examples include the City of Redding's Foothill WTP, City of Sacramento's Fairbairn WTP and Sacramento WTP, Sacramento County WA's Vineyard WTP, El Dorado ID's El Dorado Hills WTP, City of Folsom's WTP, City of Roseville's Barton Road WTP, San Juan WD's Petersen WTP, and Carmichael WD's Bajamont WTP.



3.11 Wastewater Treatment Plants

The WEAP software uses a brown circular object to represent wastewater treatment plants. However, in most cases, SacWAM does not use this object. Instead, SacWAM uses a single return flow arc to a specified river mile to represent the discharge of treated wastewater from large urban centers with dedicated or regional wastewater facilities to surface water bodies. Wastewater treatment plants that discharge to surface waters were identified from the NPDES permits database (EPA, 2014). Points of discharge, along with the wastewater treatment plant names (where applicable) are listed inTable 6-20.



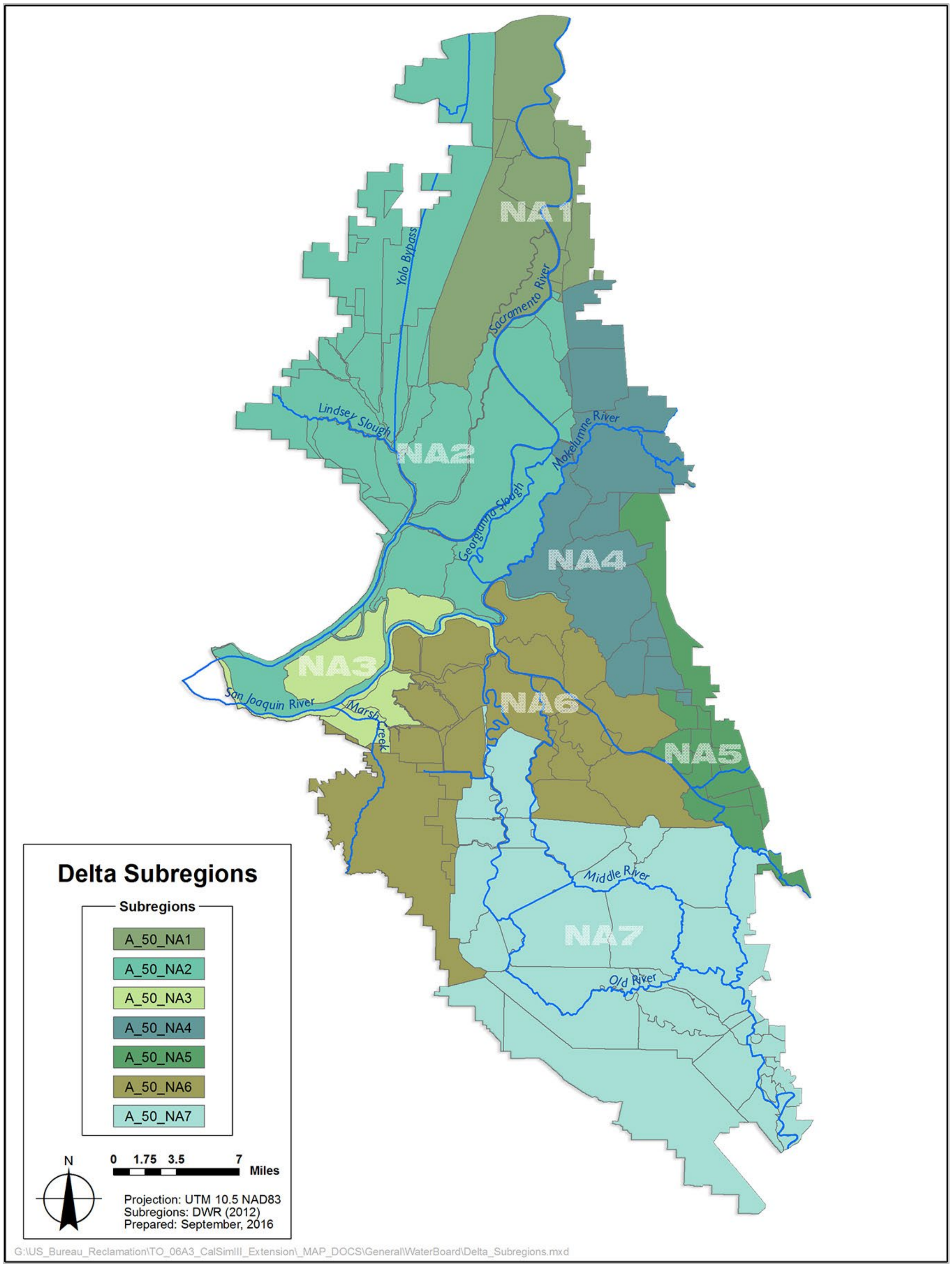
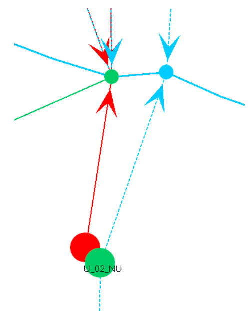


Figure 3-4. Delta Subregions

An exception to how wastewater treatment plants are displayed in SacWAM is the representation of the Sacramento Regional Wastewater Treatment Plan (WWTP). Because there are many DUs that use this facility to discharge water to the Sacramento River, multiple return flow arcs would crowd the schematic. Consequently, WEAP's wastewater treatment plant object is used to simplify the schematic. Return flows from nine DUs are aggregated at the Sacramento Regional WWTP and subsequently discharge to the Sacramento River below the Freeport gauge (USGS 11447650) at RM 48.

3.12 Return Flows

In SacWAM, WEAP's return flow arcs are associated with urban DUs and represent discharge of treated wastewater to a surface water body, to the underlying groundwater aquifer, or a mix of both. The return flow arcs are represented in the schematic as a red line to differentiate the return flow of treated wastewater from runoff/infiltration arcs.



Agricultural DUs that lie outside the valley floor are represented by a WEAP demand site object, rather than a catchment object. For example, Nevada ID's Deer Creek system is represented by demand site NIDDC_NA. In these instances, irrigation return flows are represented using a return flow arc, rather than a runoff/infiltration arc.

3.13 Flow Requirements

A purple 'sun cross' is used to represent WEAP 'Instream Flow Requirement' objects. Three types of flow requirements are represented in the SacWAM schematic. These objects are distinguished by a prefix in their object name as follows:

- **REG**: Flow requirements that are regulatory in nature.
- **OPS**: Flow requirements that are used to drive simulated upstream storage regulation or simulated diversions through canals and tunnels.
- **SWRCB**: Potential new regulatory flow requirements in which the flow requirement is specified as a fraction of the unimpaired flow.

Table 6-9 lists the regulatory instream flow requirements included in SacWAM. Table 6-11 lists potential instream flow requirements that may be implemented as part of a revised Bay-Delta Plan. Priorities for flow requirements, demand sites and catchments, and reservoirs are discussed in Section 7.12. Flow requirements are discussed in detail in Sections 6.1.3 and 7.7.

3.13.1 Cost

The WEAP Cost feature for Flow Requirements is not used in SacWAM.

3.14 Run of River Hydro Plants

The WEAP software includes 'Run of River Hydro' objects to simulate hydropower generation. These objects are not used in SacWAM. However, SacWAM does represent powerhouses and penstocks using diversion arcs.

3.15 Streamflow Gauges

WEAP 'streamflow gauge' objects allow rapid comparison of simulated flows to historical observed data using the WEAP 'results' view. These gauge objects also help orient the model user in interpreting the SacWAM schematic. In WEAP, streamflow gauges are represented by a blue circle with an associated diagonal arrow. SacWAM gauge names are prefixed with 'HIS' to indicate associated data are historical observed mean monthly flows. The designation 'FNF' indicates that full natural flow data[17] are available for the gauge. Historical streamflows for gauge objects with the prefix 'EST' have been estimated from a water balance based on reservoir releases, change in reservoir storage, and reservoir evaporation, or are synthetic data estimated using streamflow correlation techniques.

Table 6-12 lists the gauges included in SacWAM. The data source for each streamflow gauge is also listed. Data for SacWAM gauges with prefix 'HIS' were obtained from either USGS online resources or DWR's Water Data Library. In cases where data were not available from these two sources, data were obtained from either the California Data Exchange Center (CDEC), USACE, or local water agencies.

3.16 Data Directory

Table 3-5 provides file location information relating to the SacWAM Data and Information DVD for the datasets referenced in this chapter.

[17] For the purposes of this report 'Full Natural Flow' indicates that observed gauge flows have been unimpaired for upstream storage regulation, upstream reservoir evaporation, and upstream imports and exports of surface water.

Table 3-5. File Location for SacWAM Schematic Construction

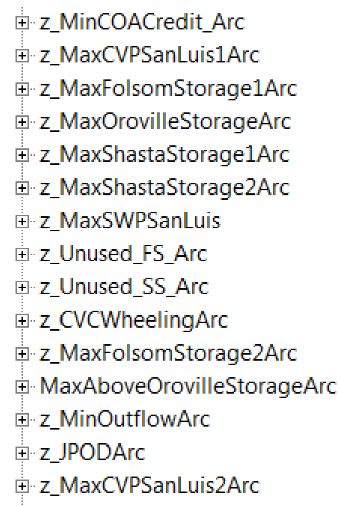
Referenced Name	File Name	File Location
American Boundaries	amriv_blw_ntms_sheds_v20130730.shp	GIS\Boundaries
Bulletin 118 GW Basins	b118_basinboundaries_v41.shp	GIS\Hydrology
Canal Miles	sac_val_canal_miles.shp	GIS\Hydrology
Demand Units	sac_val_demand_units.shp	GIS\Boundaries
Flow Accumulation	nhdplusfac18b, nhdplusfac18c	GIS\Hydrology
Groundwater Basin Intersection	sac_val_groundwater_intersection.shp	GIS\Hydrology
Groundwater Basins	sac_val_groundwater_basins.shp	GIS\Hydrology
Groundwater Functions	groundwaterfunctions.xlsm	Data\Supply_and_Resources\Groundwater\
GW Basins Spreadsheet	sacval_groundwater.xlsx	Data\Supply_and_Resources\Groundwater\
HUC-12 Watersheds	nrcs_huc12s.shp	GIS\Hydrology
Returns Intersection	sac_val_returns_intersection.shp	GIS\Hydrology
River Miles	sac_val_stream_miles.shp	GIS\Hydrology
Surface Returns	sacval_surface_runoff_and_returns.xlsx	Data\Supply_and_Resources\Runoff_Infiltration_and_Return_Flows
Valley Floor Returns	sac_val_returns.shp	GIS\Hydrology
Water Budget Areas	water_budget_areas.shp	GIS\Boundaries
Watershed Boundaries	sac_val_watersheds.shp	GIS\Hydrology

3.17 Dummy Arcs and Nodes

The complexity of water resources management in the Sacramento Valley and Delta requires a more sophisticated implementation of priorities and constraints than WEAP is typically configured to allow. In SacWAM, this sophistication can be achieved using a mix of four devices, as follows:

- **Priority-based constraints**: Within a particular time step, constraints may be activated and deactivated according to an assigned priority. This is implemented by placing a text file named 'UDCActivePriority.yes' in the WEAP Area directory, which lists the name of the constraints to be activated and deactivated with the associated priorities. In the example below, the COA sharing formulae are only active when solving for priorities 45 through 99.
  - User Defined LP Constraints\Coordinated Operations Agreement\Sharing Formulae\COA_CVP,45,99
  - User Defined LP Constraints\Coordinated Operations Agreement\Sharing Formulae\COA_SWP,45,99
- **Switches**: Dummy demand sites can be created with a water supply furnished by a transmission link from a dummy stream. In the WEAP allocation algorithm, flows through the transmission link are set to zero when solving for the higher priorities (i.e., numerically lower or senior) than that associated with the dummy demand site. Therefore, a UDC that restricts a decision variable to be less than flow through the dummy transmission link can only have a non-zero value when solving for the lower priority demands.

- **Minimization**: Dummy demand sites, as described above, may be used to minimize the value of a decision variable (X) when solving for a particular priority. First, the headflow in the dummy stream and the demand site monthly demand are set to large values. Second, a UDC is defined that constrains the decision variable X to be less than the flow in the dummy stream below the point of delivery to the demand site. When solving for flow to the dummy demand site, the WEAP algorithm will try to maximize flow through the transmission link, which in turn, will minimize flow in the dummy stream below the point of diversion and thus the value of decision variable X referenced in the UDC.



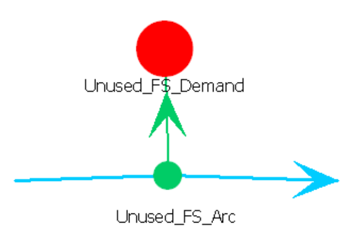
- **Maximization**: Similar to minimization, dummy demand sites may be used to maximize the value of a decision variable (X) when solving for a particular priority. First, the headflow in the dummy stream and the demand site monthly demand are set to large values. Second, a UDC is defined that constrains the decision variable X to be greater than the flow in the transmission link. When solving for flow to the dummy demand site, the WEAP algorithm will try to maximize flow through the transmission link, which in turn, will maximize the value of the decision variable X referenced in the UDC.

The elements of the dummy networks (river arcs, transmission links, and demand sites) are assigned a prefix of 'z_' so that the elements appear together in the SacWAM data tree. They are shown in Figure 3-5.

The use of the dummy networks is illustrated by the simulation of CVP use of unused SWP water and to SWP use of unused CVP water. The 1986 COA states that 'whenever a party's storage withdrawal available for export is greater than its export capability, the difference shall be available for export by the other party'. A similar clause allows use of one party's unused unstored water for export by the other party.

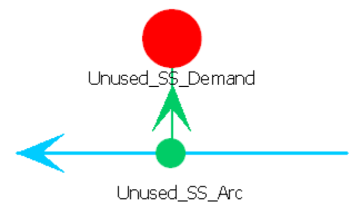
3.17.1 Use of Unused Federal Water

The dummy network shown below is used to restrict use of CVP water by the SWP. The dummy network consists of a river arc with a constant headflow of 1 cfs and a demand site with a water demand of 1 cfs. The demand site has a priority of 85 (*Other\Water Allocation Priorities\SWP use of unused Federal Share*). A UDC constrains use of unused Federal water to be less than the flow in the transmission link multiplied by a large number (99,999). This allows CVP and SWP operations to be simulated prior to the introduction of unused Federal share.



3.17.2 Use of Unused State Water

The dummy network shown below is used to restrict use of SWP water by the CVP. The dummy network consists of a river arc with a constant headflow of 1 cfs and a demand site with a water demand of 1 cfs. The demand site has a priority of 89 (*Other\Water Allocation Priorities\CVP use of unused State Share*). A UDC constrains use of unused State water to be less than the flow in the transmission link multiplied by a large number (99,999). This allows CVP and SWP operations to be simulated prior to the introduction of unused State share.



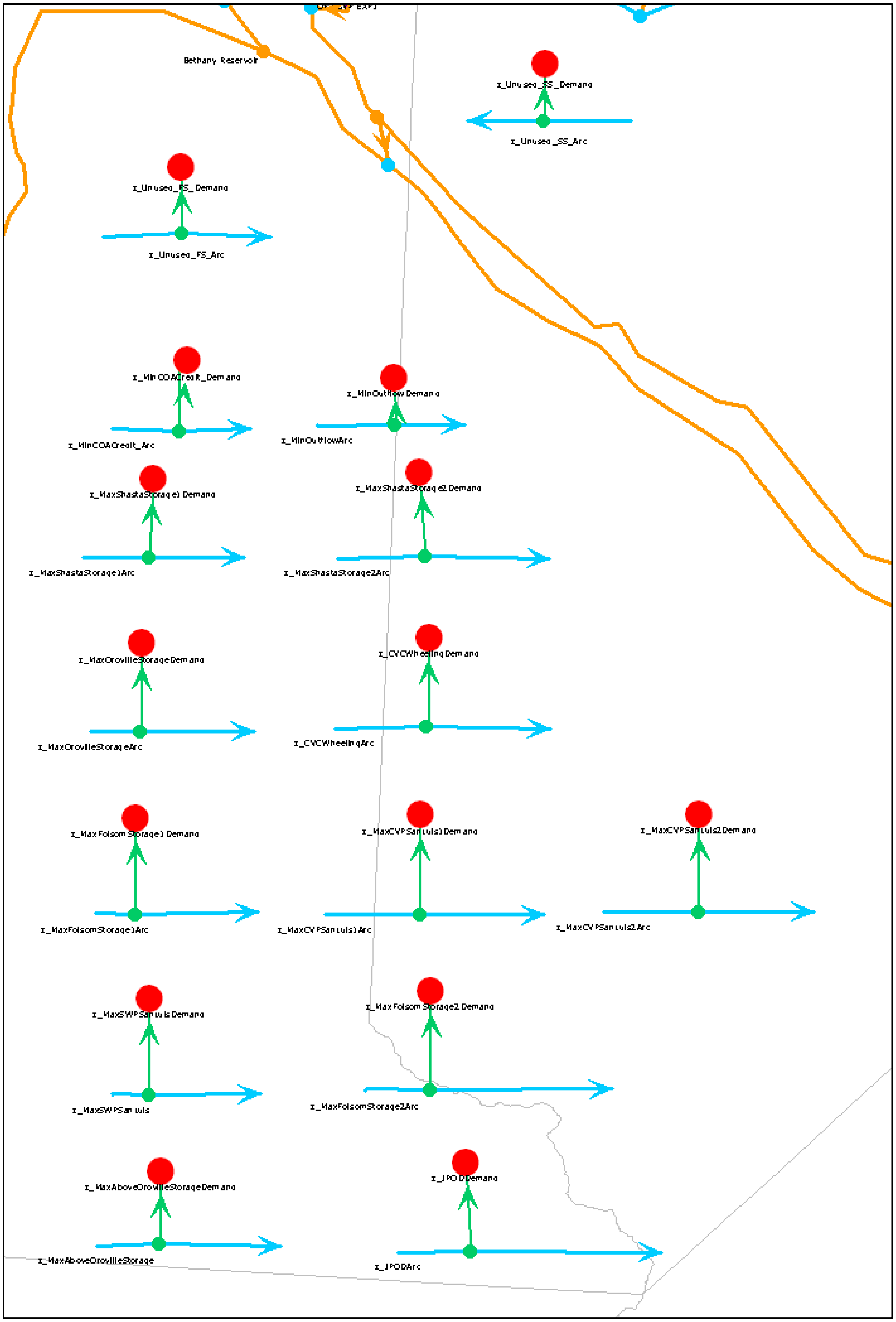


Figure 3-5. SacWAM Dummy Networks

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4 Demand Sites and Catchments – Valley Floor and Delta

This chapter describes the representation of water demands and water use on the Sacramento Valley floor portion of SacWAM using WEAP's catchment objects. Catchments are divided by land use type into agricultural, urban, and refuge areas. Additionally, 'demand sites' are used to represent urban water demands and deliveries to water users located outside the model domain (e.g., SWP south-of-Delta contractors).

Description of catchment object properties/parameters is organized using headings of the data tree in the WEAP software. Screenshots of the WEAP interface for each parameter are provided where possible to help the model user understand where parameters are entered into the model.

4.1 Delineation of Valley Floor

4.1.1 Water Budget Areas

The valley watersheds are aggregated into 25 WBAs (Figure 4-1). SacWAM WBAs are aggregated versions of WBAs defined by DWR for use in their planning models. The one exception to this is WBA 61N, where SacWAM only represents the area to the north of the Stanislaus River.

WBAs describe large regions with similar characteristics (e.g., climatic conditions). In SacWAM, WBAs serve the following purposes:

- To define the boundary of non-district agricultural water users within a region who are aggregated and represented as a single water demand.
- To define the boundary of scattered water users whose water supplies for domestic (or industrial) use are self-produced, who rely on groundwater, and who are represented as a single water demand.
- To define the spatial resolution of hydrologic input data (e.g., precipitation, temperature, wind, and humidity).

In the 1960s, DWR subdivided the Central Valley into three hydrologic regions: Sacramento River, San Joaquin River, and Tulare Lake. These regions were in turn disaggregated into 55 planning regions, termed Detailed Analysis Units (DAU), which are DWR's standard unit for collecting and reporting land use data, preparing water budgets, and making projections for land use change and urban growth for the California Water Plan. Many of the WBAs follow the boundaries of DAUs, which represent the resolution of DWR's land use and water-use data. This simplifies the generation of model input data and model validation through comparison with annual water budgets prepared by DWR for use in the California Water Plan (DWR, 2009a).

Figure 4-1. Valley Floor Water Budget Area Boundaries

4.1.2 Demand Units

WBAs are subdivided into DUs based on physical, legal, and contract types. DUs are computational units represented by WEAP catchment or demand objects in SacWAM and represent groups of water users who have similar land uses, climatic conditions, water delivery systems, and water use efficiencies. DUs are differentiated by land use and contract types. Land use types include agricultural, urban, and managed wetland classes. Contract user types include CVP settlement contractors, CVP water service contractors, water right holders in the FRSA who have signed settlement agreements with DWR as part of the SWP, and non-project water users. Grouping users by their water entitlements and water use characteristics facilitates simulation of surface water availability under different hydrologic conditions and proposed regulatory and operational changes.

4.1.2.1 Naming Convention

The naming convention provides a unique identifier for each DU, based on land use type, WBA, and contract type (Table 4-1). These pieces of information are separated by underscores within the naming scheme. The first character in the DU name indicates the land use type ('A' for irrigated agriculture, 'U' for urban, and 'R' for refuge), followed by the WBA number(s) in which the DU exists, and then by a character indicating the contract type ('S' for settlement or exchange contract holders, 'P' for CVP or SWP water service contract holders, and 'N' for non-project users). For example, in the naming scheme of DU 'A_02_NA,' 'A' indicates that the DU is an irrigated agricultural area, '02' indicates that it is part of WBA 02, and 'NA' specifies that these agricultural water users are provided water by non-project sources. The final letter in the name is a repeat of the first letter. The reason for the repetition is due to a naming convention restriction in the WEAP software.

Table 4-1. Demand Unit Naming Convention

Land Use	Settlement/Exchange Contract Holder	CVP/SWP Contract Holder	Non-Project Water Users
Irrigated Agriculture	A_(WBA#)_SA	A_(WBA#)_PA	A_(WBA#)_NA
Urban	U_(WBA#)_SU	U_(WBA#)_PU	U_(WBA#)_NU
Refuge	N/A	R_(WBA#)_PR	R_(WBA#)_NR

Key:
CVP = Central Valley Project
N/A = not applicable
SWP = State Water Project
WBA = Water Budget Area

There are some cases where a further distinction must be made in the naming convention. An example is 'A_14_15N_NA,' in which there are two groups of users sharing land use, contract type, and climatic characteristics, except that the groups have different water sources and returns. To differentiate between the two groups, a number is placed at the end of the naming scheme, creating DUs 'A_14_15N_NA1' and 'A_14_15N_NA2.'

The naming convention discussed above provides an explanation of DUs located in WBAs, but there is another naming convention for DUs not contained within a WBA. In the case where municipal areas outside of a WBA are supplied by a river within the Sacramento River Hydrologic Region, a four- to five-character acronym is used. For example, DUs 'U_NAPA_PU' and 'U_NAPA_PU_A21' represents the cities of Napa, St. Helena, Calistoga, Yountville, and American Canyon, supplied by the North Bay Aqueduct. There are two DUs to represent these cities because there are two sources of water (Article 21 and Table A water).

4.1.2.2 Represented Area

The valley floor portion of the model represents a total of approximately 6,060,000 acres. Agricultural land makes up 5,474,000 acres (680,000 acres of which is agricultural land within the Delta), urban areas make up 538,000 acres, and refuge land accounts for 49,000 acres (Figure 4-2). These areas are represented by 153 DUs, 78 of which are agricultural DUs, 69 of which are urban DUs, and six of which are refuge DUs.

Table 4-2, Table 4-3, and Table 4-4 list each SacWAM DU with water provider information. For agricultural DUs, the water district (WD) or WA supplying water to the DU is listed; for urban DUs, the represented municipal area and water agency supplying this area is listed; and for refuge DUs, the associated refuge area and water provider is listed.

4.1.2.2.1 Agricultural Lands

SacWAM represents agricultural water use in the Sacramento Valley using DUs built on the standard WEAP catchment object. Each DU receives water from a network of arcs, (known as *Transmission Links* in WEAP), which can include multiple surface water and groundwater sources. All agricultural DUs have at least one groundwater source, additionally most have a surface source(s). The surface water supply arcs link to specified RMs or CMs on a surface water body. Runoff arcs—of which there can be several—from the DU to the stream network, convey both rainfall-runoff and irrigation return flows. Runoff arcs from the DU to underlying groundwater aquifer(s) represent deep percolation from precipitation and irrigation. At runtime, SacWAM dynamically simulates crop water demands, water deliveries, groundwater pumping, irrigation return flows, and rainfall-runoff.

There are 78 agricultural catchment objects in SacWAM, defining most land use on the valley floor (Figure 4-2). Table 4-2 contains a list of all SacWAM agricultural DUs, with the name of the WD or WA represented by the DU. The assignment of land to DUs not only considers WD boundaries and access to surface water, but also similarity of cropping patterns and water use efficiency.

4.1.2.2.2 Urban Lands

Urban water demands represent a small portion of total water demand when compared to agricultural use but their representation in SacWAM is still significant. In the past, urban demands have been met largely through groundwater pumping rather than through the supply of surface water. However, there is notable predicted urban growth during the next 20 years, which will require a reassessment of urban water demands, and perhaps greater reliance on surface sources (California Water Foundation, 2014).

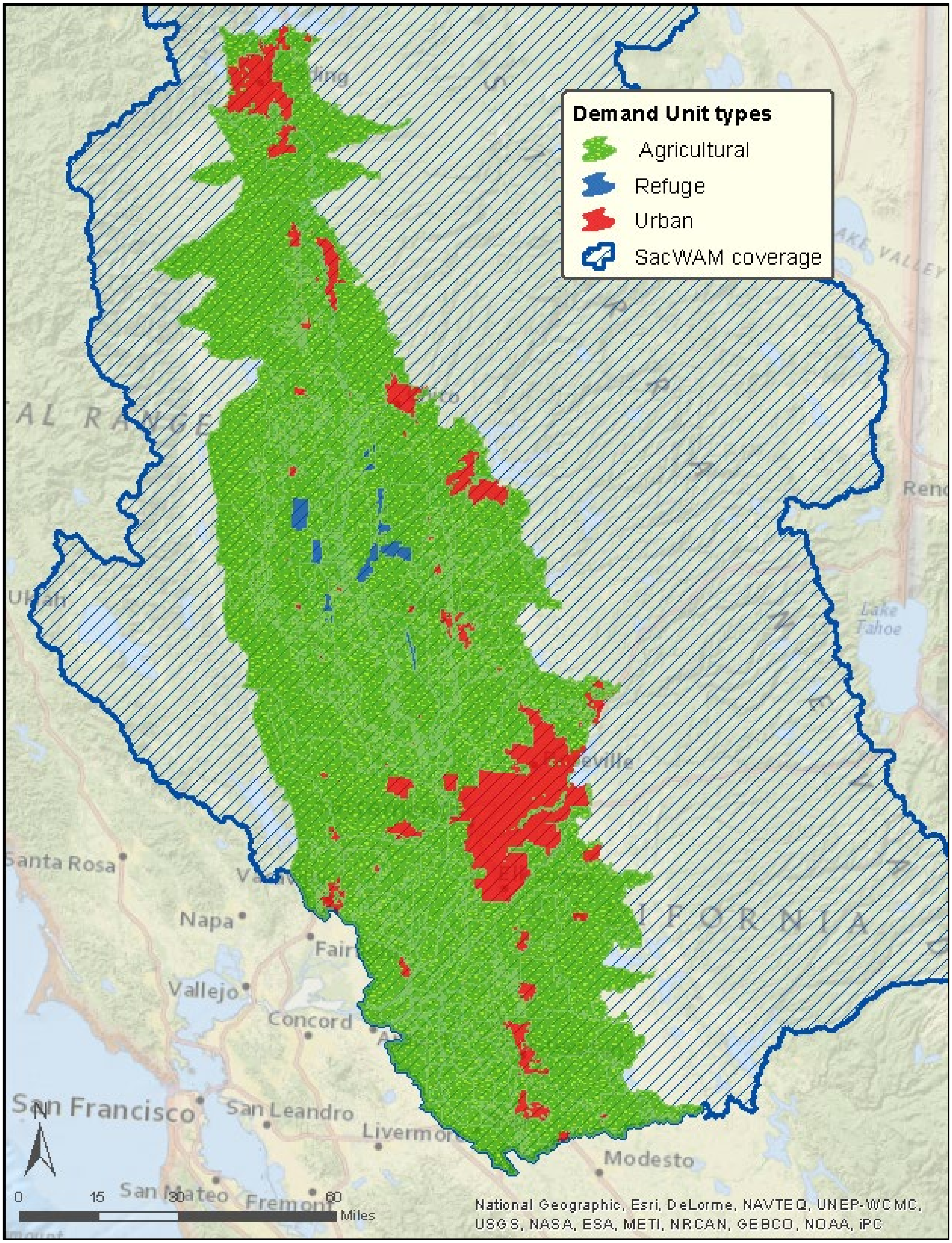


Figure 4-2. Agricultural, Refuge, and Urban Demand Units

There are 69 urban DUs represented in SacWAM (Figure 4-2). Fifty of these units are in WBAs within the Sacramento Valley. Each WBA contains a minimum of one urban DU, but in some cases, there are multiple urban DUs within a WBA to account for differing sources of water, contract types, water rights, or water treatment technology. There are also sixteen urban DUs located in the upper watersheds that are not included in the **DUs** shapefile. Although these DUs are outside of the valley floor, their representation in SacWAM is necessary, as these DUs are supplied by exports from canals and rivers that originate within the Sacramento Valley. Like valley-floor DUs, in some cases, there are multiple DUs to represent a group of urban areas in the upper watersheds. This allows the model to account for different sources of water, contract types, water rights, or water treatment technology.

Typically, in WEAP models, urban DUs are represented by a single demand site object. However, DUs that are in the Sacramento River Hydrologic Region are represented by both a catchment object and demand site object, placed next to one another. For example, DU 'U_03_PU' will have demand site object 'U_03_PU' and catchment object 'U_03_PU_O'. The demand site object represents indoor and outdoor urban demands derived from purveyor data. The catchment object represents the rainfall-runoff processes for the entire urban land area. The catchment node is differentiated from the demand site node with the suffix '_O'.

Similar to agricultural catchments, a single urban catchment, such as 'U_03_PU_O,' will have one or multiple runoff links to the stream network and one or more infiltration links to a groundwater basin(s) representing deep percolation. The demand site, such as 'U_03_PU' will have one or multiple transmission links from a surface source(s) and/or groundwater basin(s) (as some urban DUs conjunctively use surface water and groundwater), and a return flow link(s) to a surface water body(s).

4.1.2.2.3 Refuge Lands

In SacWAM, refuges or managed wetlands are the third major land use classification. The SacWAM refuge classification includes National Wildlife Refuges (NWRs), National Wildlife Management Areas (WMA), State Wildlife Areas, and private duck clubs. There are also private wetlands within agricultural catchments, but these were combined with crop water demands and included as part of the agricultural demand. SacWAM includes six catchment objects to represent individual refuges or groups of refuges. These refuge DUs are described in Table 4-4 and their location shown in Figure 4-2.

Table 4-2. Agricultural Demand Units in SacWAM

WBA	Demand Unit	Water District or Agency	Water Provider
02	A_02_NA	Non-district	N/A
	A_02_PA	Clear Creek CSD	CVP
	A_02_SA	Anderson-Cottonwood ID	CVP
		Misc. settlement contractors	
03	A_03_NA	Non-district	N/A
	A_03_PA	Bella Vista WD	CVP
	A_03_SA	Anderson-Cottonwood ID	CVP
		Misc. settlement contractors	
	A_04_06_NA1	Orland Unit WUA	Reclamation
04_06	A_04_06_NA2	Non-district (including misc. settlement contractors)	N/A
	A_04_06_PA1	Corning WD	CVP
		Proberta WD	
		Thomes Creek WD	
	A_04_06_PA2	Kirkwood WD	CVP
05	A_05_NA	Los Molinos MWC	N/A
		Non-district (including misc. CVP settlement contractors)	
07	A_07_NA	Non-district	N/A
	A_07_PA	Glide WD	CVP
		Holthouse WD	
		Kanawha WD	
		Orland-Artois WD	
		4-M WD	
		Colusa County WD	
		Cortina WD	
		Davis WD	
		Dunnigan WD	
		Glenn Valley WD	
		La Grande WD	
		Myers-Marsh MWC	
		Westside WD	
08	A_08_NA	Non-district	N/A
	A_08_PA	Colusa Drain MWC	CVP
	A_08_SA1	Maxwell ID	CVP
		Princeton-Codora-Glenn ID	
		Provident ID	
		Sycamore Family Trust	
		Misc. settlement contractors	
	A_08_SA2	Glenn-Colusa ID	Glenn-Colusa ID (55% of total)
	A_08_SA3	RD 108	CVP
		River Garden Farms	
		Misc. settlement contractors	
09	A_09_NA	Llano Seco Ranch	N/A
		Dayton MWC	
		Non-district	
	A_09_SA1	Pacific Realty Associates (formerly M&T Chico Ranch)	CVP
	A_09_SA2	RD 1004	CVP
		Carter MWC	
		Jack Baber	
		Misc. settlement contractors	
10	A_10_NA	Rancho Esquon	N/A
		Durham MWC	
		Non-district	
11	A_11_NA	Sutter Butte MWC	N/A

WBA	Demand Unit	Water District or Agency	Water Provider
		Non-district	
	A_11_SA1	Western Canal WD	SWP
	A_11_SA2	Richvale ID	SWP
	A_11_SA3	Biggs-West Gridley WD	SWP
		Butte WD	
	A_11_SA4	Sutter Extension WD	SWP
12_13	A_12_13_NA	South Feather Water and Power Agency	N/A
		Yuba County WD	
		Non-district	
	A_12_13_SA	Misc. FRSA diverters	N/A
14_15N	A_14_15N_NA1	Non-district	N/A
	A_14_15N_NA2	Cordua ID	Yuba County WA
		Hallwood ID	
		Ramirez WD	
	A_14_15N_NA3	Browns Valley ID	Browns Valley ID, Yuba County WA
	A_14_15N_SA	Misc. FRSA diverters	N/A
15S	A_15S_NA	Non-district	N/A
		Wheatland WD	
		Dry Creek WD	Yuba County WA
		South Yuba WD	
		Brophy WD	
	A_15S_SA	Plumas MWC	SWP
		Misc. FRSA diverters	
16	A_16_NA	Non-district	N/A
	A_16_PA	Feather WD	CVP
	A_16_SA	Garden Highway MWC	SWP
		Tudor ID	
		Oswald ID	
		Misc. FRSA diverters	
17	A_17_NA	Sutter Bypass-Butte Slough WUA	N/A
		Non-district	
	A_17_SA	Misc. FRSA diverters	N/A
		Minor settlement contractors	
18_19	A_18_19_NA	Butte Slough Irrigation Company	N/A
		Sutter Butte MWC	
		Non-district	
	A_18_19_SA	Meridian Farms WC	CVP
		Lomo Cold Storage	
		Sutter MWC	
		Tisdale IDC	
		Bardis et al.	
		Pelger MWC	
		Misc. settlement contractors	
20_25	A_20_25_NA1	Yolo County Flood Control & WCD	N/A
		Non-district	
	A_20_25_NA2	North Delta WA, non-district	N/A
	A_20_25_NA3	Non-district	N/A
	A_20_25_PA[2]	University of California at Davis	Solano County WA
		Solano ID	Reclamation
		Maine Prairie WD	Reclamation
21	A_21_NA	Non-district	N/A
	A_21_PA	Colusa Drain MWC (22% of total)	CVP
	A_21_SA	Conaway Conservancy Group	N/A
		Misc. settlement contractors	
22	A_22_NA	Non-district	N/A

WBA	Demand Unit	Water District or Agency	Water Provider
	A_22_SA1	Natomas Central MWC	CVP
		Pleasant Grove-Verona MWC	
		Misc. settlement contractors	
	A_22_SA2	Misc. FRSA diverters	N/A
23	A_23_NA	Camp Far West ID	South Sutter WD
		South Sutter ID	
		Non-district	
24	A_24_NA1	Nevada ID	Nevada ID
	A_24_NA2	PCWA Zone 5	PCWA
		Non-district	
	A_24_NA3	PCWA Zone 1	PCWA
26	A_26_NA	Non-district	N/A
50	A_50_NA1	North Delta WA	N/A
	A_50_NA2	North Delta WA	N/A
	A_50_NA3	Central Delta WA	N/A
		North Delta WA	
	A_50_NA4	Central Delta WA	N/A
		North Delta WA	
	A_50_NA5	Central Delta WA	N/A
		North Delta WA	
		South Delta WA	
	A_50_NA6	Byron Bethany ID	N/A
		Central Delta WA	
		North Delta WA	
	A_50_NA7	Byron Bethany ID	N/A
		South Delta WA	
60N	A_60N_NA1	Jackson Valley ID	N/A
	A_60N_NA2	Omochumne-Hartnell WD, Clay WD, Galt ID	N/A
	A_60N_NA3	North San Joaquin WCD	N/A
	A_60N_NA4	Woodbridge ID	N/A
	A_60N_NA5	Riparian diverters, non-district	N/A
60S	A_60S_NA	Non-district	N/A
	A_60S_PA	Stockton East WD	CVP Reclamation
		Central San Joaquin WCD	CVP
61N	A_61N_PA	Oakdale ID north	CVP
		South San Joaquin ID	
	A_61N_NA1	Non-district	N/A
	A_61N_NA2	Non-district	N/A
		Stanislaus River riparian diverters	
	A_61N_NA3	Non-district	N/A
		San Joaquin River riparian diverters	
N/A[1]	A_GDPUD_NA	Georgetown Divide PUD	Georgetown Divide PUD
	A_NIDDC_NA1	Nevada ID	Nevada ID
	A_NIDDC_NA2	Nevada ID	Nevada ID
	A_NIDBR_NA	Nevada ID	Nevada ID
	A_SCKWD_NA	Stony Creek WD	Stony Creek WD
	A_SIDSH_NA	Solano ID (external to WBA domain)	Solano ID

Notes: [1] Demand units located outside of the valley floor/Water Budget Area domain. [2] Demand unit A_20_25_PA is mislabeled in SacWAM. It is a non-project demand unit.

Key:

CSD = Community Service District, CVP = Central Valley Project, DWR = Department of Water Resources, FRSA = Feather River Service Area, ID = Irrigation District, IDC = Irrigation and Drainage Company, Misc. = miscellaneous, MWC = Mutual Water Company, N/A = not applicable, PUD = Public Utility District, Reclamation = U.S. Department of the Interior, Bureau of Reclamation, SWP = State Water Project, WA = Water Agency WBA = Water Budget Area, WC = Water Company, WCD = Water Conservation District, WD = Water District, WUA = Water Users Association

Table 4-3. Urban Demand Units in SacWAM

WBA	Demand Unit	Cities, Towns, and Communities	Water Agency
02	U_02_NU	Anderson	City of Anderson
		Cottonwood	Cottonwood WD
		Lake California	Rio Alto WD
		Small communities	Self-supplied
	U_02_PU	Centerville and Redding	Centerville CSD
		Happy Valley	Clear Creek CSD
		Shasta CSA No. 25	Keswick CSA
		Shasta	Shasta CSD
	U_02_SU	Redding- Foothill, Hill 900, and Cascade zones	City of Redding
03	U_03_NU	Small communities	Self-supplied
	U_03_PU	Shasta CSA No. 6	Jones Valley CSA
		Shasta Lake	City of Shasta Lake
		Mountain Gate	Mountain Gate CSD
		Stillwater Valley	Bella Vista WD
		Bella Vista	
		Palo Cedro	
		Redding	
		Redding- Buckeye and Hilltop zones	City of Redding
	U_03_SU	Redding- Hilltop and Enterprise zones	City of Redding
04_06	U_04_06_NU	Red Bluff	City of Red Bluff
		Corning	City of Corning
		Gerber	Gerber-Las Flores CSD
		Orland	City of Orland
		Small communities	Self-supplied
05	U_05_NU	Red Bluff	City of Red Bluff
		Los Molinos	Los Molinos CSD
		Small communities	Self-supplied
07	U_07_NU	Willows	California Water Service Company
		Arbuckle	Arbuckle Public Utility District
		Small communities	Self-supplied
08	U_08_NU	Hamilton City	California Water Service Company
		Colusa	City of Colusa
		Williams	City of Williams
		Small communities	Self-supplied
09	U_09_NU	Small communities	Self-supplied
10	U_10_NU1	Chico	California Water Service Company
	U_10_NU2	Durham	Durham ID
		Small communities	Self-supplied
11	U_11_NU1	Oroville	Thermalito ID
	U_11_NU2	Biggs	City of Biggs
		Gridley	City of Gridley
		Live Oak	Live Oak WD
		Small communities	Self-supplied
12_13	U_12_13_NU1	Oroville	California Water Service Company; South Feather Water and Power Agency
	U_12_13_NU2	Small communities	Self-supplied; South Feather Water and Power Agency
14_15N	U_14_15N_NU	Marysville	California Water Service Company
		Small communities	Self-supplied
15S	U_15S_NU	Olivehurst	Olivehurst Public Utility District
		Wheatland	City of Wheatland
		Linda	Linda County WD
		Small communities	Self-supplied

WBA	Demand Unit	Cities, Towns, and Communities	Water Agency
16	U_16_NU	Small communities	Self-supplied
	U_16_PU	Yuba City	City of Yuba City
17	U_17_NU	Sutter	Sutter CSD
		Small communities	Self-supplied
18_19	U_18_19_NU	Small communities	Self-supplied
20_25	U_20_25_NU	Davis	City of Davis
		El Macero	
		Willowbank	
		UC Davis	University of California at Davis
		Woodland	City of Woodland
		Winters	City of Winters
		Esparto	Esparto CSD
		Madison	Madison CSD
		Rio Vista	City of Rio Vista
		Dixon	California Water Service Company
		Small communities	Self-supplied
	U_20_25_SU	City of Vacaville	City of Vacaville - use of settlement
	U_20_25_PU	Vacaville	City of Vacaville - use of project/permit water
21	U_21_NU	Knights Landing	Knights Landing Service District
		Small communities	Self-supplied
	U_21_PU	West Sacramento (partly in Delta)	City of West Sacramento
22	U_22_NU	Sacramento International Airport	City of Sacramento
		Metro Air Park	Sacramento County WA - Zone 41
		Northgate 880	
		Small communities	Self-supplied
23	U_23_NU	Small communities	Self-supplied
24	U_24_NU1	Auburn	PCWA - Upper Zone 1
		Bowman	
		Christian Valley Park	Christian Valley Park CSD
		North Auburn	Nevada ID
		Small communities	Self-supplied
	U_24_NU2	Loomis	PCWA - Lower Zone 1
		Newcastle	
		Penryn	
		Rocklin	
		Granite Bay (portion)	
		City of Roseville (portion)	
		City of Lincoln	PCWA
		West Placer	Cal-Am WC
26	U_26_NU1	Northridge	Sacramento Suburban WD
		Arbors at Antelope McClellan Business Park	Sacramento Suburban WD
		Arcade- North Highlands	Sacramento Suburban WD
		Antelope	Cal-Am WC
		Lincoln Oaks	Cal-Am WC
		Rio Linda	Rio Linda Elverta CWD
		Elverta	Rio Linda Elverta CWD
		Arcade	Sacramento Suburban WD
		Arden	Golden State WC
		Del Paso Service Area	Del Paso Manor WD
		Arden Park Vista Service Area	Sacramento County WA - Zone 41
		Arden	Cal-Am WC
	U_26_NU2	Carmichael	Carmichael WD
	U_26_NU3	City of Sacramento- North	City of Sacramento
		City of Sacramento- South	

WBA	Demand Unit	Cities, Towns, and Communities	Water Agency
26	U_26_NU4	Parkway	Cal-Am WC
		Suburban	Cal-Am WC
		Rosemont	Cal-Am WC
		Florin	Florin County WD
		Fruitridge	Fruitridge Vista WD
		Tokay Park	Tokay Park WC- Zone 41
	U_26_NU5	Groundwater remediation	Aerojet
	U_26_NU6	Folsom Lake shoreline	California Parks and Recreation
	U_26_PU1	Roseville	City of Roseville
	U_26_PU2	San Juan Retail Service Area	San Juan WD
		Orange Vale	Orange Vale WC
		City of Citrus Heights	Citrus Heights WD
		Fair Oaks	Fair Oaks WD
		City of Folsom	City of Folsom
		Ashland	San Juan WD
	U_26_PU3	City of Folsom	City of Folsom
		Folsom State Prison	Folsom State Prison
	U_26_PU4	Laguna	Sacramento County WA
		City of Elk Grove	Elk Grove WD- Tariff Areas No. 1 and 2
		Vineyard	Sacramento County WA
		Mather-Sunrise	Sacramento County WA
		Sunrise/Security Park	Cal-Am WC, Sacramento County WA
	U_26_PU5	Rancho Cordova	Golden State WC
60N	U_60N_NU1	Galt (City of Galt)	City of Galt
		Lodi (City of Lodi)	City of Lodi
		Small communities	Self-supplied
	U_60N_NU2	Rancho Murieta	Rancho Murieta CSD
	U_60N_PU	Rancho Seco Power Plant	Sacramento Municipal Utility District
60S	U_60S_NU1	City of Stockton	City of Stockton; California Water Service Company
	U_60S_NU2	Small communities	Self-supplied
61N	U_61N_NU1	Lathrop	City of Lathrop
			South San Joaquin ID
		Escalon	City of Escalon
			South San Joaquin ID
		Manteca	South San Joaquin ID
	U_61N_NU2	Ripon	City of Ripon
		Oakdale	City of Oakdale
		Riverbank	City of Riverbank
		Small communities	Self-supplied
N/A[1]	U_AMADR_NU	Amador, Ione, Pioneer, Silver Lake Pines, Sutter Creek	Amador WA
	U_ANTOC_NU	Antioch	City of Antioch
	U_BNCIA_PU	Benicia (SWP water)	City of Benicia
	U_BNCIA_SU	Benicia (Settlement water)	City of Benicia
	U_CaCWD_NU	West Point	Calaveras County WD
	U_CaPUD_NU	San Andreas, Mokelumne Hill, Paloma	Calaveras PUD
	U_CCWD_PU	Bay Point, Clayton, Clyde, Oakley, Pittsburg, Port Costa	Contra Costa WD
	U_CLLPT_NU	Clear Lake, Lakeport, Small communities	Various M&I water purveyors
	U_CSPS_NU	California State Prison – Solano	California State Prison – Solano
	U_EBMUD_NU	Berkeley, Oakland, Richmond, Walnut Creek	East Bay Municipal Utility District
	U_ELDID_NU1	Placerville, Pollock Pines, Diamond Springs	El Dorado ID

WBA	Demand Unit	Cities, Towns, and Communities	Water Agency
	U_ELDID_NU2	El Dorado Hills, Cameron Park, Shingle Springs	El Dorado ID
	U_FRFLD_PU	Fairfield	City of Fairfield - use of project/permit water
	U_FRFLD_SU	Fairfield	City of Fairfield – use of settlement water
	U_GDPUD_NU	Georgetown	Georgetown Divide PUD
	U_JLIND_NU	Jenny Lind/Valley Springs	Calaveras County WD
	U_NAPA_PU	American Canyon Napa, St Helena Calistoga	City of American Canyon City of Napa City of Calistoga/Napa
	U_NAPA_PU_A21	American Canyon	City of American Canyon
		Napa, St. Helena Calistoga	City of NapaCity of Calistoga/Napa
	U_NIDBR_NU	Lake of the Pines	Nevada ID
	U_NIDDC_NU	Nevada City, Grass Valley	Nevada ID
	U_PCWA3_NU	Alta	Dutch Flat Mutual WC
		Dutch Flat	Weimar WC
		Colfax	Midway Heights County WD
		Applegate	Heather Glen CSD
		Meadow Vista	Meadow Vista County WD
	U_SUISN_NU	Suisun	City of Suisun
	U_TAFB_PU	Travis Air Force Base	Travis Air Force Base
	U_VLLJO_PU	Vallejo	City of Vallejo – use of project/permit water
	U_VLLJO_SU	Vallejo	City of Vallejo – use of settlement water

Note:
[1] Demand units located outside of the valley floor/Water Budget Area domain.
Key:
CSA = Community Service Area, CSD = Community Service District, CWD = Community Water District, ID = Irrigation District, N/A = not applicable, SA = Service Area, WA = Water Agency, WBA = Water Budget Area, WC = Water Company, WD = Water District, WSD = Water Service District.

Table 4-4. Refuge Demand Units in SacWAM

Water Budget Area	Demand Unit	Refuge/Wildlife Area	Water Provider
08	R_08_PR	Sacramento NWR	Reclamation
		Delevan NWR	
		Colusa NWR	
09	R_09_PR	Llano Seco Unit, Upper Butte Basin SWA	Llano Seco Rancho
		Llano Seco Unit, Sacramento River NWR	
11	R_11_PR	Little Dry Creek, Upper Butte Basin SWA Howard Slough Unit, Upper Butte Basin SWA	Western Canal WD Richvale ID
17	R_17_NR	Butte Sink Duck Clubs	Landowner
			Western Canal WD
	R_17_PR1	Gray Lodge SWA	Reclamation
			DWR (by Exchange)
	R_17_PR2	Sutter NWR	Reclamation
			Sutter Extension WD

Key:
DWR = Department of Water Resources, ID = Irrigation District, NWR = National Wildlife Refuge, SWA = State Wildlife Area, WD = Water District.

4.2 Simulation of Crop Water Demands

On the valley floor, evapotranspiration from the land surface is calculated on a daily time step using the dual crop coefficient approach described in Food and Agricultural Organization (FAO) Irrigation and Drainage Paper No. 56 (Allen et al., 1998). Within the WEAP software, this approach is referred to as the

MABIA method. The method requires inputs of temperature, precipitation, humidity, and wind speed. These data are used to calculate a reference evapotranspiration using the Penman-Monteith Equation. Individual crop types are assigned crop coefficients that are used to scale the reference evapotranspiration to reflect crop planting dates, canopy development rates, and harvest dates. In SacWAM, this approach is also used to simulate bare soil evaporation and water use by native and wetland vegetation.

In addition to calculating plant and soil evapotranspiration, the MABIA method calculates surface runoff, infiltration, and deep percolation. For this reason, in addition to the climatic inputs mentioned above, the MABIA algorithm requires specification of soil parameters such as soil water capacity and soil depth. The Soil Conservation Service (SCS) curve number method is used in a modification to the MABIA method to calculate effective rainfall. This modification is described in Section 4.4.3.4. For more details on the MABIA method, the reader is referred to the Help files of the WEAP software (Help>Contents>Calculation Algorithms>Evapotranspiration, Runoff, Infiltration, and Irrigation>MABIA Method).

Crop water-use parameters for the MABIA module were based on information obtained from the Sacramento – San Joaquin Basin Study (Reclamation, 2014c). Planting dates, season length, and single crop coefficient values were obtained from the study (Table 4-5, Table 4-6, and Table 4-7). A discussion of the calibration of the crop coefficients is provided in Appendix A.

Table 4-5. Perennial Crop Season Length and Growing Season Parameters Used in SacWAM

Crop	Length of Growing Season (Days)	Start of Growing Season	End of Growing Season
Alfalfa (annual)	365	1-Jan	31-Dec
Almonds	229	1-Mar	15-Oct
Apple	229	1-Apr	15-Nov
Orange	365	1-Jan	31-Dec
Pasture (improved)	365	1-Jan	31-Dec
Wine grapes	215	1-Apr	1-Nov

Table 4-6. Annual Crop Season Length and Growing Season Parameters Used in SacWAM

Crop	Length of Growing Season (Days)	Planting Date	Harvest Date
Beans (dry)	108	15-Jun	30-Sep
Corn (grain)	153	1-May	30-Sep
Corn (silage)	107	1-May	15-Aug
Cotton	154	15-May	15-Oct
Cucumber	93	15-May	31-Aug
Melon	123	15-May	15-Sep
Onion (dry)	215	1-Mar	1-Oct
Potato	123	15-Apr	15-Aug
Rice	139	15-May	30-Sep
Safflower	122	1-Apr	31-Jul
Sugarbeet	200	15-Mar	30-Sep
Tomato	153	1-Apr	31-Aug
Wheat	212	1-Nov	31-May

Table 4-7. Season Length and Crop Coefficients Used for Sacramento San Joaquin Basin Study

Crop	Length of Season (Days)	Percent of Growing Season			Crop Coefficients		
		Initial	Development	Mid-Season	K_c initial	K_c mid-season	K_c end-of-season
Alfalfa (annual)	365	25	50	75	1.00	1.00	1.00
Almonds[1]	229	0	50	90	0.55	1.20	0.65
Apple	229	0	50	75	0.55	1.15	0.80
Beans (dry)	108	24	40	91	0.20	1.10	0.10
Corn (grain)	153	20	45	75	0.20	1.05	0.60
Corn (silage)	107	20	45	100	0.20	1.05	1.00
Cotton	154	15	25	85	0.35	1.00	0.50
Cucumber	93	19	47	85	0.80	1.00	0.75
Melon[2]	123	21	50	83	0.75	1.05	0.75
Onion (dry)	215	13	42	72	0.55	1.20	0.55
Orange1	365	0	33	67	1.00	1.00	1.00
Pasture (improved)	365	25	50	75	0.95	0.95	0.95
Potato	123	20	45	78	0.70	1.15	0.50
Rice[3]	139	24	37	86	1.16	1.04	1.05
Safflower	122	17	45	80	0.20	1.05	0.25
Sugarbeet	200	15	45	80	0.20	1.15	0.95
Tomato	153	25	50	80	0.20	1.20	0.60
Wheat	212	25	60	90	0.30	1.05	0.15
Wine grapes	215	0	25	75	0.45	0.80	0.35

Notes:
[1] Mid-season crop coefficients for almonds and other tree crops may vary between 0.90 – 1.15 depending on whether a cover crop is present.
[2] The growing season for melons was revised from 229 days given in Basin Study to 123 days.
[3] Rice parameters were updated for this study using crop coefficients from Linquist et al. (2015).

4.3 Climate

Historical climate data were needed for the entire model domain for water years 1922 to 2015. In consultation with State Water Board staff and in response to advice from the peer review panel, the SacWAM development team developed two spatially interpolated, gridded datasets. One was developed by Livneh et al. (2013), the other developed by the PRISM Group at Oregon State University (PRISM, 2016).

The Livneh dataset provides daily precipitation, maximum and minimum temperature, and wind speed (at 10 meters [m] height) for January 1, 1915, to December 31, 2011, on a 1/16-degree grid. The following steps were followed in developing the data:

1. The **Livneh grid** was intersected with the **water budget areas** boundaries.
2. A VBA macro in **valley floor processor** was used to calculate the average of the maximum and minimum daily temperature, precipitation, and wind speed for all **Livneh grid** cells that intersected each WBA.
3. The spreadsheet **Daily CIMIS RH Analysis** was used to calculate an average maximum and minimum daily relative humidity time series based on CIMIS data.
4. Data from steps 2 and 3 were combined to create the input files found in **WEAP Input Data**.

The wind data in the Livneh et al. (2013) dataset is provided as wind speed at 10 m above the ground. These data were modified to represent wind speed at 2 m above the ground using the following relationship (Neitsch et al., 2005):

$$wind_2 = wind_{10} * (2/10)^{0.2} \quad \text{Equation 4-1}$$

where:

$wind_2$ is the wind speed at 2 m above the ground;

$wind_{10}$ is the wind speed at 10 m above the ground.

The PRISM dataset is a combination of daily data (1981-2015) and monthly data (1922-1980). The data set contains precipitation and maximum and minimum temperature on a 4-km grid. The following steps were followed in developing the data:

1. For 1922-1980, the daily Livneh precipitation, maximum temperature, and minimum temperature were scaled on a monthly basis so that the monthly average values matched the monthly PRISM data. Wind data were taken from the Livneh data set, and the relative humidity described above for the Livneh dataset were used.
2. For 1981-2015, the daily PRISM precipitation, maximum temperature, and minimum temperature were used. The wind data were taken from the Livneh data set, and the relative humidity described above for the Livneh dataset were used. For dates after 2011, the daily average wind speed values from the Livneh dataset were used.
3. Spatial processing that involved averaging PRISM grid data for each SacWAM catchment is described in **Prism spatial processing**.
4. The process utilized to scale the PRISM data and develop the input files read by SacWAM is provided in **SacWAM_PRISM_Data_Processor** and **SacWAM_UpperWatershed_PRISM_Data_Processor**.

SacWAM users can choose which data set to use by entering either ';Livneh' or ';PRISM' in *Key/Climate* in the data tree. In the results presented in the appendix of this document, PRISM data were used as climate inputs.

4.4 Agricultural Catchment Parameters

SacWAM represents agricultural water use in the Sacramento Valley using DUs built on the standard WEAP catchment object. Within each catchment, calculations of crop ET are performed for each crop type using the MABIA method described above. To meet the crop water demand, the demand unit receives water from surface water and groundwater sources via transmission links (solid green line). Return flows are routed using the dashed blue line, which represents either runoff (for surface water) or infiltration (for deep percolation). These links convey return flows from both rainfall and irrigation. Agricultural catchments can be recognized by their 'A_' prefix. Rainfall-runoff is simulated using the SCS Curve Number method, which is described in Section 4.4.3.4.

4.4.1 Conceptual Framework

Agricultural water use in SacWAM is represented using the conceptual framework illustrated in Figure 4-3. The solid lines shown in the figure are represented in the SacWAM schematic. Additional dashed lines are used to describe water use within the demand unit, are conceptual in nature, and are represented using various water use parameters. Definitions of each flow arc are provided in Table 4-8. In the conceptual framework, water supplies available to meet crop water demands are a mix of stream and canal diversions, groundwater pumping, and reuse of tailwater. Stream diversions and deliveries from major canal systems are subject to conveyance losses (evaporation and seepage).[18] In contrast, groundwater pumping is considered at field elevation and not subject to conveyance losses, unless a water district supplements canal deliveries with groundwater pumping into the district canal distribution system. Within the irrigation district, the canal distribution system is subject to operational spills and lateral flow through the canal banks to adjacent toe drains. Tailwater leaving the field (including flow-through from rice fields and drawdown of ponded water) is available for reuse. Water supplies must meet applied water demands. A fixed fraction of water demands must be met from groundwater pumping, representing farmers who do not have access to surface water.

Groundwater pumping is assumed to be at field scale. Therefore, simulated groundwater pumping is not subject to operational spills and lateral flows. However, in the case of surface water, these flows cannot be represented explicitly in WEAP, and must be represented implicitly by reducing the irrigation efficiency.

[18] WEAP losses on a transmission link consist of *Loss from System* and *Loss to Groundwater*. The software cannot represent operational spills and other water lost from the conveyance system that never reaches the field but returns to the surface drainage network. Because of this limitation, operational spills and other lost water are incorporated in to the WEAP irrigation efficiency.

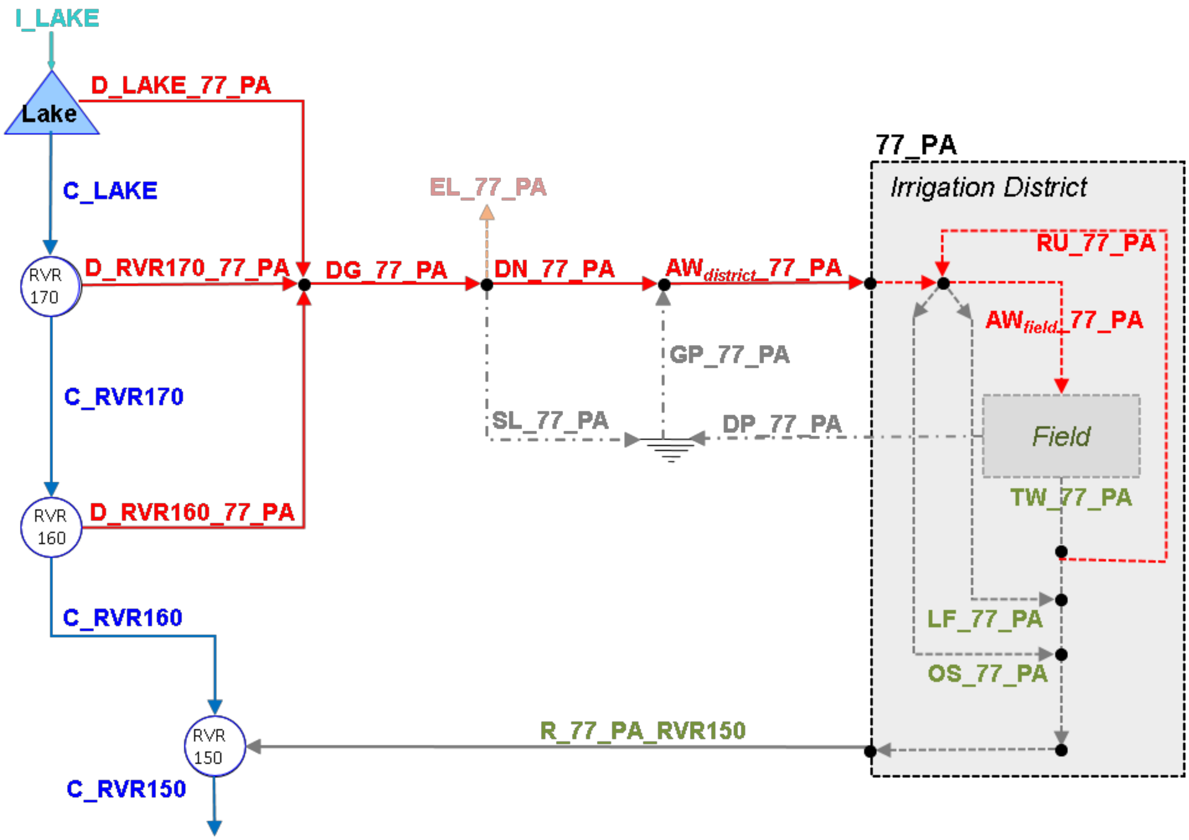


Figure 4-3. Template for Agricultural Water Use

Table 4-8. Flow Arcs for Agricultural Water Use

Arc Prefix	Name	Description
DG	Diversion Gross	The sum of all surface water diversions from the stream or canal system to the demand unit.
DN	Diversion Net	Net surface water reaching the district after accounting for evaporation and seepage conveyance losses.
EL	Evaporation Loss	Evaporative loss from surface water conveyance channels, including that from riparian growth adjacent to these channels.
SL	Seepage Loss	Seepage loss from conveyance structures such as canals.
LF	Lateral Flow Loss	Lateral flow through the banks of the canal distribution system to the adjacent toe drains.
OS	Operational Spill Loss	Flow leaving the canal distribution system, discharging directly to the drain system.
GP	Groundwater Pumping	Groundwater pumping (not subject to conveyance losses).
RU	Reuse	Reuse of tailwater, operating spills, and lateral flows at farm and district scales.
AW_{field}	Applied Water	Applied water at field scale, after accounting for losses from lateral flow and operational spills and supplies from reuse of water.
$AW_{district}$	Applied Water	Applied water at district scale is the sum of surface water deliveries, less conveyance loss, and groundwater pumping.
DP	Deep Percolation Loss	Deep percolation of irrigation water and precipitation at field scale.
TW	Tailwater	Return flow from irrigation at field scale.
R	Return Flow	Return flow at district scale consisting of operational spills, lateral flow, and tailwater, which are not reused.

4.4.1.1 Applied Water

The irrigation water required at the head of the field or farm gate is known as the applied water. The portion of irrigation water that is stored in the root zone and subsequently consumed through ET is known as the consumptive use of applied water. Applied water is related to the consumptive use of applied water by the seasonal application efficiency (SAE).

$$AW_{field}=CUAW/\ SAE \qquad \text{Equation 4-2}$$

where:

AW_{field}=applied water at head of the field
CUAW=consumptive use of applied water
SAE=seasonal application efficiency

Crop-specific SAEs are defined for each WBA. The term SAE is used, rather than irrigation efficiency, to indicate that values are constant over the irrigation season.

4.4.1.2 Potential Application Efficiency

Distribution uniformity is a measure of how uniformly water is distributed across the field. It is typically defined as the ratio of some measure of the smallest accumulated depths in the distribution of applied water to the average depth accumulated. Since 1940, NRCS has used the average of the lowest quarter of the distribution to the average of the distribution to define distribution uniformity (Burt et al., 1997). Distribution uniformity differs from irrigation efficiency. For example, water could be applied uniformly across the field, but in excess of crop water requirements and available soil moisture storage, resulting in a low application efficiency and deep percolation of applied water to groundwater. However, distribution uniformity can be used as an upper bound for potential application efficiency (PAE). PAE is based on the concept that the applied water is sufficient to achieve average soil moisture across the least watered quarter of the field equal to field capacity. For this assumption, PAE may be calculated using the following equation:

$$PAE_{field}=DU_{lq} \qquad \text{Equation 4-3}$$

where:

DU_{lq}=distribution uniformity based on the 'lower quarter' concept
PAE=potential application efficiency

SAEs estimated by DWR's Division of Statewide Integrated Water Management (DSIWM) are typically 1 to 1.10 times lower than PAEs based on DUs. The reason for this is that SAEs account for surface water leaving the field as tailwater. To account for this, the SAE is calculated as follows:

$$SAE_{field}=PAE.(1-f_{TW}) \qquad \text{Equation 4-4}$$

and:

$$AW_{field}=\frac{CUAW}{PAE.(1-f_{TW})} \qquad \text{Equation 4-5}$$

where:

f_{TW}=tailwater factor

As described above, at a district scale there are operational spills from the canal distribution system, and lateral flow through the canal banks to the toe drains. Tailwater leaving the field may be captured and reapplied. It is assumed that there is no reuse of operational spills and lateral flows.[19] The applied water at the boundary of the district and the associated SAE at the district scale may be calculated as follows:

$$AW_{district} = AW_{field}.\frac{(1-f_{RU})}{(1-f_{os}-f_{LF})} \qquad \text{Equation 4-6}$$

$$AW_{district} = \frac{CUAW}{PAE.(1-f_{TW})}.\frac{(1-f_{RU})}{(1-f_{os}-f_{LF})} \qquad \text{Equation 4-7}$$

$$SAE_{district} = PAE.\frac{(1-f_{TW}).(1-f_{OS}-f_{LF})}{(1-f_{RU})} \qquad \text{Equation 4-8}$$

where:

$SAE_{district}$ = seasonal application efficiency at district scale
f_{OS} = operational spill factor
f_{LF} = lateral flow factor
f_{TW} = tailwater factor
f_{RU} = reuse factor

Ideally, the operational spills and the lateral flows would be a function of the surface water deliveries rather than the applied water. However, currently there is no mechanism in the WEAP software to

[19] Operational spills and lateral flows that are captured and used to meet applied water demands are notnor represented in SacWAM as these flows are internal to the demand unit and do not affect the water balance.

account for these flows explicitly. Therefore, operational spills and lateral flows have been included in the irrigation efficiency.

4.4.1.3 Surface Water Demands

The demand for surface water at field level is calculated as follows:

$$DN_{max} = (1 - f_{GW})\ AW_{district} \qquad \text{Equation 4-9}$$

where:

DN_{max} = demand for surface water
f_{GW} = minimum groundwater pumping factor

Surface water deliveries are subject to conveyance losses. When water supplies, water contracts, and/or water rights are not limiting, stream diversions (DG) or deliveries from major canal systems are determined as follows:

$$DG_{max} = DN_{max}/(1 - f_{EV} - f_{SP}) \qquad \text{Equation 4-1}$$

where:

DG = gross surface water diversion (i.e., as measured at point of diversion)
f_{EV} = evaporative loss factor
f_{SP} = seepage loss factor

The net delivery (DN) is only equal to the demand for surface water (DN_{max}) when there are no binding constraints on surface water diversions.

4.4.1.4 Surface Irrigation Return Flows

Irrigation water returning to the stream system can be expressed as a function of the applied water demand at the district boundary, as follows:

$$RF = (f_{OS} + f_{LF}).AW_{district} + f_{TW}.AW_{field}.(1 - f_{RU}) \qquad \text{Equation 4-11}$$

$$RF = (f_{OS} + f_{LF}).AW_{district} + f_{TW}.AW_{district}.(1 - f_{OS} - f_{LF}) \qquad \text{Equation 4-12}$$

4.4.1.5 Deep Percolation from Applied Water

Irrigation water that infiltrates the soil surface and percolates to the underlying groundwater can be expressed as a function of the applied water demand at the district boundary, as follows:

$$DP = (1 - PAE) \qquad \text{Equation 4-13}$$

$$DP = AW_{field}.(1 - PAE - f_{TW}) \qquad \text{Equation 4-14}$$

$$DP = AW_{district}.\frac{(1-f_{OS}-f_{LF})}{(1-f_{RU})}.(1 - PAE - f_{TW}) \qquad \text{Equation 4-15}$$

4.4.1.6 Ponded Fields (Rice and Flooded Refuge Lands)

Fields that are ponded utilize a different conceptual model than the one described above. In SacWAM, this applies to rice fields and the portions of refuges that are seasonally or permanently flooded.

Like other crops, there are seepage and evaporative losses from the canal system that are represented in the *Loss to Groundwater* and *Loss to System* on the transmission links that connect the DUs catchment object to a stream.

Losses from the flooded lands consist of deep percolation and flow through. Deep percolation is specified in the *Maximum Percolation Rate* parameter. This parameter is set in *Other Assumptions\Valley Floor Hydrology\Calibration Factors\Rice\MaxPercRate*. Flow through, for salinity control, and losses to surface drains are set by the *Release Requirement* parameter. Values for *Release Requirement* are read from the comma-separated values (csv) file SACVAL_Rice_Drainage.csv located in *Data\Param\Rice*.

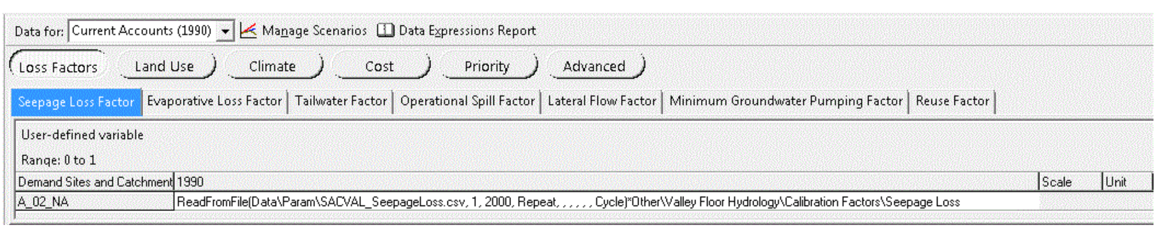
4.4.2 Loss Factors

Loss factors are entered at the DU level in the catchment interface, except for *Potential Application Efficiency*, *Loss to Groundwater*, and *Loss to System*. *Potential Application Efficiency* is listed by WBA and is entered into the SacWAM branch *Other Assumptions\Valley Floor Hydrology\Potential Application Efficiency*, and Loss to Groundwater and Loss to System are both entered as transmission losses in *Supply and Resources\Transmission Links\Loss to Groundwater* and *Supply and Resources\Transmission Links\Losses* branch of the model.

To maintain flexibility in adjusting model parameters, all loss factors are read into SacWAM using a read-from-file command that references a column in the relevant csv file. There are two ways to adjust these parameters, either by altering the factors within the csv file, or globally scaling a factor in the *Other Assumptions\Valley Floor Hydrology\Calibration Factors* branch. To decrease evaporative losses across the model by 20%, for instance, one would change the value of 1 in the *Other Assumptions\Valley Floor Hydrology\Calibration Factors\Evaporative Loss* branch to 0.8. The factors that can be adjusted in this way are: *Seepage Loss*, *Evaporative Loss*, *Tailwater*, *Operational Spill*, *Lateral Flow*, *Reuse*, and *Potential Application Efficiency*.

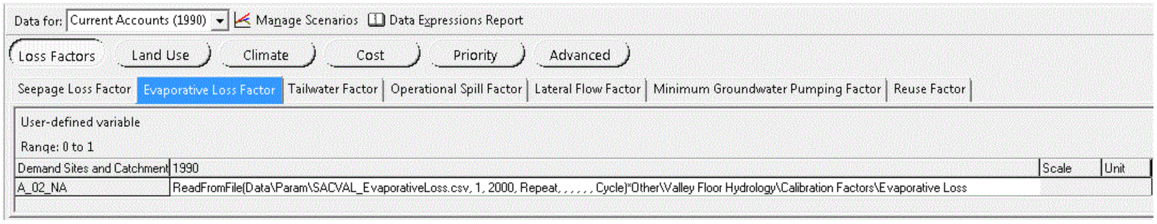
In the current version of SacWAM, loss factors are based on values derived for DWR models. All global factors are currently set to a value of 1.0.

4.4.2.1 Seepage Loss Factor



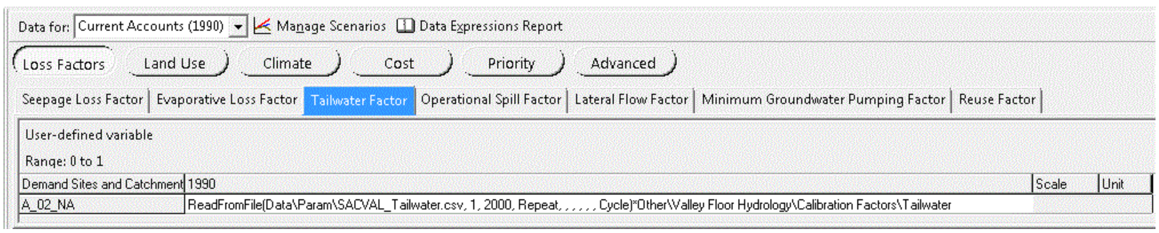
Seepage Loss is loss to the groundwater system from conveyance channels. Initial values were based on default DWR values. These values range from 0.0 to 0.28.

4.4.2.2 Evaporative Loss Factor



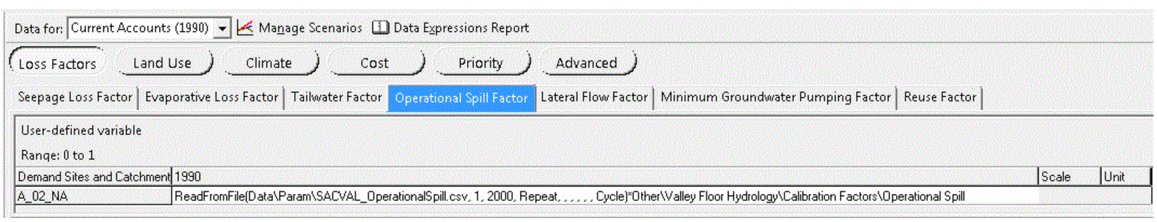
Evaporative Loss is defined as evaporative loss from surface water conveyance channels, including that from riparian growth adjacent to these channels. Except for the Delta DUs (DUs A_50_XXX), which have a value of zero, all DUs were assumed to have a value of 0.01.

4.4.2.3 Tailwater Factor



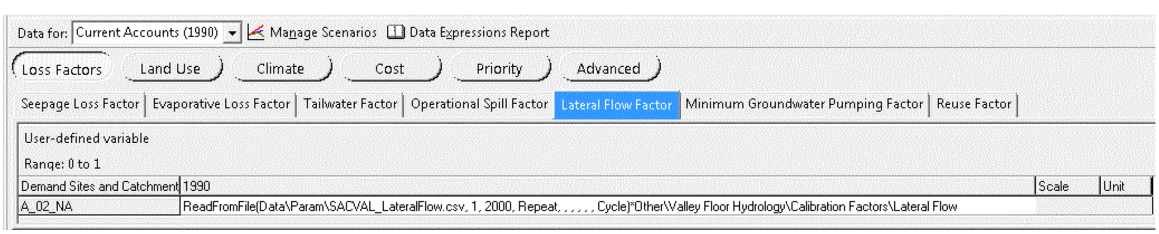
Tailwater factors are assumed to be 0.1, i.e., ten percent of applied water leaves the field as tailwater.

4.4.2.4 Operational Spill Factor



Operational spills associated with canal conveyance in agricultural and refuge DUs and are typically assumed equal to three percent of the surface water diversion. However, for a few DUs where operational spills are known to be large (e.g., Anderson-Cottonwood ID), operational losses were increased up to a maximum of 25 percent of the diversion. For buried pipe systems, operational spills are assumed to be zero. These values were based on default DWR values.

4.4.2.5 Lateral Flow Factor



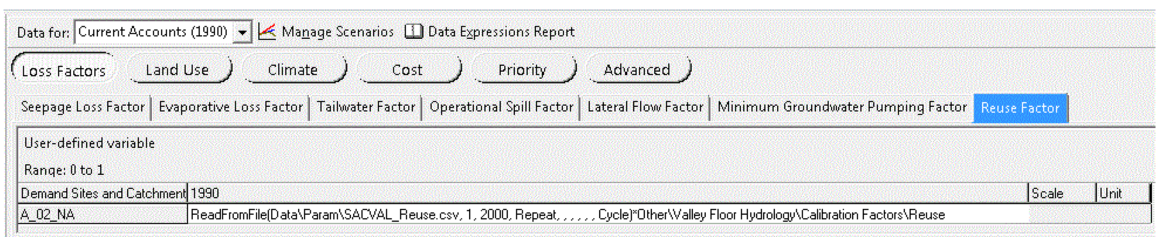
Lateral flow is horizontal seepage to the canal toe drains. The portion of lateral flow that is recaptured for irrigation is not represented explicitly in WEAP because this does not affect the water balance or water available at the farm gate. For WEAP, this recaptured water is simulated as remaining within the canal system. These values were based on default DWR values and range from 0.0 to 0.25.

4.4.2.6 Minimum Groundwater Pumping Factor

Minimum **groundwater pumping** factors are specified in SacWAM representing the part of the applied water demand that must be met from groundwater pumping. Applied water demands in excess of minimum groundwater pumping are met from surface water and additional groundwater pumping, if necessary.

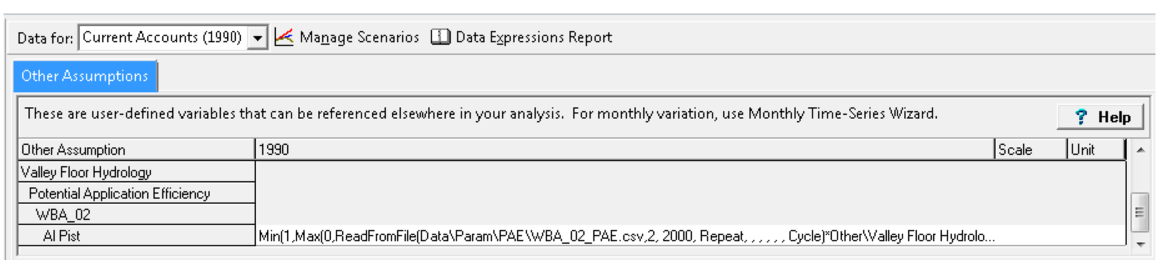
The *Minimum Groundwater Pumping Factor* was determined using information from DWR's county land use surveys (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a). Initial groundwater pumping fractions were calculated as the lands dependent on groundwater only divided by the area of lands that 1) use surface water only 2) use groundwater only or 3) have access to both surface water and groundwater. Each agricultural and urban DU has a *Minimum Groundwater Pumping Factor* in SacWAM. This parameter is used to define the *Maximum Flow Percent of Demand* parameter on the surface water transmission links (Section 6.6).

4.4.2.7 Reuse Factor



Reuse of tailwater from crops other than rice is set equal to zero to ten percent of applied water demand.

4.4.2.8 Potential Application Efficiency



Potential application efficiencies are WBA- and crop-specific. They are discussed in this section as they relate to other Loss Factor parameters, although in SacWAM they are specified in the *Other Assumptions\Valley Floor Hydrology\Potential Application Efficiency* branch of the model. These values are based on UC Davis (2013) and Sandoval-Solis et al. (2013).

4.4.3 Land Use

Under the *Agricultural Catchments\Land Use* branch, parameter values were set according to the descriptions provided below.

4.4.3.1 Area

The following are the data sources used in determining the distribution of area classes in SacWAM DUs:

- WD and WA boundaries and service areas obtained from the California Spatial Information Library (CaSIL), which comprises separate GIS layers for Federal, State, and private water-districts (CaSIL, 2013).
- County land use surveys undertaken by DWR's DSIWM, formerly Division of Planning and Local Assistance (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a).
- County and regional integrated water resources plans and integrated water management plans.
- Reclamation CVP water supply contract renewal (Reclamation, 2013a) and supporting environmental documents (Assessments, Environmental Impact Statements, and Findings of No Significant Impacts) (Reclamation, 2013b).

To define SacWAM agricultural land acreages, DWR land use data were obtained (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a). In the 1950s, DWR began to collect geospatial urban and agricultural land use data by county. Each county is surveyed every seven years. The DWR data include over seventy crop classifications. Due to the large number of classifications, crop types were aggregated where possible to create fewer land use classes for use in SacWAM (Table 4-9). The scheme includes twenty crop classifications in addition to classifications for urban (UR) and native vegetation (NV) areas. Note that the acreages given for wetland areas (DWR classes NR4 and NR5) are lumped with the NV class. The acreages given for wetland areas represent identified wetlands in agricultural areas and were only identified in the upper half of the Sacramento Valley by the DWR Northern District office.

Table 4-9. SacWAM Agricultural Land Use Classifications

SacWAM Classification Crop Type (Code)	Code	DWR Land Use Classification Description
Alfalfa (AL)	P1	Pasture: Alfalfa
Almonds & Pistachios (AP)	D12	Deciduous Fruits & Nuts: Almonds
	D14	Deciduous Fruits & Nuts: Pistachios
Corn (CR)	F6	Field Crops: Corn
Cotton (CO)	F1	Field Crops: Cotton
Cucurbits (CU)	T9	Truck, Nursery, Berry: Melons, Squash, and Cucumbers
Dry Beans (DB)	F10	Field Crops: Beans
Grain (GR)	G	Grain & Hay: Miscellaneous
	G1	Grain & Hay: Barley
	G2	Grain & Hay: Wheat
	G3	Grain & Hay: Oats
	G6	Grain & Hay: Miscellaneous Mixed
Native Vegetation and Refuges (NV)	E	Entry Denied
	I	Idle
	I1	Land not cropped in current or previous season, but cropped in past three years
	I2	New lands being prepared for crop production
	NB	Barren Land
	NB1	Dry Stream Channel
	NB2	Mine Tailing
	NB3	Native Barren
	NC	Native Classes Unsegregated
	NR	Riparian Vegetation
	NR1	Marsh
	NR2	High Water Table Meadow
	NR3	Trees and Shrubs
	NR4	Seasonal Duck Marsh
	N45	Permanent Duck Marsh
	NS	Not Surveyed
	NV	Native Vegetation
	NV1	Grass
	NV2	Light Brush
	NV3	Medium Brush
	NV4	Heavy Brush
	NV5	Brush and Timber
	NV6	Forest
	NW	Water Surface
Onions and Garlic (OG)	T10	Truck, Nursery, Berry: Onions and Garlic
Other Deciduous Orchard (OR)	D	Deciduous Fruits & Nuts: Not Classified
	D1	Deciduous Fruits & Nuts: Apples
	D2	Deciduous Fruits & Nuts: Apricots
	D3	Deciduous Fruits & Nuts: Cherries
	D5	Deciduous Fruits & Nuts: Peaches and Nectarines
	D6	Deciduous Fruits & Nuts: Pears
	D7	Deciduous Fruits & Nuts: Plums
	D8	Deciduous Fruits & Nuts: Prunes
	D9	Deciduous Fruits & Nuts: Figs
	D10	Deciduous Fruits & Nuts: Miscellaneous Deciduous
	D13	Deciduous Fruits & Nuts: Walnuts
Crop Type (Code)	**Code**	**Description**
Other Field (FI)	F	Field Crops: Not Classified
	F3	Field Crops: Flax
	F4	Field Crops: Hops

SacWAM Classification Crop Type (Code)	Code	DWR Land Use Classification Description
	F7	Field Crops: Sorghum
	F8	Field Crops: Sudan
	F11	Field Crops: Miscellaneous Field
	F12	Field Crops: Sunflowers
Pasture (PA)	P	Pasture: Not Classified
	P2	Pasture: Clover
	P3	Pasture: Mixed
	P4	Pasture: Native
	P5	Pasture: High Water Native
	P6	Pasture: Miscellaneous Grasses
	P7	Pasture: Turf Farms
Potatoes (PO)	T12	Truck, Nursery, Berry: Melons, Squash, and Cucumbers
Rice (RI)	R	Rice: Rice
Safflower (SF)	F2	Field Crops: Safflower
Subtropical (SO)	C	Citrus & Subtropical: Not Classified
	C1	Citrus & Subtropical: Grapefruit
	C2	Citrus & Subtropical: Lemons
	C3	Citrus & Subtropical: Oranges
	C4	Citrus & Subtropical: Dates
	C5	Citrus & Subtropical: Avocados
	C6	Citrus & Subtropical: Olives
	C7	Citrus & Subtropical: Misc. Subtropical
	C8	Citrus & Subtropical: Kiwis
	C9	Citrus & Subtropical: Jojoba
	C10	Citrus & Subtropical: Eucalyptus
Sugar Beets (SB)	F5	Field Crops: Sugar Beets
Tomatoes (TM: TH)	T15	Truck, Nursery, Berry: Tomatoes
Vineyards (VI)	V	Vineyard: Not Classified
	V1	Vineyard: Table Grapes
	V2	Vineyard: Wine Grapes
	V3	Vineyard: Raisin Grapes

Once SacWAM land use classes were determined, acreages for each class were found. Irrigated crop acreage (ICA) of DAUs from water years 1998-2007 were obtained from DSIWM. The average annual ICA for this 10-year period was assumed representative of 'existing conditions.' Then, land use for the Central Valley was assembled from the different county land use surveys to create a continuous mosaic in GIS, although the land use data are derived from different years. The GIS mosaic was intersected with DU polygons and with DAU polygons to obtain the historical irrigated land area for each DU and for each DAU. These historical values were converted to a value representing 'existing conditions' by scaling the 'snapshot' land use data to match the 10-year DAU value. The following example illustrates this process:

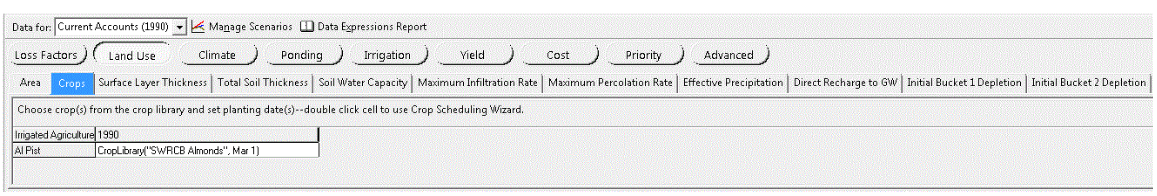
- Assume the 10-year historical average for wheat in DAU X=10,000 acres
- Assume the GIS data from the land use mosaic shows 8,000 acres of wheat in DAU X
- Assume the GIS data from the land use mosaic shows 500 acres of wheat in DU A
- If DU A is located within DAU X, the existing level acreage for wheat=500*(10,000/8,000) acres

A table was created containing acreage data for each SacWAM DU, displayed in twenty-four columns. Each column indicates the acreage of a crop within a DU, listed by its crop code. For instance, 'A_02_NA_AL' will contain the acreage of alfalfa in catchment 'A_02_NA.' There are instances where irrigated land exists inside municipal boundaries which are represented by an urban DU. In this case, the irrigated land was removed from the urban DU and associated with a neighboring agricultural DU. For example, 'A_02_NA' may supply water to neighboring demand site 'U_02_SU' for 500 acres of alfalfa. Consequently, the crop acreage of 'A_02_NA_AL' will be larger than the irrigated alfalfa physically present in 'A_02_NA,' because it includes the alfalfa acreage of 'U_02_SU.' It is also the case that agricultural catchments include urban area. These areas include semi-agricultural, industrial, and commercial lands that exist outside of municipal boundaries, such as schools, motels, and mills. These areas are simulated using parameters that reflect mostly impermeable surfaces in SacWAM. The final land use dataset for all agricultural lands except for the Delta DUs (A_50_NA1 through A_50_NA7) is contained in the **agricultural land use** file.

In instances in which irrigated land exists inside municipal boundaries (which are represented by an urban DU), the irrigated land was 'removed' from the urban DU and associated with a neighboring agricultural DU. For example, assume there exist 4,000 acres of irrigated land in U_02_NU and 6,000 acres of irrigated land in neighboring agricultural DU A_02_NA. The 4,000 acres of irrigated land were removed from U_02_NU and associated with A_02_NA. Consequently, there are 10,000 total acres of irrigated land represented by agricultural DU A_02_NA. The total areas of each DU (A_02_NA and U_02_NU) were preserved by adjusting the amount of native vegetation adjusted. In the example above, 4,000 acres of native vegetation lands would be added to DU U_02_NU and 6,000 acres of native vegetation lands would be subtracted from A_02_NA.

The land use dataset for areas within the Sacramento–San Joaquin Delta is documented in the **delta land use** file. A similar approach as described above was used to determine land use acreages in the Delta. In 2006, the Delta Evapotranspiration of Applied Water model (DETAW) was developed by the University of California at Davis to estimate consumptive water demands within the Delta (Kadir, 2006). This development was in cooperation with DSIWM and funded by the Modeling Support Branch of the Bay-Delta office. DETAW estimates consumptive water demands for 168 subareas within the Delta Service Area. To determine land use acreage for the Delta, a shapefile containing these 168 DETAW subregions (DWR, 2014b) was intersected with DWR's land use survey of Delta lands (DWR, 2007). A look-up table was used to associate each of the DETAW subregions with its SacWAM DU. The result of this process was land use data by crop type for each DU.

4.4.3.2 Crops



The Crops parameter is used to specify crop type and planting date. WEAP has a **crop library** (General>Crop Library) where information on crop coefficients, season length, management allowable depletion, and rooting depth is contained. The twenty-two SacWAM crops, plus Native Vegetation and Urban classes were added to the **crop library**. The planting date information entered into the Crop Library were obtained from the DWR Consumptive Use Program (CUP) and Simulation of Evapotranspiration of Applied Water (SIMETAW) models (Orang et al., 2013). The crop coefficients were calibrated to match crop ET values produced by the CUP model. Rooting depth, depletion factors, and maximum height information were obtained from the WEAP database, which is based on FAO56 (Allen et al., 1998).

4.4.3.3 Direct Recharge to GW

Direct Recharge to GW was assumed to be equal to 0 percent as this feature of the WEAP software was not used.

4.4.3.4 Effective Precipitation

A modified SCS Curve Number approach (NRCS, 1986; SCS, 1972) was used to partition the daily rainfall into runoff and infiltration. The modification to the standard approach makes the maximum soil moisture retention, S, a function of the soil moisture at the end of the previous day (Schroeder et al., 1994).

The effective precipitation is calculated as:

$$P_{eff} = \frac{P-Q}{P} \; x \; 100 \qquad \text{Equation 4-3}$$

where:

P_{eff} = effective precipitation (%)
Q = runoff (in)
P = precipitation (in)

Runoff is calculated using:

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)} \qquad \text{Equation 4-4}$$

where:

S = maximum soil moisture retention (in)

These equations are calculated in the Effective Precipitation parameter of the interface. The expression requires the value of the maximum soil moisture retention, S, which is calculated as a function of the current soil moisture status and is described in the Max Soil Moisture Retention parameter definition.

4.4.3.5 Initial Bucket 1 Depletion

Initial Bucket 1 Depletion was assumed to be equal to 0 mm (the WEAP default value).

4.4.3.6 Initial Bucket 2 Depletion

Initial Bucket 2 Depletion was assumed to be equal to 0 mm (the WEAP default value).

4.4.3.7 Max Soil Moisture Retention

The maximum soil moisture retention, S, is calculated using:

$$S = \begin{bmatrix} S_m\left[1 - \frac{SM-[(FC+WP)/2]}{UL-[(FC+WP)/2]}\right] & for\ SM > (FC+WP)/2 \\ S_m & for\ SM < (FC+WP)/2 \end{bmatrix} \qquad \text{Equation 4-2}$$

where:

S_m = maximum value of S where S = 1000/CN – 10, in inches

SM = soil moisture at the end of the previous day

FC = field capacity of soil

WP = wilting point of soil

UL = soil saturation

In SacWAM, soil saturation (UL) is replaced by the expression:

*Bucket 1 Field Capacity[%]*Other\Valley Floor Hydrology\SCS Curve Number\FactorHigh_Crops*

And the expression for the average of field capacity and wilting point ([FC+WP]/2) is replaced by the expression:

*Bucket 1 Field Capacity[%]*Other\Valley Floor Hydrology\SCS Curve Number\FactorLow_Crops*

Typical values of soil moisture for a clay soil are as follows: saturation 53%, field capacity 43%, wilting point 23% (IILRI, 1972). Values of 1.25 and 0.75 have been adopted for *FactorHigh_Crops* and *FactorLow_Crops*, respectively.

Making the maximum soil moisture retention a function of the soil moisture results in increasing runoff as soil moisture increases. The expressions for *Max Soil Moisture Retention* and *Effective Precipitation* are located in the **effective precipitation** spreadsheet.

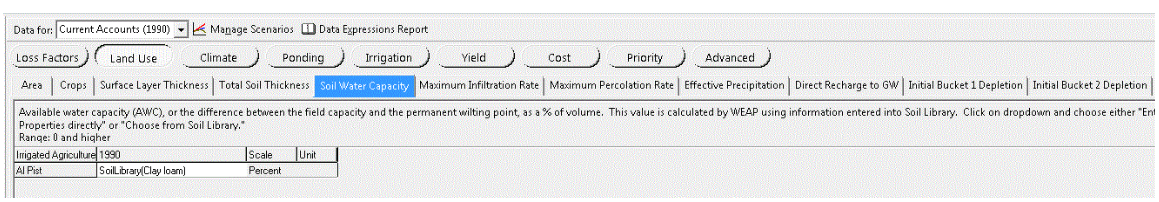
4.4.3.8 Maximum Infiltration Rate

The *Maximum Infiltration Rate* was not specified.

4.4.3.9 Maximum Percolation Rate

The Maximum Percolation Rate was specified to 0.025 inches/day for rice based on information from the UC Davis Cooperative Extension. This value is set in *Other Assumptions\Valley Floor Hydrology\Calibration Factors\Rice\MaxPercRate* for Rice and Rice Early. A maximum percolation rate was not set for other crops.

4.4.3.10 Soil Water Capacity



Soil water capacity is plant-available water calculated as the difference between field capacity and permanent wilting point. This value is specified in the Soil Library (General>Soil Library). All soils were assumed to be clay loam with an available water capacity of 14.5%. This assumption was based on an analysis of **surface soils** in the STATSGO database that found loam and clay loam are the dominant surface soil textures on the Sacramento Valley floor.

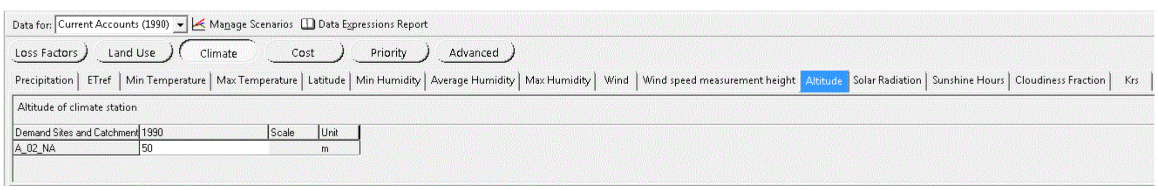
4.4.3.11 Surface Layer Thickness
Surface Layer Thickness was assumed to be equal to 0.1 m (the WEAP default value). This is the portion of the soil from which bare soil evaporation can extract water.

4.4.3.12 Total Soil Thickness
Total Soil Thickness was assumed equal to 2 m (the WEAP default value). Transpiration can remove moisture from the depth of soil penetrated by roots (specified in the Crop Library). This parameter specifies the total depth over which the soil moisture balance is calculated.

4.4.3.13 Fraction Covered
Fraction Covered is used to specify the fraction of the soil that is covered by crop. This value is used to determine the portion of the soil that should be subjected to bare soil evaporation. If this parameter is left blank, then MABIA uses an algorithm found in FAO56 that calculates the covered fraction as a function of crop development stage and maximum crop height. In SacWAM, this value has been specified for three crops. Alfalfa and pasture were given values of 1.0 since they maintain complete cover year-round. Rice was given a value of 1.0 during the rice growing season. This forces the MABIA model to calculate rice ET as the product of the basal crop coefficient and the reference ET. It eliminates all bare soil evaporation. By substituting the literature based single crop coefficient for the basal crop coefficient, the model was forced to calculate the rice ET at the rate specified in the literature (Linquist et al., 2015).

4.4.4 Climate

4.4.4.1 Altitude



The *Altitude* parameter is specified for the valley floor catchments that use the MABIA calculation algorithm. This value was assumed to be 50 m for all catchments.

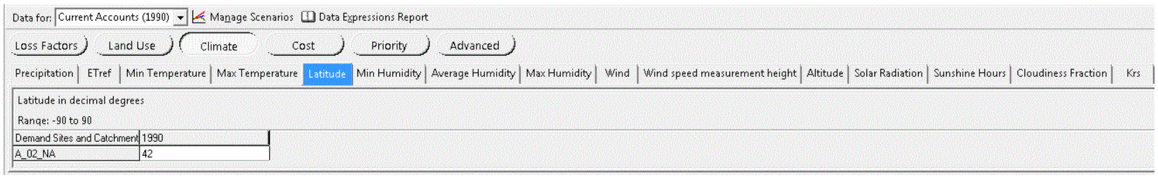
4.4.4.2 Average Humidity
No data were input for *Average Humidity*, because *Minimum Humidity* and *Maximum Humidity* were both specified.

4.4.4.3 Cloudiness Fraction
No data were input for the *Cloudiness Fraction*. It was assumed that errors introduced by this assumption are minimal since there is little cloudiness during the period of highest ET (Apr – Oct).

4.4.4.4 ETref
No data were input for *ETref*, because SacWAM uses the Penman-Monteith equation to calculate *ETref*.

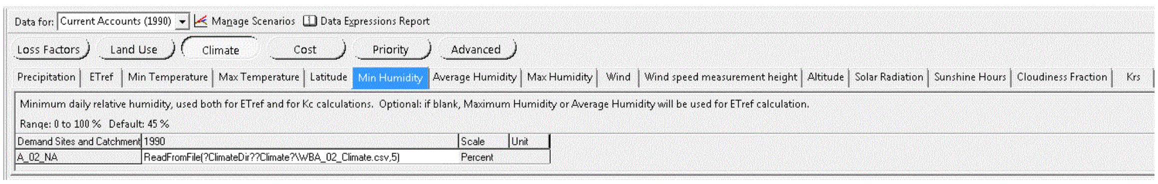
4.4.4.5 Krs
Krs is not used in SacWAM as the Penman Monteith equation is used to calculate *ETref.*

4.4.4.6 Latitude



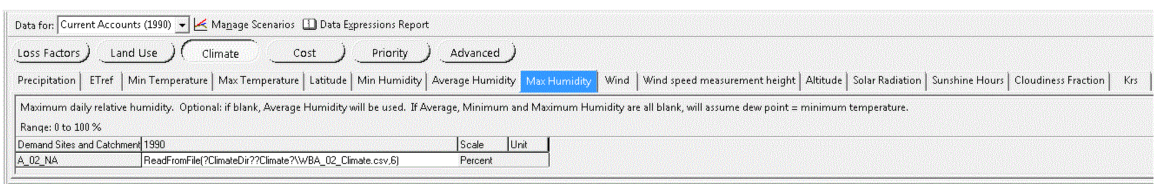
Centroids were calculated in ArcGIS for all DUs and catchments after DUs and catchments had been dissolved into multi-part features. This allowed the calculation of one centroid per DU and catchment rather than one centroid per DU or catchment part. Latitudes were calculated for these points in decimal degrees in WGS1984 UTM Zone 11 N. **Latitudes** were rounded to three decimal places and imported into WEAP.

4.4.4.7 Min Humidity



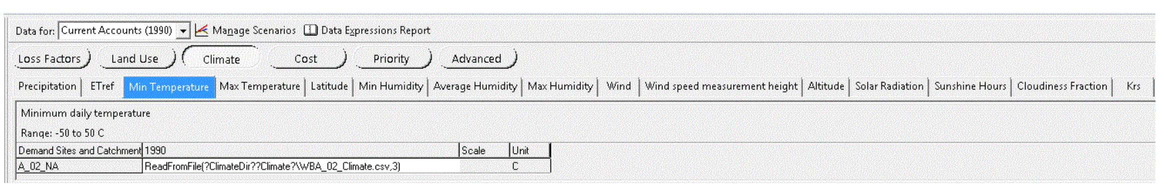
This dataset is read from a csv file located in the model data directory specified in *Key Assumptions\ClimateDir*. The model data directory is located within the Area directory and is called 'Data.' These data were derived using the approach discussed in Section 4.3.

4.4.4.8 Max Humidity



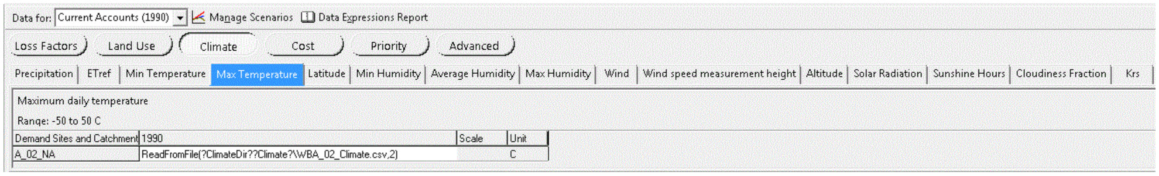
This dataset is read from a csv file located in the model data directory specified in *Key Assumptions\ClimateDir*. The model data directory is located within the Area directory and is called 'Data.' These data were derived using the approach discussed in Section 4.3.

4.4.4.9 Min Temperature



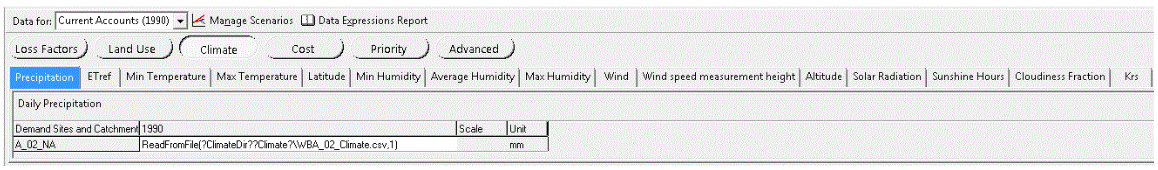
This dataset is read from a csv file located in the model data directory specified in *Key Assumptions\ClimateDir*. The model data directory is located within the Area directory and is called 'Data.' These data were derived using the approach discussed in Section 4.3.

4.4.4.10 Max Temperature



This dataset is read from a csv file located in the model data directory specified in *Key Assumptions\ClimateDir*. The model data directory is located within the Area directory and is called 'Data.' These data were derived using the approach discussed in Section 4.3.

4.4.4.11 Precipitation



This dataset is read from a csv file located in the model data directory specified in *Key Assumptions\ClimateDir*. The model data directory is located within the Area directory and is called 'Data.' These data were derived using the approach discussed in Section 4.3.

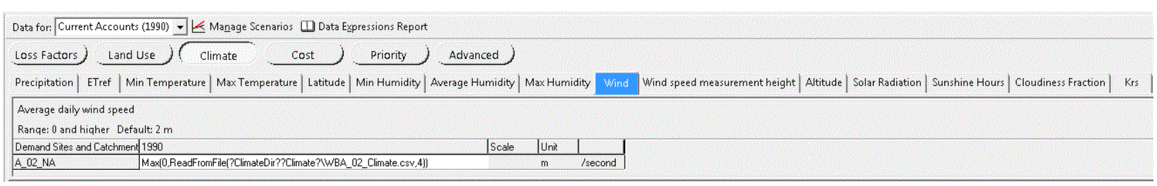
4.4.4.12 Solar Radiation

No value for solar radiation was entered; it was calculated in the MABIA module using the minimum and maximum daily temperature and the Hargreaves formula (Hargreaves and Samani, 1985).

4.4.4.13 Sunshine Hours

No data were input for *Sunshine Hour*s as it is not required.

4.4.4.14 Wind



This dataset is read from a csv file located in the model data directory specified in *Key Assumptions\ClimateDir*. The model data directory is located within the Area directory and is called 'Data.' These data were derived using the approach discussed in Section 4.3.

4.4.4.15 Wind Speed Measurement Height

The *Wind speed measurement height* was set to 2 m which is the standard used in the Penman-Monteith equation.

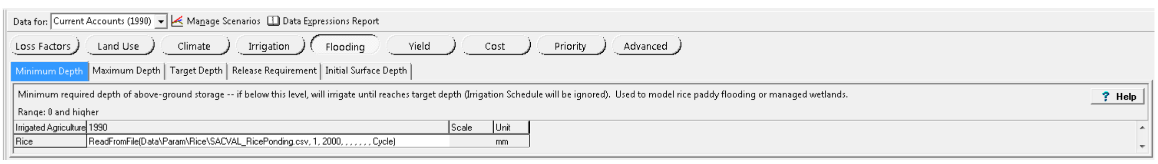
4.4.5 Flooding

Minimum Depth, Maximum Depth, and *Target Depth* were specified in SacWAM only for rice and flooded wetlands in refuge areas.

The timing and magnitude of rice flooding was based on a **rice management description** written by Todd Hillaire of DWR. The flooding pattern begins with a pre-planting irrigation used to saturate the soil and pond water to a depth of 3 inches. This irrigation starts five days prior planting day. Following planting, the water can drain. After plant emergence, water is ponded to a depth of 5 inches (125 mm) on May 26. This depth is maintained until July 1 at which point the depth is increased to a depth of 8 inches (200 mm) by July 31. This depth is maintained until the end of August at which point the field can drain until September 15. For early rice, this pattern is shifted 3 weeks earlier.

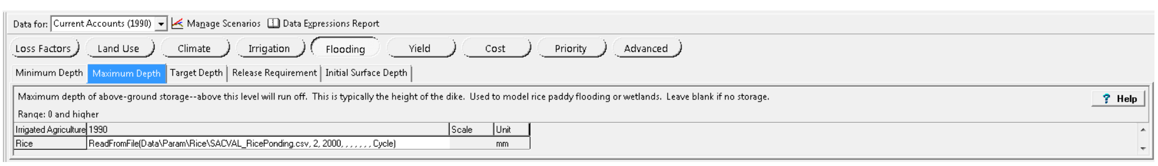
During the winter months, the fields are flooded to promote rice-straw decomposition and to attract waterfowl. In SacWAM, this flooding is assumed to start on October 15 and reach a *Target Depth* of 3 inches by January 1. Rainfall can collect in the fields up to a depth of 8 inches. Starting January 15, no more water is added to the fields. During the first two weeks of March, the fields are actively drained to a depth of zero inches.

4.4.5.1 Minimum Depth



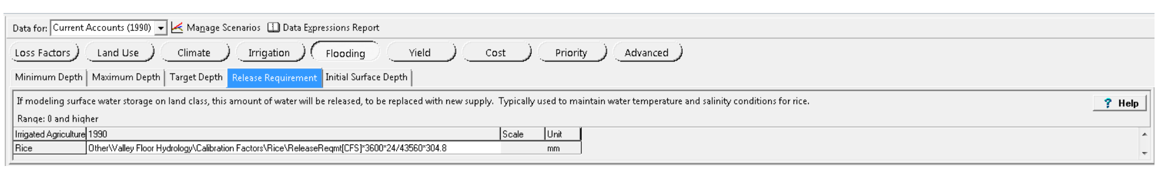
The minimum depth was specified using the time series described above.

4.4.5.2 Maximum Depth



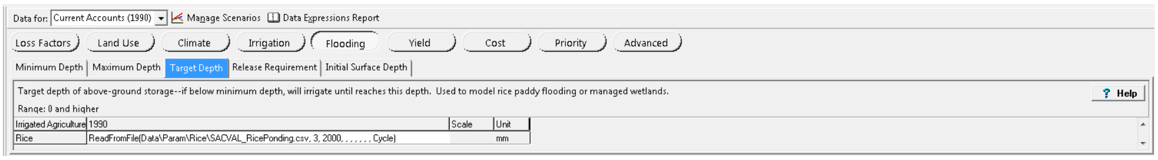
The maximum depth was specified using the time series described above with the exception at the end of the rice season this value was kept at 8 inches (200 mm) to allow the ponded water to dissipate due to evaporation and deep percolation.

4.4.5.3 Release Requirement



This value was initially set at 2.275 mm/d to represent the continuous flow of water through the rice paddies that is used to control the salt concentration. During calibration, this value was adjusted for some regions. These values can be found in SACVAL_Rice_Drainage.csv located in *Data\Param\Rice*.

4.4.5.4 Target Depth



The target depth was set using the time series described above.

4.4.5.5 Initial Surface Depth

The flooding depth at the beginning of the water year is assumed to be 0 mm for all crops and non-irrigated areas in agricultural catchments.

4.4.6 Irrigation

Fraction Wetted, Irrigation Efficiency, Irrigation Schedule, Loss to Groundwater, and Loss to Runoff were specified in SacWAM.

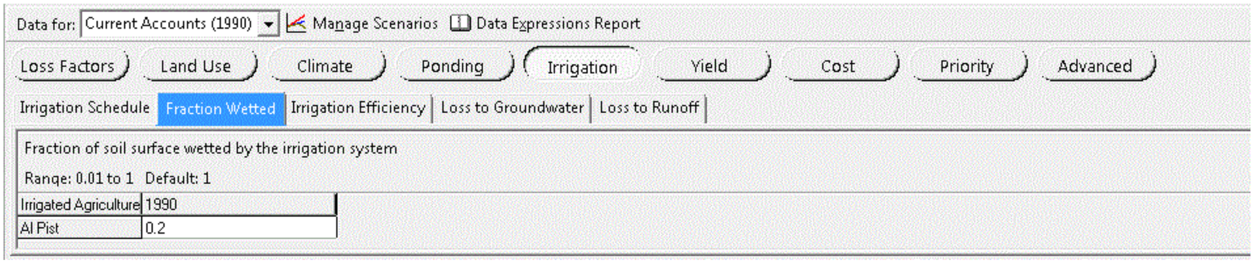
4.4.6.1 Irrigation Schedule

The irrigation schedule is used to enter parameters that control irrigation management. Multiple schedules can be entered if management varies over the growing season. In SacWAM all crops use one irrigation schedule. The information in the schedule includes:

1. The starting day (within the growing season) for which the parameters will apply. In SacWAM, this is set to the first day of the growing season.
2. The ending day (within the growing season) for which the parameters will apply. In SacWAM, this is set to the last day of the irrigation season.
3. The irrigation trigger. In SacWAM, this is set to 100% of the Readily Available Water. The Readily Available Water is the portion of the Available Water Capacity that is usable by the plant without it experiencing water stress.
4. The irrigation amount. In SacWAM, this is set to 100% of the depleted water. This means that irrigation will be sufficient to increase soil moisture to field capacity.

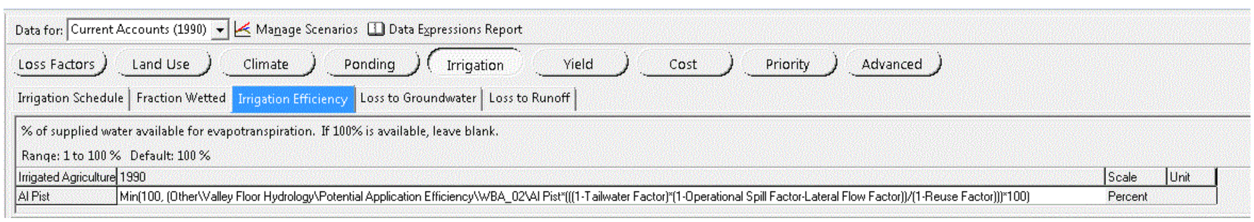
The exception to this schedule is rice. Rice is irrigated if the Target Depth is non-zero and the ponding depth is less than the minimum depth. The irrigation schedule is ignored.

4.4.6.2 Fraction Wetted



The **fraction wetted** parameter sets the fraction of the soil that is wetted by an irrigation. This value is a function of the type of irrigation. A range of values from 0.3 to 1.0 is provided in Table 20 of FAO 56 (Allen et al., 1998). In SacWAM the values range from 0.2 for mature orchards to 0.75 for truck crops commonly irrigated with furrow irrigation. These values were set using the dominant irrigation technology found in the county land use reports (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a). For flooded rice, this value is set to 1.0 automatically.

4.4.6.3 Irrigation Efficiency



An **irrigation efficiency** is entered at the crop level for each DU, as shown above. *Irrigation Efficiency* is defined in WEAP as the percentage of supplied water available for ET. The following equation is used to calculate this parameter, and its value is constrained between 0 and 100 percent in SacWAM.

$$\textit{Irrigation Efficiency}\ (\%) = \text{PAE}.\ \frac{(1 - f_{TW}).(1 - f_{OS} - f_{LF})}{(1 - f_{RU})} \qquad \text{Equation 4-6}$$

where:

PAE = Potential Application Efficiency

f_{TW} = Tailwater Factor

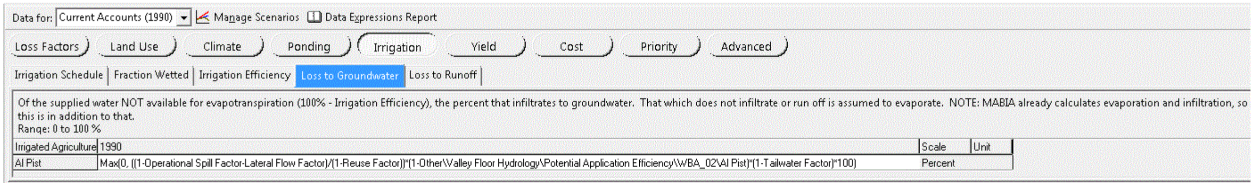
f_{os} = Operational Spill Factor

f_{LF} = Lateral Flow Factor

f_{RU} = Reuse Factor

Note: these factors are defined above in the Conceptual Framework section. For rice, the irrigation efficiency parameter is not used.

4.4.6.4 Loss to Groundwater



Loss to groundwater is entered at the crop level for each DU. It is defined as the percent of supplied water not available for ET (100% Irrigation Efficiency) that infiltrates to groundwater. The following equation is used to calculate this parameter, and its value is constrained between 0 and 100 percent in SacWAM.

$$\textit{Loss to Groundwater}\ (\%) = \frac{(1-f_{os}-f_{LF})}{(1-f_{RU})}\ .\ (1-PAE)\ .\ (1-f_{TW}) \qquad \text{Equation 4-7}$$

where:

f_{os} = Operational Spill Factor

f_{LF} = Lateral Flow Factor

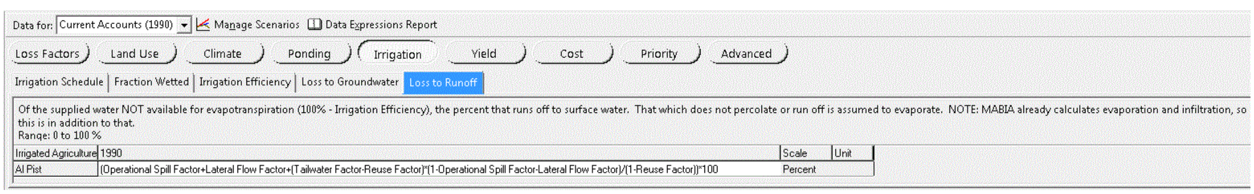
f_{RU} = Reuse Factor

PAE = Potential Application Efficiency

f_{TW} = Tailwater Factor

These factors are defined above in the Conceptual Framework section. For flooded rice, this parameter is not used.

4.4.6.5 Loss to Runoff



Loss to runoff is entered at the crop level for each DU. It is defined as the percent of supplied water not available for ET (100%-Irrigation Efficiency) that runs off as surface water. The following equation is used to calculate this parameter, and that value is constrained between 0 and 100 percent in SacWAM.

$$\textit{Loss to Runoff}\ (\%) = f_{OS} + f_{LF} + (f_{TW} - f_{RU}).(1 - f_{OS} - f_{LF})/(1\text{-}f_{RU}) \qquad \text{Equation 4-8}$$

where:

f_{os}= Operational Spill Factor (as defined in as defined in 2.3.1.1 Loss Factors)

f_{LF}= Lateral Flow Factor (as defined in as defined in 2.3.1.1 Loss Factors)

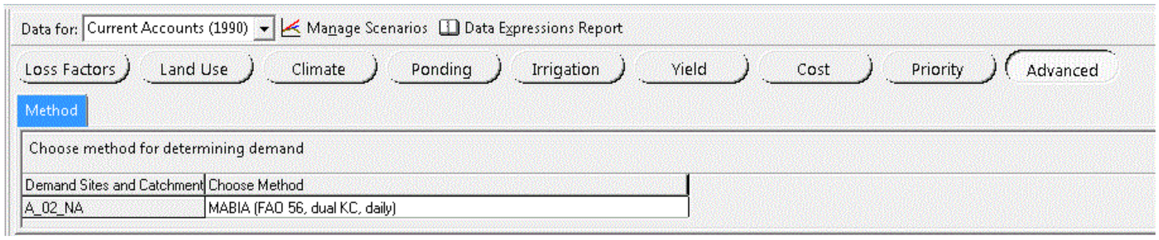
f_{TW}= Tailwater Factor (as defined in as defined in 2.3.1.1 Loss Factors)

f_{RU}= Reuse Factor (as defined in as defined in 2.3.1.1 Loss Factors)

Note: for flooded rice, this parameter is not used.

4.4.7 Advanced

4.4.7.1 Method



This is the screen in the WEAP interface where the calculation method for rainfall-runoff and irrigation management is selected. In the case of the valley floor catchments, the MABIA crop water demand model was selected.

4.5 Refuge Catchment Parameters

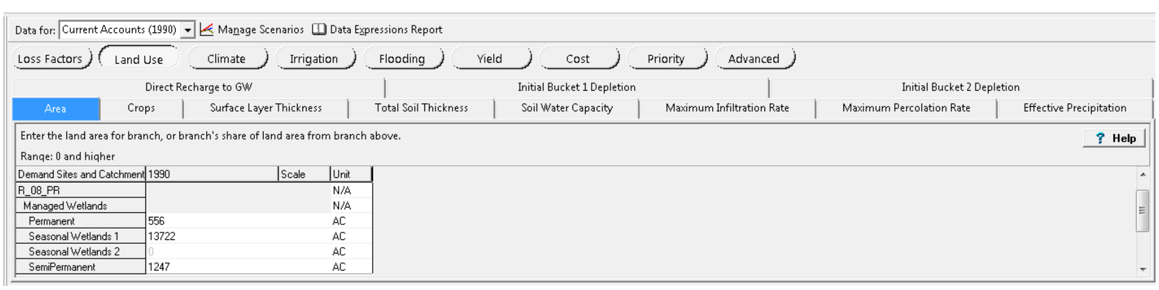
The refuge catchments in SacWAM simulate the management of wildlife refuges including the flooding of permanent, semi-permanent, and seasonal wetlands. Location information for datasets relating to these parameters is contained in Table 4-15.

4.5.1 Loss Factors

Loss associated with water deliveries to refuge catchments is treated in the same way as for agricultural catchments. See Section 4.4.2 for details.

4.5.2 Land Use

4.5.2.1 Area



The following are the data sources used to calculate **refuge land use** areas in SacWAM:

- Water Management Plans (Reclamation, 2011a-b)
- California Water Plan (DWR, 2005) and Update (DWR, 2009a)
- Butte and Sutter Basins Water Data Atlas (DWR, 1994c)
- NWR Draft Comprehensive Conservation Plan (USFWS, 2008)

Four SacWAM wetland classes are used to represent refuge habitat acreage, in addition to an 'Uplands' class. These include Permanent, SemiPermanent, Seasonal 1, and Seasonal 2. Many refuges and wildlife areas include multiple class types. The classes have distinct management practices, each making favorable habitat for species.

4.5.2.1.1 Permanent

Permanent wetlands are kept flooded year-round but are drawn down every few years to recycle nutrients, increase productivity and discourage carp populations. Water depths in permanent wetlands vary throughout the year due to precipitation patterns, but a permanent wetland will be flooded during every month of the year. Permanent wetlands serve as habitat for egrets, heron, and other fish-eating birds.

4.5.2.1.2 SemiPermanent

Semi-permanent wetlands are kept flooded ten months of the year (October through July) and provide wetland habitat during summer months when seasonal wetlands are not flooded. These wetlands are more productive than permanent wetlands because they have a drying cycle. Semi-permanent wetlands are flooded so that the water depth is between four and twelve inches to allow ducks and other water birds access to food.

4.5.2.1.3 Seasonal 1

Seasonal wetlands are kept flooded from October 1 to January 15 and are managed to grow seed and produce invertebrates for migratory waterfowl and shorebirds. They are typically shallow, and include plants such as timothy, smartweed, and watergrass.

4.5.2.1.4 Seasonal 2

The second class of seasonal wetlands are kept flooded from September 1 through January 15 and are managed to grow seed and produce invertebrates for migratory waterfowl and shorebirds.

4.5.2.1.5 Uplands

The 'Uplands' SacWAM class includes non-flooded habitat (riparian, pasture, grains, grasses) as well as roads and buildings within the refuges.

Refuge acreages were determined for federal and state refuge and wildlife areas. These data were extracted from a variety of sources. Where possible, Water Management Plans (Reclamation, 2011a-b) were used to determine the habitat acreage within NWRs and WAs. These plans exist for most national refuges and include tables containing habitat types with their associated 2010 acreages. Table 4-10 provides information on the aggregation of Urban Water Management Plan (UWMP) habitat types into SacWAM classes.

Table 4-10. Refuge Water Management Plan Habitat Types

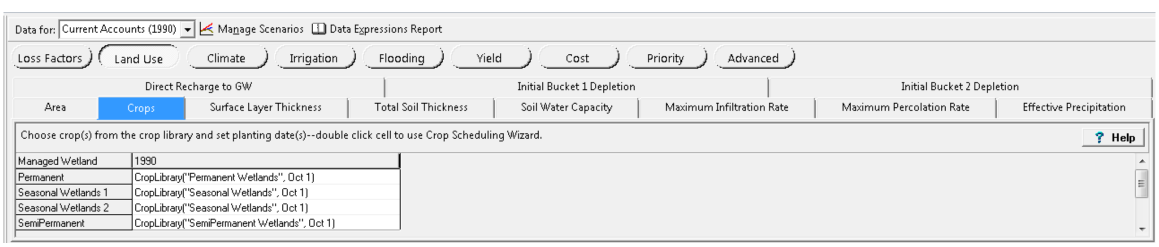
SacWAM Class	Refuge Water Management Plan Habitat Types
Permanent	Permanent wetland
SemiPermanent	Semi-permanent wetland/brood pond
Seasonal	Seasonal wetland – timothy (not irrigated)
	Seasonal wetland – timothy (irrigated)
	Seasonal wetland – smartweed
	Seasonal wetland – watergrass
Reverse	Reverse cycle wetlands
Uplands	Riparian
	Irrigated pasture
	Upland (not irrigated)
	Upland (managed)
	Upland (grains)
	Roads, buildings, etc.
	Miscellaneous habitat
	Other

The Sacramento, Delevan, Colusa, and Sutter Draft Comprehensive Conservation Plan (USFWS, 2008) was used to determine habitat acreage in Sutter NWR. The Draft Comprehensive Conservation Plan includes a map of Sutter NWR (Figure 9), with polygons of twelve different habitat types and their associated acreages. These acreages were aggregated into SacWAM refuge classes.

To determine habitat acreages for the Sutter and Butte Sink Duck Clubs, the Butte and Sutter Basins Water Data Atlas (DWR, 1994a) was used. In GIS, the map was overlaid on a parcel map and the various land holdings were analyzed. It was determined that all acreage in the Sutter and Butte Sink Duck Clubs should be considered 'Seasonal' wetlands in SacWAM.

Habitat acreages for California wildlife areas are given in the California Water Plan (DWR, 2005) and Table 6-10 (DWR, 2009a). These data are based on correspondence between DWR's regional offices and wildlife area managers.

4.5.2.2 Crops



Permanent, semi-permanent, seasonal 1 and seasonal 2 wetlands crop types were added to the **crop library**. These 'crop' types were given a season length of 365 days and a crop coefficient of 1.0.

4.5.2.3 Maximum Percolation Rate

A *Maximum Percolation Rate* for Managed Wetlands was set at 0.025 in/day through *Other Assumptions\Valley Floor Hydrology\Calibration Factors\ Rice\MaxPercRate*. No maximum percolation rate was set for Uplands.

4.5.2.4 Other Land-Use Parameters

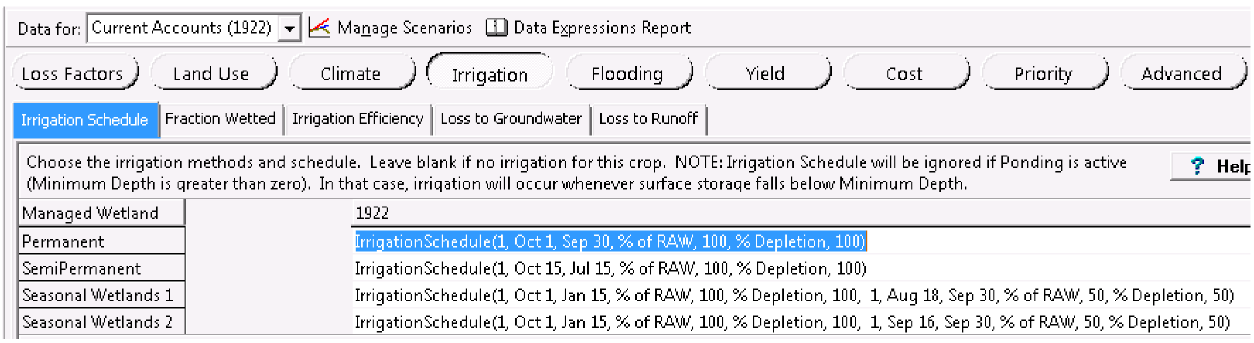
Other land-use parameters (*Surface Layer Thickness, Total Soil Thickness, Soil Water Capacity, Maximum Infiltration Rate, Effective Precipitation, Direct Recharge to GW, Initial Bucket 1 Depletion, and Initial Bucket 2 Depletion*) follow the same parameterization rules as indicated for agricultural and urban catchments. Refer to Section 4.4.3 for details.

4.5.3 Climate

All climate parameters follow the same parameterization rules as indicated for agricultural and urban catchments. Refer to Section 4.4.4 for details.

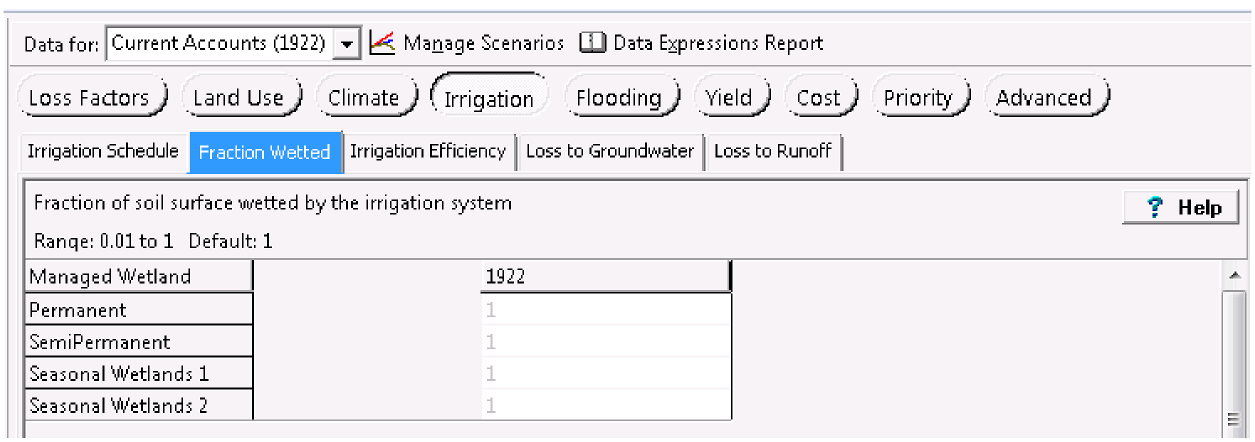
4.5.4 Irrigation

4.5.4.1 Irrigation Schedule



For wetlands, the irrigation schedule was set to be in effect during the flooding period. The irrigation trigger and irrigation amount parameters were given values of 30% of RAW and 100% of depletion; however, these values are meaningless as WEAP orders the irrigation necessary to maintain the Target Depth of ponding.

4.5.4.2 Fraction Wetted



This value is meaningless since the land is flooded. It was given the default value of 1.0.

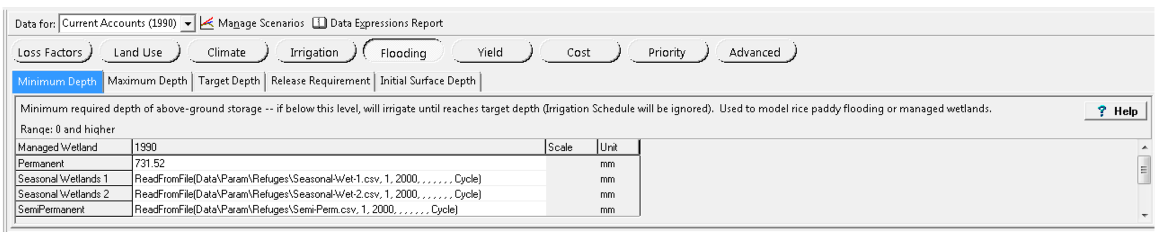
4.5.4.3 Other Irrigation Parameters

Other Irrigation Parameters include *Irrigation Efficiency*, *Loss to Groundwater*, and *Loss to Runoff*. These three parameters were given values of 100%, 0%, and 0% (WEAP default values) based on the assumption that there are no losses (other than the simulated deep percolation and evaporation) of water in the management of ponded wetlands.

4.5.5 Flooding

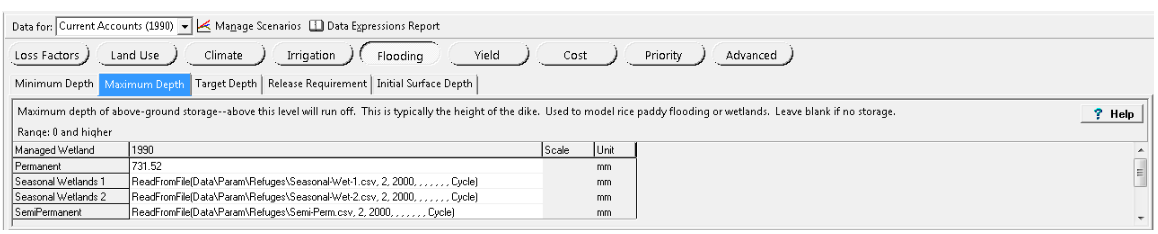
Flooded refuge lands were assumed to belong to one of four classes: permanent, semi-permanent, seasonal 1, or seasonal 2. The permanent wetlands have a constant depth of 30 inches (762 mm). The semi-permanent wetlands have a flooding schedule that starts October 15 and increases to 12 inches (300 mm) by October 31. This depth is maintained until July 31. Seasonal wetlands 1 are flooded from zero on September 1 to 12 inches (300 mm) on November 18. That depth is maintained until January 15. Seasonal wetlands 2 begins to flood up on October 1 and reaches a depth of 12 inches (300 mm) by November 25. That depth is maintained until January 15.

4.5.5.1 Minimum Depth



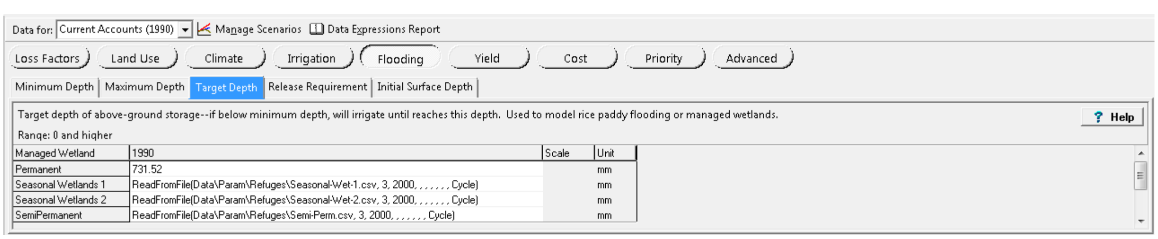
The minimum depth is specified using the time series described above.

4.5.5.2 Maximum Depth



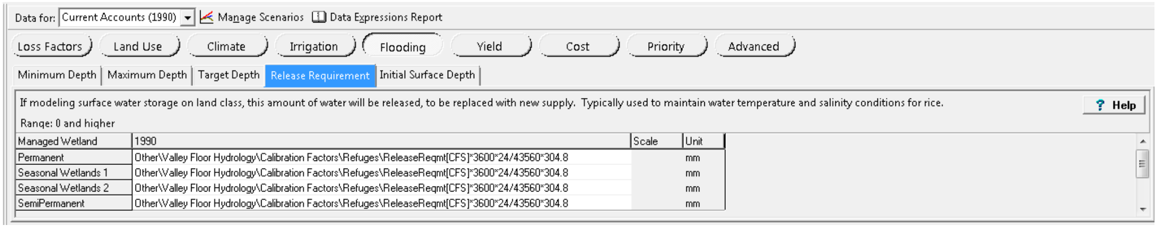
The maximum depth is specified using the time series described above with the exception that the maximum depth is held constant for an additional month in the winter to allow the seasonal wetlands to drain through infiltration and evaporation.

4.5.5.3 Target Depth



The target depth is specified using the time series described above.

4.5.5.4 Release Requirement



The release requirement for all flooded wetlands was set to 3 mm/day to simulate the flow through that managers utilize to maintain water quality.

4.5.5.5 Initial Surface Depth

This parameter was set to 476 mm for the permanent wetlands and 75 mm for the Seasonal Wetland 1. These are the only two wetland types that need a non-zero flood depth at the beginning of the water year (October 1).

4.5.6 Yield

The WEAP *Yield* feature for refuge catchments is not used.

4.5.7 Cost

The WEAP *Cost* feature for refuge catchments is not used.

4.5.8 Priority

Prioties are discussed in Section 7-12.

4.5.9 Advanced

Use of the MABIA method is specified here, which follows the same parameterization rules as indicated for agricultural catchments. Refer to Section 4.4.7 for details.

4.6 Urban Catchment Parameters

Two nodes represent each urban area: a demand site (red) and a catchment (green). Urban catchments can be distinguished from their demand site counterparts by their '_O' suffix. For more on this distinction, see Urban Lands in Section 4.1.2.2. The urban catchment node in SacWAM contains parameters including Loss Factors, Land Use Climate, and Ponding. Refer to Table 4-15 for the location information of data associated with these parameters.

4.6.1 Loss Factors

The urban catchments simulate the rainfall-runoff processes of the urban area. They do not simulate irrigation. Irrigation of urban landscapes is represented by the outdoor water in the urban demand sites. For that reason, the loss factors are generally not applicable to the urban catchments.

4.6.1.1 Minimum Groundwater Pumping Factor

For a complete discussion, see the corresponding Minimum Groundwater Pumping Factor sub-section in the Agricultural Catchments Section (4.4.2.6).For urban DUs, the factor is equal to 0.0, except for DUs U_02_SU, U_03_SU, U_26_NU2, and U_26_PU5, with factors of 0.3, 0.3, 0.2, and 0.5, respectively.

4.6.2 Land Use

4.6.2.1 Area

The following are the data sources used to determine **urban land use** data for SacWAM DUs:

- Important Farmland maps (Department of Conservation, 2006)
- County land use surveys undertaken by DWR's DSIWM, formerly Division of Planning and Local Assistance (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a)

Since urban catchments are used to simulate runoff for DUs, land use acreages for these areas were needed. Land use in urban areas is divided between two land use classes: UR and NV. These land classes were aggregated from DWR Land Use Classifications for urban (Table 4-11) and native vegetation lands (Table 4-12).

Table 4-11. DWR Land Use Classifications Included in SacWAM Urban Land Use Classes

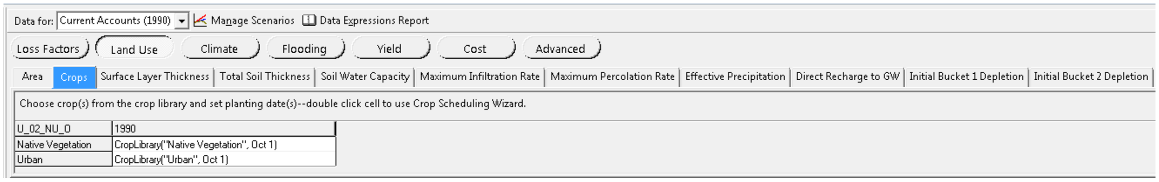
Category	Code	Description
Semi-agricultural	S1	Farmsteads
	S2	Livestock Feed Lots
	S3	Dairies
	S4	Poultry Farms
Urban	U	Not Classified
Urban Commercial	UC	Not Classified
	UC1	Offices, Retailers
	UC2	Hotels
	UC3	Motels
	UC4	Recreation Vehicle Parking, Camping
	UC5	Institutions
	UC6	Schools
	UC7	Municipal Auditoriums, Stadiums, Theaters
	UC8	Misc. High Water Use
Urban Industrial	UI	Not Classified
	UI1	Manufacturing, Assembling and Processing
	UI2	Extractive Industries
	UI3	Storage and Distribution
	UI6	Sawmills
	UI7	Oil Refineries
	UI8	Paper Mills
	UI9	Meat Packing Plants
	UI10	Steel and Aluminum Mills
	UI11	Fruit and Vegetable Canneries
	UI12	Misc. High Water Use
	UI13	Sewage Treatment Plant/Ponds
	UI14	Waste Accumulation Sites
	UI15	Wind/Solar Farms
Urban Landscape	UL	Not Classified
	UL1	Lawn Area (irrigated)
	UL2	Golf Course (irrigated)
	UL3	Ornamental Landscape (irrigated)
	UL4	Cemeteries (irrigated)
	UL5	Cemeteries (not irrigated)
Urban Residential	UR	Not Classified
	UR1	Single Family (1-5 acres)
	UR2	Single Family (1-8 units/acre)
	UR3	Multi Family
	UR4	Trailer Courts
	UR11	Single Family (1-5 acres), <25% irrigated
	UR13	Single Family (1-5 acres), 51%-75% irrigated
Urban Vacant	UV	Not Classified
	UV1	Unpaved Areas
	UV3	Railroad Right-Of-Way
	UV4	Paved Areas
	UV6	Airport Runways

Table 4-12. DWR Land Use Classifications Included in SacWAM Native Vegetation Land Use Classes

Code	Description
NR4	Seasonal Duck Marsh
N45	Permanent Duck Marsh
E	Entry Denied
I	Idle
I1	Land not cropped in current or previous season, but cropped in past 3 years
I2	New lands being prepared for crop production
NB	Barren Land
NB1	Dry Stream Channel
NB2	Mine Tailing
NB3	Native Barren
NC	Native Classes Unsegregated
NR	Riparian Vegetation
NR1	Marsh
NR2	High Water Table Meadow
NR3	Trees and Shrubs
NS	Not Surveyed
NV	Native Vegetation
NV1	Grass
NV2	Light Brush
NV3	Medium Brush
NV4	Heavy Brush
NV5	Brush and Timber
NV6	Forest
NW	Water Surface

Although there is an ‘urban’ land use classification within the ICA-DSIWM dataset, Important Farmland maps (Department of Conservation, 2006) were used instead as they provide updated information on urban land areas. Important Farmland maps are provided by county from the Farmland Mapping and Monitoring Program. To create these maps, current land use information is combined with NRCS soil survey data (NRCS, 2013b). Land use type for the Important Farmland dataset was determined using current and historical aerial imagery coupled with field verification. Aerial image sources include the US Department of Agriculture National Agricultural Imagery Program, AirPhotoUSA, the High Altitude Missions Branch of the National Aeronautics and Space Administration (NASA), USGS’ Earth Resources Observation and Science (EROS) Center, and SPOT Data Corporation (Department of Conservation, 2006). Lands are grouped into the following classes: Prime Farmland, Farmland of Statewide Importance, Unique Farmland, Farmland of Local Importance, Grazing Land, Urban and Built-Up Land, Other Land, and Water. Acreages from Department of Conservation classes ‘Urban and Built-Up Land’ were used to represent the SacWAM urban land class (UR). Since these data were presented on the county level, these acreages were intersected with a county-DAU layer and a DU layer to determine the urban acreages at the DAU and DU level. Because these acreages were used instead of the ICA-DSIWM dataset, an adjustment had to be made to preserve the total area of the DUs. Consequently, an adjustment was made for native vegetation acreage to offset the increase or decrease in urban acreage within a single DU.

4.6.2.2 Crops



Native Vegetation and Urban classes were added to the **crop library** (General>Crop Library), just as agricultural crops were. Since these 'crop' types have no planting date, they were assigned a planting date of October 1 (the start of the water year) and a season length of 365 days.

4.6.2.3 Maximum Percolation Rate

A *Maximum Percolation Rate* was not set for the urban class of urban catchments; it was set at 1000 for the native vegetation class under *Other Assumptions**Valley Floor Hydrology**Calibration Factors**MaxPercRate_NV*.

4.6.2.4 Other Land-Use Parameters

Other land-use parameters (*Surface Layer Thickness, Total Soil Thickness, Soil Water Capacity, Maximum Infiltration Rate, Effective Precipitation, Direct Recharge to GW, Initial Bucket 1 Depletion, and Initial Bucket 2 Depletion*) follow the same parameterization rules as indicated for agricultural catchments. Refer to Section 4.4.3 for details.

4.6.3 Climate

All climate parameters (*Precipitation, ETref, Min Temperature, Max Temperature, Latitude, Min Humidity, Average Humidity, Max Humidity, Wind, Wind speed measurement height, Altitude, Solar Radiation, Sunshine Hours, Cloudiness Fraction, and Krs*) follow the same parameterization rules as indicated for agricultural catchments. Refer to Climate in Section 4.4.4 for details.

4.6.4 Flooding

Flooding does not apply to urban catchments. Therefore, all parameters remain as their WEAP default value (*Initial Surface Depth*, *Minimum Depth, Maximum Depth, Target Depth,* and *Release Requirement* all have values of 0 mm).

4.6.5 Yield

The WEAP 'Yield' feature for urban catchments is not used.

4.6.6 Cost

The WEAP 'Cost' feature for urban catchments is not used.

4.6.7 Advanced

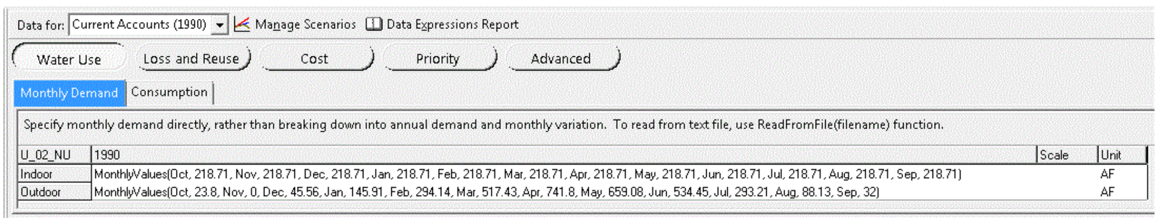
Use of the MABIA method is specified here, which follows the same parameterization rules as indicated for agricultural catchments.

4.7 Urban Demand Site Parameters

Urban demand sites contain data on monthly indoor and outdoor use of piped water for urban DUs. They can be distinguished from urban catchments by their lack of '_O' at the end of their demand unit name. Rainfall-runoff processes related to urban land are simulated in the urban catchment objects. Location information for urban demand site data are provided in Table 4-15.

4.7.1 Water Use

4.7.1.1 Monthly Demand



Monthly Demand was specified for Indoor (D_I) and Outdoor (D_O) use in SacWAM and are given in acre-feet. The following are the data sources used to determine monthly water demands for urban areas:

DSIWM datasets are summarized in the California Water Plan (Bulletin 160-09 series), and in periodic urban water use (Bulletin 166 series) and industrial water use reports (Bulletin 124 series) (DWR, 1982, 1994d). Water use data from years 1998 to 2003 (DWR, 2011) include:

- Population by DAU,
- Percentage water use by customer class (residential, manufacturing, commercial, industrial, large landscape),
- Indoor-outdoor split for residential and commercial sectors,
- Source of water (groundwater or surface water), and
- Per capita water use (DWR Northern Regional Office).

4.7.1.1.1 Urban Water Management Plans

California municipal suppliers providing service to more than 3,000 customers or supplying more than 3,000 acre-feet of water per year are required to prepare and follow an UWMP. These plans are submitted to DWR every five years and are summarized by DSIWM as part of the California Water Plan. Suppliers report and evaluate their water deliveries and uses, water supply sources, efficient water uses, and demand management measures. These plans also include information on base daily per capita water use, urban water use targets, interim urban water use targets, and compliance daily per capita water use. UWMPs aim to help municipal suppliers develop long-term conservation plans.

4.7.1.1.2 Water Forum Agreement

The Water Forum Agreement helps manage water supply for regions next to the lower American River, and specifically applies to water purveyors within WBAs 26N and 26S (Water Forum, 2006). The goal of this agreement is to balance providing a safe and reliable water supply with maintaining ecological and recreational habitat.

4.7.1.1.3 National Census Data

The US Census Bureau collects information via a mailed questionnaire every 10 years. Questions regard income, ethnicity, and housing. Geospatial population data are then given on the block-level and larger geographical units.[20]

Urban demands were determined mostly using Public Water System Statistics (PWSS) questionnaires and 2010 Census data, with some information provided from UWMPs and the integrated groundwater–surface water model developed for Placer, Sacramento, and San Joaquin Counties. Calculation of urban demands relied on the same process as that used in DSIWM. The only exception is that the data provided by DSIWM were originally at the county or DAU scale, and then aggregated at the DU level in SacWAM.

DSIWM collects water use and population data through PWSS questionnaires that are mailed annually to public water purveyors. The data collected from the purveyors in these questionnaires include water production data, population data, metered water deliveries (if applicable), and active service connections by customer class. The six customer classes are Single-Family Residential, Multi-Family Residential, Residential, Commercial, Industrial and Landscape, and Other. The 'Other' class includes a variety of uses, such as system flushing and wholesale water sold. These data exist through calendar year 2010.

PWSS publicly served water purveyor production data are used to determine urban water demands in SacWAM. The assumption made in using this dataset is that water demands are equal to water production data. Total urban water demand is the sum of production data for public and self-supplied users, but only publicly supplied production data are given in PWSS questionnaires. Publicly supplied and self-supplied production data were combined to determine urban water demands on the county or DAU scale. These data were then aggregated at the urban DU level for use in SacWAM. For each DU, a list of water purveyors, the population served by that purveyor, and water production data are given. To determine the population that is self-supplied rather than publicly supplied, the population served by public water suppliers was subtracted from the total population within a WBA. The total population within a WBA was determined from 2010 National Census data. This calculation assumes that the population located outside public WA service areas is self-supplied by groundwater. Water use for the self-supplied population was determined by calculating the product of the population and per capita water use. Data on per capita water use was determined in a dataset supplied by DWR's Northern Regional Office. SacWAM population estimates were determined from DSIWM data for 2010, and were defined by DU in the following way:

- GIS data layers of county and DAU boundaries are intersected with 1990 and 2000 census block data to estimate populations for these years.

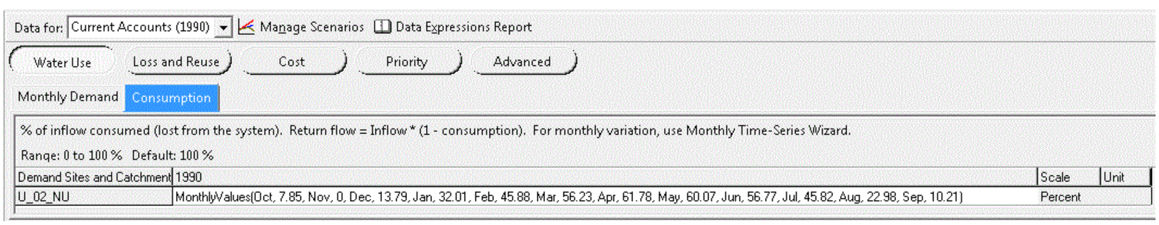
[20] These data are available on-line at www.census.gov.

- California Department of Finance estimates define city (incorporated) and unincorporated populations for counties following year 2000.
- Unincorporated population defined by the California Department of Finance is disaggregated into county-DAUs based on growth rates for unincorporated populations from 1990 to 2000.

SacWAM uses monthly urban demands, so annual DSIWM data had to be disaggregated before being input into SacWAM. Monthly urban demands were based on historical production data for water years 2006 to 2010 from PWSS. In some cases, no delivery data were available for cities within a SacWAM DU, so the monthly delivery pattern is assumed to be the same as that of an adjacent DU. Within the urban demand site node, SacWAM separates urban demand sites into two classes: indoor and outdoor demands. SacWAM defines the monthly indoor demand as equivalent to the demand of the lowest month and assumes that the indoor demand is constant throughout the year. The outdoor demand class for each month is defined as the difference between that month's total demand and the indoor demand. For example, the minimum demand month for 'U_02_NU' is February, with a demand of 218.71 acre-feet, so the indoor demand is 218.71 acre-feet for each month of the year. In March, the total demand is 264.27 acre-feet, so the outdoor demand for March is 45.56 acre-feet (264.27-218.71=45.56 acre-feet). Urban demand data are input into WEAP as a monthly time series. The **urban demand** includes all processing steps relating to the *Monthly Demand* data input into SacWAM.

There are SacWAM regions where no PWSS data exist. In these cases, *Monthly Demand* data were taken from the 2010 UWMPs, and aggregated on the DU level. For regions in SacWAM WBAs 26S and 26N, water purveyor data assembled by Boyle Engineering in the Integrated Groundwater Surface Water Model were used.

4.7.1.2 Consumption



Consumption is defined as the percentage of inflow that is consumed (lost from the system). **Urban consumption** monthly demands are explicitly divided into indoor and outdoor water use, so the percentage of consumed water must include a weighted average of these two demands. Indoor water use is assumed to be non-consumptive, meaning that there is no loss from the system. SacWAM assumes that 80% of water for outdoor use is consumed (through landscape ET). The following equation is used to calculate monthly consumption for urban demand sites:

$$\text{Consumption (\%)} = \frac{(0 * D_I + 0.8 * D_O)}{(D_I + D_O)}$$

where: D_O= Outdoor Monthly Demand (as defined above in Monthly Demand, Section 4.7.1.1)

For urban demand sites that discharge to surface water bodies, such as to the Sacramento Regional WWTP, the assumption that indoor consumption is zero percent and outdoor consumption is 80 percent is tested during calibration. Historical flows from WWTPs were obtained from CDEC and used to compare to model outputs. Where outflows do not match historical data, the *Loss to Groundwater* parameter was adjusted.

4.7.2 Loss and Reuse

4.7.2.1 Loss Rate
The *Loss Rate* is assumed to be zero.

4.7.2.2 Reuse Rate
The *Reuse Rate* is assumed to be zero.

4.7.3 Cost

The WEAP *Cost* feature for urban demand sites is not used.

4.7.4 Priority

Demand priorities are discussed in Section 6.1.2.6.

4.7.5 Advanced

Use method for specifying water use is 'monthly demand.'

4.8 Other Demand Site Parameters

4.8.1 South of Delta Demands

4.8.1.1 Central Valley Project
CVP contractors located south of the Delta are served by both the Delta-Mendota Canal and California Aqueduct. These contractors were divided by geographical region and by contract type: exchange contractors, Cross Valley Canal contractors, and water service contractors, the latter subdivided in to agricultural, urban, and refuge demand sites. Annual water demands are assumed equal to full contract amounts derived from Reclamation's **CVP Contractor data**. These data are presented in Table 4-13. Additional water demands were developed to represent canal conveyance losses.

4.8.1.2 State Water Project
Water demands met from the North Bay Aqueduct were initially divided into those supplied by Napa FCWCD and those supplied by Solano County WA – both agencies are long-term SWP contractors and sell SWP water to their member agencies. Napa FCWCD demands were split between two demand sites to represent Table A demands and Article 21 demands. This allows these water demands to be assigned different water allocation priorities. SacWAM provides a more detailed depiction of Solano County WA member agencies – many of whom receive water from both the North Bay Aqueduct and Putah South Canal. The City of Vacaville (U_20_25_PU) is represented by a catchment object beacuse it lies within the Sacramento Valley. The Cities of Benicia, Fairfield, and Vallejo are represented by separate demand sites. SacWAM assumes that none of these agencies request Article 21 water. Additionally, Travis Air

Force Base is represented as a separate demand site because it receives a share of the City of Vallejo's Table A water.

Demands for SWP water from the California Aqueduct were divided into four geographical regions: South Bay Aqueduct; San Joaquin Valley; Central Coast and Tulare Lake; and South Coast. Water demands in each of these regions are disaggregated to four demand sites that represent:

- Table A deliveries
- Table A deliveries delivered in a later month (make-up water[21])
- Article 21 (interruptible supplies)
- Canal conveyance losses

Water demands are assumed equal to full Table A amounts with additional demands for Article 21 water, when available. Table A amounts were derived from DWR's **Bulletin 132** and are presented in Table 4-14.

4.8.1.3 Wheeling

SacWAM does not represent wheeling of CVP water through the California Aqueduct for delivery to the Kern and Pixley NWRs, as represented by demand site 'CVP CA Refuges'. To simplify the modeling, a transmission link connects the CVP share of the Joint Reach of the California Aqueduct (diversion arc CA_CVP) directly to the demand site.[22]

SacWAM contains a simplified approach to simulate wheeling of CVP water through Banks Pumping Plant and the California Aqueduct for delivery to the CVP Cross Valley Canal contractors, as represented by demand site 'Cross Valley Canal'. Monthly demands are a fixed percentage of the annual contract amount. Wheeling amounts were omitted from the COA sharing formulae.

[21] Make-up water exists in years when SWP allocations are increased from an initial low value.

[22] Under a refuge wheeling agreement, DWR conveys CVP water from the California Aqueduct at the end of the Joint Reach (Reach 7) to Buena Vista Water Storage District turnouts in Reaches 10A and 12E for delivery to Kern NWR.

Table 4-13. Demand Sites Used to Represent South-of-Delta Central Valley Project Water Use

SacWAM Demand Site	Central Valley Project Contractor	Contract Amount (acre-feet)
Upper Delta-Mendota Canal		
CVP Upper DMC Urban Demands	Tracy, City of	10,000
CVP Upper DMC Ag Demands	Byron-Bethany ID (former Plainview ID)	20,600
	Banta-Carbona ID	20,000
	Del Puerto WD	140,210
	City of Tracy (West Side ID)	2,500
	City of Tracy (Banta Carbona ID)	5,000
	Patterson ID	16,500
	West Stanislaus ID	50,000
	West Side ID	5,000
	Total	**259,810**
CVP Upper DMC Water Rights	Patterson ID	6,000
San Felipe Unit		
CVP San Felipe Ag Demands	San Benito County WD	38,244
	Santa Clara Valley WD	22,500
	Pajaro Valley WD	6,260
	Total	**67,004**
CVP San Felipe Urban Demands	San Benito County WD	5,556
	Santa Clara Valley WD	130,000
	Total	**135,556**
Lower Delta-Mendota Canal		
CVP Lower DMC Exchange Demands	Central California ID (north)	140,000
CVP Lower DMC Ag Demands	San Luis WD (north)	65,000
	Eagle Field WD	4,550
	Mercy Springs WD	2,842
	Oro Loma WD	600
	Panoche WD	6,600
	Total	**79,592**
CVP Lower DMC Refuge Demands	Volta WA	13,000
	San Luis NWR – Kesterson Unit	10,000
	San Luis NWR – Freitas Unit	5,290
	Los Banos WA	16,670
	North Grasslands WA – Salt Slough Unit	6,680
	North Grasslands WA – China Island Unit	6,967
	Grasslands WD (north)	95,000
	Total	**153,607**
Mendota Pool		
CVP Mendota Pool Exchange Demands	Central California ID	392,400
	Columbia CC	59,000
	Firebaugh CC	85,000
	San Luis CC	163,600
	Total	**700,000**
CVP Mendota Pool Ag Demands	James ID	35,300
	Laguna WD	800
	Reclamation District 1606	228
	Terra Linda Farms	2,080
	Tranquility ID	13,800
	Tranquility PUD	70

SacWAM Demand Site	Central Valley Project Contractor	Contract Amount (acre-feet)
	Westlands WD (Laguna WD assignment)	4,000
	Westlands WD (Oro Lomo WD assignment)	4,000
	Total	**60,278**
CVP Mendota Pool Refuge Demands	Grasslands WD (south)	30,000
	Mendota WA	27,594
	San Luis NWR – San Luis Unit	19,000
	San Luis NWR – West Bear Creek Unit	7,207
	Total	**83,801**
CVP Mendota Pool Water Rights Demands	Fresno Slough WD	866
	James ID	9,700
	Reclamation District 1606	342
	Terra Linda Farms	1,332
	Tranquility ID	20,200
	Tranquility PUD	93
	Total	**32,533**
California Aqueduct Joint Reach (San Luis Canal)		
CVP San Luis Canal Ag Demands	Califonia State Parks and Recreation	2,250
	Pacheco WD	10,080
	Panoche WD	87,400
	San Luis WD (south)	60,080
	State of California	10
	Westlands WD	1,150,000
	Westlands WD Distribution District 1&2	36,688
	Total	**1,346,508**
CVP San Luis Canal Urban Demands	Avenal, City of	3,500
	Coalinga, City of	10,000
	Huron, City of	3,000
	Total	**16,500**
California Aqueduct below Joint Reach		
Cross Valley Canal	Fresno, County of	3,000
	Hills Valley ID	3,346
	Kern-Tulare WD	40,000
	Lower Tule River ID	31,102
	Pixley ID	31,102
	Kern-Tulare WD	13,300
	Tri-Valley WD	1,142
	Fresno, County of	5,308
	Total	**128,300**
CVP CA Refuges	Kern NWR	9,950
	Pixley NWR	1,280
	Total	**11,230**
TOTAL		**3,230,719**

Key:
CC=Canal Company
ID=Irrigation District
NWR=National Wildlife Refuge
PUD=Public Utility District
WA=Wildlife Area
WD=Water District.

Table 4-14. Demand Sites and Catchments Used to Represent State Water Project Water Use

SacWAM Demand Site or Catchment	State Water Project Long-term Contractor	Maximum Table A (acre-feet)
Feather River		
N/A	County of Butte[1]	27,500
N/A	Plumas County FC&WCD[2]	2,160
U_16_PU	City of Yuba City	9,600
	Total for Feather River	**39,260**
North Bay Aqueduct		
U_NAPA_PU	Napa County FC&WCD	29,025
U_BNCIA_PU, U_FRFLD, U_TRAFB_PU, U_VLLJO_PU, U_20_25_PU	Solano County WA	47,506
N/A	**Total for North Bay Aqueduct**	**76,531**
California Aqueduct		
SWP SBA Table A	Alameda County FC&WCD, Zone 7	80,619
	Alameda County WD	42,000
	Santa Clara Valley WD	100,000
	Total for South Bay Aqueduct	**222,619**
SWP San Joaquin Table A	Oak Flat WD	5,700
SWP CentralCoastTulare Table A	County of Kings	9,305
	Dudley Ridge WD	50,343
	Empire West Side ID[3]	3,000
	Kern County WA	982,730
	Tulare Lake Basin WSD[3]	88,922
	San Luis Obispo County FC&WCD	25,000
	Santa Barbara County FC&WCD	45,486
	Total for Central Coast and Tulare Lake	**1,204,786**
SWP South Coast Table A	Antelope Valley-East Kern WA	141,400
	Castaic Lake WA	95,200
	Coachella Valley WD	138,350
	Crestline-Lake Arrowhead WA	5,800
	Desert WA	55,750
	Littlerock Creek ID	2,300
	Mojave WA	82,800
	Metropolitan WD of Southern California	1,911,500
	Palmdale WD	21,300
	San Bernardino Valley MWD	102,600
	San Gabriel Valley MWD	28,800
	San Gorgonio Pass WA	17,300
	Ventura County FCD	20,000
	Total for South Coast	**2,623,100**
N/A	**Table A Total**	**4,171,996**

Notes:

[1] The County of Butte acts as a wholesaler of SWP water to urban water agencies within the county. SacWAM assumes that Table A water is sold to Thermalito ID (U_11_NU1) and CalWater-Oroville (U_12_13_NU1).

[2] Plumas County FCWCD diverts water from Big Grizzly Creek below Lake Davis to serve the City of Portola. Annual surface water diversions are less than 1 TAF. These diversions are not represented in SacWAM.

Key: FC&WCD = Flood Control and Water Conservation District, FCD = Flood Control District, ID = Irrigation District, MWD = Metropolitan Water District, N/A = not applicable, WA = Water Agency, WD = Water District, WSD = Water Storage District.

4.8.1.4 Water Use

4.8.1.4.1 Annual Activity Level

The WEAP *Annual Activity Level* feature for other demand sites is not used.

4.8.1.4.2 Annual Water Use Rate and Monthly Variation

Monthly demands for south-of-Delta CVP contractors are set equal to the product of the annual full contract amount and percent monthly variation. For the CVP, this variation is based on recent historical deliveries.

4.8.1.4.3 Monthly Demand

Monthly demands for south-of-Delta SWP contractors are specified by month. These demands are dynamically calculated based on the Table A amount and the monthly pattern of requests, which is a function of the SWP allocation.

4.8.1.4.4 Consumption

All deliveries to CVP and SWP south-of-Delta contractors are assumed to be 100 percent consumed; all return flows exit the model domain.

4.9 Data Directory

Table 4-15 provides location information in the SacWAM data directory for the datasets referenced in Chapter 1.

Table 4-15. File Location Information for Valley Floor Demand Sites and Catchments

Referenced Name	File Name	File Location[1]
Agricultural land use	sacval_ag_lu_area.xlsx	Agricultural_Catchments\Land_Use
Bulletin 113	132-12_table1-6.pdf and 132-12_tableb-4.pdf	South of Delta Demand Sites
Camino conduit	camino conduit demand calculation.xlsx	Other Demand Sites
Crop library	crop library.xlsx	Agricultural_Catchments\Land_Use
Cvp contractor data	cvp_water_contractors_2015.pdf	South of Delta Demand Sites
Daily cimis rh analysis	daily cimis rh analysis.xlsm	Climate\Valley Floor
Delta land use	sacval_ag_delta_lu_area.xlsx	Agricultural_Catchments\Land_Use
Dus	sac_val_demand_units.shp	GIS\Boundaries
Effective precipitation	effective precipitation.xlsx	Agricultural_Catchments\Land_Use
ET calibration	et calibration.xlsx	Agricultural_Catchments\Land_Use
Evaporative loss	sacval_evaporative_loss.xlsx	Agricultural_Catchments\Loss_Factors
Fraction wetted	sacval_fractionwetted.xlsx	Agricultural_Catchments\Irrigation
Groundwater pumping	sacval_minimum_goundwater_pumping.xlsx	Agricultural_Catchments\Loss_Factors
Irrigation efficiency	sacval_irrigation_efficiency.xlsx	Agricultural_Catchments\Irrigation
Lateral flow	sacval_lateral_flow.xlsx	Agricultural_Catchments\Loss_Factors
Latitudes	catchment_and_du_latitudes.xlsx	...
Livneh grid	livneh_grid_coords_utm11.shp	GIS\Climate
Loss to groundwater	sacval_loss_to_groundwater.xlsx	Agricultural_Catchments\Irrigation
Loss to runoff	sacval_loss_to_runoff.xlsx	Agricultural_Catchments\Irrigation
Operational spills	sacval_operational_spill.xlsx	Agricultural_Catchments\Loss_Factors
Potential application efficiencies	*individual files by water budget area*	Agricultural_Catchments\Loss_Factors\PAE
Rainfall-runoff calibration	rainfall-runoff calibration.xlsb	Other_Assumptions\Valley Floor Hydrology\SCS Curve Number
Refuge land use	sacval_refuge_lu_area.xlsx	Refuge_Catchments\Land_Use
Reuse	sacval_reuse.xlsx	Agricultural_Catchments\Loss_Factors
Rice management description	hillaire_2000.pdf	References
Seepage loss	sacval_seepage_loss.xlsx	Agricultural_Catchments\Loss_Factors
Surface soils	central valley soil analysis.xlsm	Agricultural_Catchments\Land_Use
Tailwater	sacval_tailwater.xlsx	Agricultural_Catchments\Loss_Factors
Urban consumption	sacval_urban_wu_consumption.xlsx	Urban_Demand_Sites\Water_Use
Urban demand	sacval_urban_wu_monthlydemands.xlsx	Urban_Demand_Sites\Water_Use
Urban land use	sacval_urban_lu_area.xlsx	Urban_Catchments
Valley floor processor	valley_floor_livneh_data_processor.xlsm	Climate\Valley Floor
Water budget areas	water_budget_areas.shp	GIS\Boundaries
Weap input data	*individual files by catchment*	Climate\WEAP Input Data

Note:
[1] Files located at Data\Demand_Sites_and_Catchments\... except for Rainfall-runoff Calibration (Data\...), Rice Management Description (References\...), and GIS files (GIS\...).

5 Demand Sites and Catchments – Upper Watersheds

Watersheds above the valley floor boundary are referred to as the upper watersheds and serve as the main supply of water for Sacramento Valley water users. In SacWAM, flows from these watersheds were originally designed to be simulated using one of two approaches. The first is the use of input flow time series developed by DWR. These flows are input into SacWAM as headflows on fictitious streams that have the same name as the DWR inflow time series. These inflows are listed in Table 6-1 and described in Section 6.1.1. The second approach to generating upper watershed flows is the use of the catchment object. In SacWAM, these objects have been set to use the Soil Moisture Model. This model is described in Yates, Sieber et al. (2005) and in the WEAP help file. These catchment objects provide a representation of rainfall-runoff processes including snow accumulation and melt, infiltration, surface runoff, ET, interflow, deep percolation, and baseflow. By adding a hydrological model of the upper watersheds to SacWAM, the inflow boundary of the model shifts from specified inflows to meteorological inputs (precipitation, temperature, wind speed, and humidity) across the upper watersheds. Using this approach permits analysis based on climate model outputs or synthetic meteorology. The creation of these catchment objects was based on work done in earlier modeling efforts including Young et al. (2009); Yates, Purkey et al. (2009); Mehta et al. (2011); and Joyce et al. (2011).

In early formulations of SacWAM, the user was given the option to select how the upper watersheds should be simulated (specified inflows or use of catchment objects). In SacWAM version 1.20, the only option is to use the specified inflows (see Key\Simulate Hydrology), because additional adjustments need to be implemented to the upper watershed catchments prior to their use. Below is a description of the construction and calibration of the upper watershed catchments that are currently non-operable. A description of the specified inflows is provided in Section 6.1.1.1. The documentation that follows describes the spatial analysis required to parameterize the catchment objects, the water management infrastructure, the operations rules for the water management infrastructure, and the calibration of the model to natural and managed flows.

5.1 Delineation of Upper Watersheds

Several spatial analysis steps were necessary to prepare geographic data for import to WEAP. First, watersheds were subdivided into subwatersheds based on the location of points of interest where the model needs to simulate flows. Typically, this is at dams and stream gauges. Second, each subwatershed was subdivided into elevation bands and a single catchment was created to represent the land area within each elevation band. This was done to represent the variation in climate that is a function of elevation. Third, each elevation band, in each subwatershed, was sub-divided into different land cover classifications. Within the catchment object, all hydrological calculations are performed for each of these individual land cover classes. A more detailed description of these three steps is provided below.

5.1.1 Selection of Pour Points

Pour points typically were created at the locations of dams and USGS stream gauges. These locations are listed in Table 5-1.

Table 5-1. Attributes of Pour Points Used in SacWAM

Watershed	Name	Latitude	Longitude	SacWAM Name
American River	Folsom Lake inflows[1]	38.71148	-121.15087	P508_American_01
	NF American River at NF Dam[1]	38.93748	-121.02316	P508_American_02
	MF American River above confluence with NF[1]	38.91493	-121.02540	P508_American_03
	SF American River nr Placerville[1]	38.77157	-120.81303	P508_American_04
	Union Valley Reservoir	38.86606	-120.44081	P508_American_05
	Ice House Reservoir	38.82355	-120.36155	P508_American_06
	Loon Lake	38.98761	-120.33170	P508_American_07
	French Meadows Reservoir	39.11095	-120.47017	P508_American_08
	Hell Hole Reservoir	39.05784	-120.41276	P508_American_09
Antelope Creek	Antelope Creek nr Red Bluff[1]	40.20007	-122.12251	P504_Antelope_01
Battle Creek	Battle Creek nr Cottonwood[1]	40.39810	-122.14651	P504_Battle_01
Bear River	Camp Far West Reservoir local inflows	39.05017	-121.31463	P508_Bear_01
	Lake Combie	39.01382	-121.04178	P508_Bear_02
	Rollins Reservoir	39.13581	-120.95260	P508_Bear_03
Big Chico Creek	Big Chico Creek nr Chico[1]	39.77542	-121.75341	P504_BigChico_01
Butte Creek	Butte Creek[1]	39.72636	-121.70803	P504_Butte_01
Cache Creek	Cache Creek above Rumsey local inflows	38.91024	-122.27961	P505_Cache_01
	Clear Lake inflow[1]	38.92520	-122.61398	P505_Cache_02
	Indian Valley inflow[1]	39.08058	-122.53654	P505_Cache_03
Calaveras River	Calaveras River at DU boundary	38.07331	-120.92668	P604_Calaveras_01
	New Hogan inflow	38.15053	-120.81357	P604_Calaveras_02
Clear Creek	Clear Creek at DU boundary[1]	40.51581	-122.52535	P502_Clear_01
	Whiskeytown Reservoir	40.59941	-122.53941	P502_Clear_02
Cosumnes River	Cosumnes River[1]	38.50861	-121.04417	P604_Cosumnes_01
	Jenkinson Lake	38.71679	-120.56931	P604_Cosumnes_02
	Camp Creek Diversion Tunnel	38.72466	-120.52505	P604_Cosumnes_03
Cottonwood Creek	NF and MF Cottonwood Creek nr Olinda[1]	40.38445	-122.47645	P502_Cottonwood_01
	SF Cottonwood Creek nr Olinda[1]	40.32576	-122.44505	P502_Cottonwood_02
Cow Creek	Sum of Cow Creeks	40.55511	-122.23131	P504_Cow_01
Deer Creek	Deer Creek nr Vina[1]	40.01387	-121.94729	P504_Deer_01
Delta	Los Vaqueros Reservoir	37.83713	-121.72798	P601_Delta_01
Dry Creek	Merle Collins Reservoir inflows[1]	39.32244	-121.31348	P508_DryofYuba_01
Elder Creek	Elder Creek nr Paskenta[1]	40.02442	-122.51086	P502_Elder_01
Feather River	Lake Oroville inflow	39.54301	-121.49225	P508_Feather_01
	Ponderosa Dam inflow[1]	39.54927	-121.30327	P508_Feather_02
	Little Grass Valley Reservoir[1]	39.72521	-121.02006	P508_Feather_05
	NF Feather River at Pulga[1]	39.79436	-121.45166	P508_Feather_07
	Lake Almanor Inflows[1]	40.17377	-121.08589	P508_Feather_08
	MF Feather River nr Merrimac[1]	39.70817	-121.27079	P508_Feather_09
	Sly Creek Reservoir inflows	39.58238	-121.11566	P508_Feather_04
	Miocene Diversion Dam	39.81391	-121.57109	P508_Feather_03
	Hendricks Diversion Dam[1]	39.93811	-121.53220	P508_Feather_06
Jackson Creek	Amador Reservoir Inflow	38.30356	-120.88944	P604_Jackson_01
Little Chico Creek	Little Chico Creek	39.73349	-121.77160	P504_LittleChico_01
Littlejohns Creek	Littlejohns d/s of Rock Creek confluence	37.91374	-120.96217	P603_Littlejohns_01
Marsh Creek	Marsh Creek[1]	37.89338	-121.72128	P601_Marsh_01
Mill Creek	Mill Creek nr Los Molinos[1]	40.05457	-122.02413	P504_Mill_01
Mokelumne River	Dry Creek d/s of Sutter Creek	38.35954	-120.98954	P604_Dry_01
	Camanche Reservoir inflow[1]	38.22614	-121.02190	P604_Mokelumne_01
	Pardee Reservoir inflow[1]	38.25710	-120.85037	P604_Mokelumne_02
	Mokelumne River nr Mokelumne Hill[1]	38.31264	-120.72019	P604_Mokelumne_03
Pit River	Pit River nr Montgomery Creek[1]	40.84323	-122.01625	P501_Pit_01
	Muck Valley-Clarks Valley watershed boundary	40.96967	-121.16871	P501_Pit_02
	Goose Lake-Upper Pit watershed boundary	41.69688	-120.40137	P501_Pit_03

Watershed	Name	Latitude	Longitude	SacWAM Name
Putah Creek	Lake Berryessa inflows[1]	38.51344	-122.10464	P505_Putah_01
Sacramento River	McCloud River above Shasta Lake[1]	40.95824	-122.21972	P501_McCloud_01
	Shasta Lake inflows[1]	40.71830	-122.41856	P501_Sacramento_01
	Sacramento River at Delta[1]	40.93955	-122.41427	P501_Sacramento_02
	Paynes and Sevenmile Creeks[1]	40.26344	-122.18707	P504_Sacramento_96
Stony Creek	Stony Creek below Black Butte Dam nr Orland[1]	39.81828	-122.32429	P502_Stony_01
	Stony Gorge Reservoir local inflows[1]	39.58579	-122.53271	P502_Stony_02
	East Park Reservoir inflow[1]	39.36184	-122.51640	P502_Stony_03
Thomes Creek	Thomes Creek at Paskenta[1]	39.88704	-122.52778	P502_Thomes_01
Trinity River	Lewiston Lake local inflows	40.72723	-122.79306	P102_Trinity_01
	Trinity Lake inflows	40.80100	-122.76271	P102_Trinity_02
Yuba River	Deer Creek inflow to Yuba R[1]	39.22447	-121.26853	P508_Yuba_01
	Englebright Reservoir local inflows[1]	39.23992	-121.26904	P508_Yuba_02
	New Bullard Bar Reservoir	39.39320	-121.14244	P508_Yuba_03
	Scott's Flat Reservoir	39.27266	-120.93077	P508_Yuba_04
	Oregon Creek below Log Cabin Dam nr Camptonville[1]	39.43944	-121.05806	P508_Yuba_05
	Middle Yuba River below Our House Dam[1]	39.41167	-120.99694	P508_Yuba_06
	Slate Creek below Div Dam nr Strawberry[1]	39.61556	-121.05167	P508_Yuba_07
	North Yuba River below Goodyears Bar[1]	39.52528	-120.93750	P508_Yuba_08
	Bowman Lake	39.44902	-120.65271	P508_Yuba_09
	Lake Spaulding	39.32730	-120.64337	P508_Yuba_10
	Jackson Meadows Reservoir	39.50865	-120.55639	P508_Yuba_11
	Fordyce Lake	39.37978	-120.49638	P508_Yuba_12

Note:
[1] There is no stream gauge associated with the pour point.
Key:
Ck = Creek, Div = Diversion, MF = Middle Fork, NF = North Fork, nr = near, R = River, SF = South Fork.

NHDPlus **flow accumulation** rasters were used to ensure pour points were located on streams. The NatGeo basemap (available in ESRI's ArcGIS) was used to guide pour-point placement at dam inflows. Stream gauge locations were based on the coordinates and descriptions available in USGS Water Data reports (USGS, 2016b).

5.1.2 Delineation of Subwatersheds

A **pour point grid** was created from the pour points shapefile using the Snap Pour Points tool and the **flow accumulation** raster as the input accumulation raster, with a snap distance of 5 m.

Subwatersheds were delineated using the pour point grid and NHDPlus **flow direction grids** for regions 18b and 18c, using the *Watershed* tool, and resulting in **upper watershed rasters**.

The *Raster-to-Polygon* tool was used to convert the watershed rasters to features, which were then unioned and clipped to the DU boundary. Gaps were disallowed so that polygons would be created for any spaces between watersheds stemming from minor discrepancies between the pour-point delineated watersheds and the HUC-12 boundaries (e.g., around the closed basins). Closed basins that fell within the 1801, 1802, and 1804 HUC-4s were added to upper watersheds based on HUC-8 and HUC-10 divisions.

A layer was created of the gaps between the watersheds and the DU boundary by making a dummy layer that encompassed all of the area that potentially held gaps, clipping this to the DU and then erasing from it the upper watersheds layer with a xy tolerance of 0 (automatically converted to two times the resolution). The gaps layer was merged with the upper watersheds and features that had not been assigned to a pour point (i.e., the gap features) were selected and multi-part features exploded.

Gap features greater than 10 km^2 were assigned a pour point value of 'Uncaptured: River Name,' where River Name is the stream/river into which the area drains. These areas are not captured by the gauge on their streams. In the two cases that a gap area drained into more than one river and each drainage area was greater than $10km^2$, the gap areas were divided along HUC-12 boundaries, and the resulting uncaptured areas assigned to their respective rivers.

The remaining gap features, those less than $10km^2$, were again selected and the Eliminate tool was run to join these sliver polygons with the neighboring polygon with which they shared the longest border. The Eliminate tool was run twice to eliminate all the slivers, resulting in a final **upper watersheds** layer (Figure 5-1).

A field was added to the upper watersheds layer—WEAP_sws. This was populated by PXXX_river_XX where PXXX was already established and the XX suffix was chosen so that 01 was located at the basin outlet and the highest numbers represented the headwaters.

5.1.3 Elevation Bands

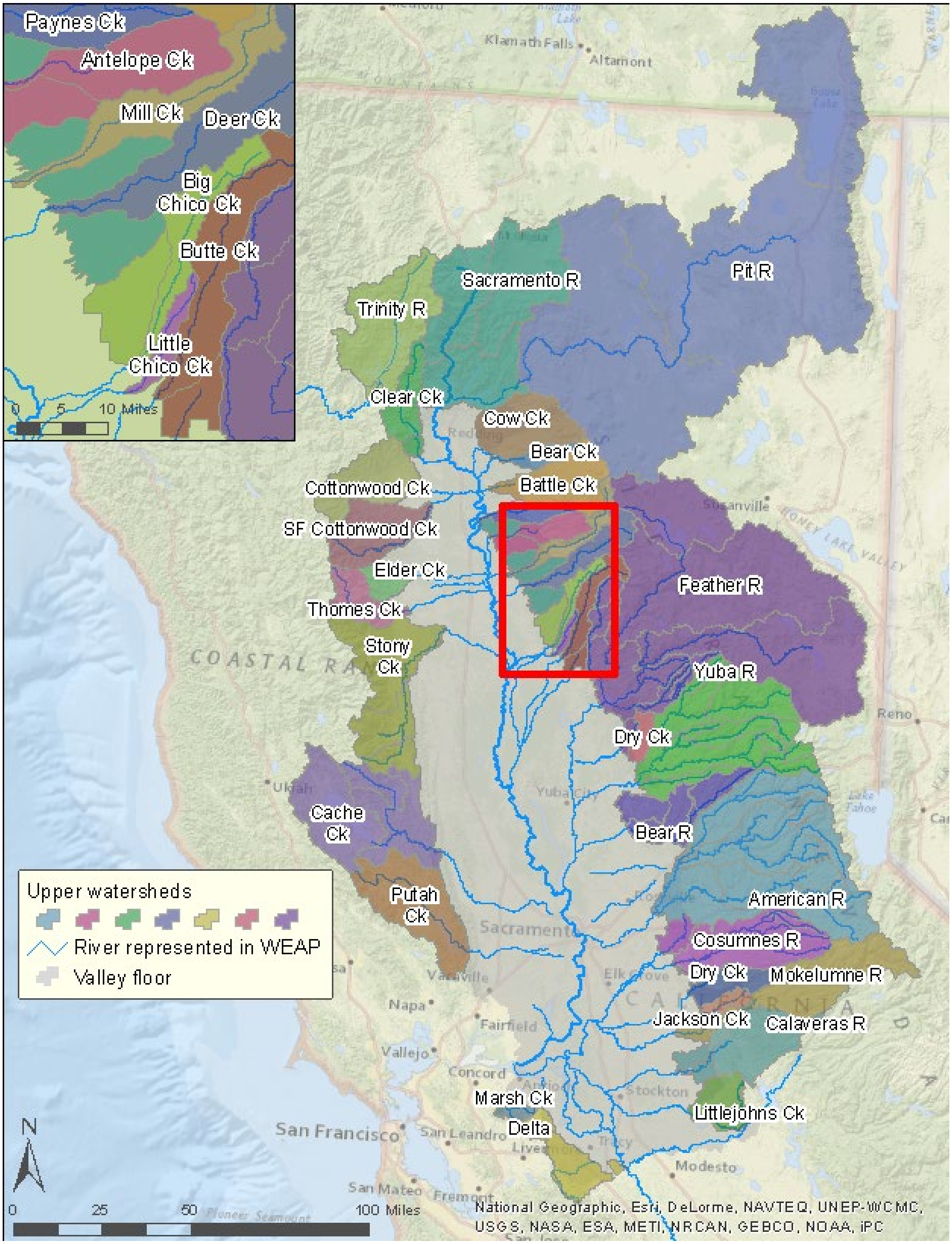
Elevation data are NHDPlus' **NEDsnapshot** reclassified (Table 5-2), using the default setting of 'double precision' to produce a **reclassified elevation grid**.

Table 5-2. Reclassification of Elevation Data

Original Value (centimeters)	New Value (meters)
-2180–50,000	500
50,000–100,000	1,000
100,000–150,000	1,500
150,000–200,000	2,000
200,000–250,000	2,500
250,000–300,000	3,000
300,000–350,000	3,500
350,000–400,000	4,000
400,000–450,000	4,500
No Data	No Data

The Raster-to-Polygon tool was used to convert these grids to shapefiles, simplify polygons left unchecked, and the shapefiles were merged and clipped to the upper watersheds to produce a **reclassified elevation shapefile**.[23]

[23] To prepare the NED 18b and 18c regions for merging, a buffer was erased from the outside edge of 18b to reduce discrepancies between the datasets where they overlapped. This was accomplished by dissolving 18b, creating a -10km buffer around it, and erasing the buffered footprint from the 18c polygon layer. The clipped 18c and buffered 18b were unioned with gaps disallowed and dissolved to achieve one feature per elevation band.



Red rectangle delineates zoomed in inset area.

Figure 5-1. Upper Watersheds

5.1.4 Creation of WEAP Catchments

Upper watersheds and the reclassified elevation shapefile were intersected to form catchments. Nine elevation bands split the 92 subwatersheds of the 34 watersheds into 351 catchments. The attribute table for catchments, including areas for each polygon, was exported from ArcGIS into a catchment analysis file. A pivot table was used to calculate relative area in each elevation band within a subwatershed. When an extreme elevation band (highest or lowest band in the subwatershed) occupied less than 15.5% of the total area of a subwatershed, this elevation band was lumped with the adjacent elevation band in the same subwatershed. If the sum of the areas of these combined elevation bands was still less than 15.5%, it was lumped with the next adjacent elevation band in the same subwatershed. Through this process, the number of catchments for use in WEAP was reduced to 194 (Table 5-3). To facilitate calibration and analysis, the model was divided into seven regions (Table 5-4). One subwatershed is included in two regions because of a transfer between regions.

Zonal statistics were performed to produce tables of the average elevation of each catchment, using the **reclassified elevation shapefiles**. The tables were joined to the **catchments** shapefile, and the average elevation data added.

Table 5-3. WEAP Catchments

Watershed	Subwatersheds	Catchments	Watershed	Subwatersheds	Catchments
American	9	22	Feather	10	21
Antelope	2	5	Jackson	2	3
Battle	1	3	LittleChico	1	2
Bear	1	2	Littlejohns	1	1
Bear	4	6	Marsh	1	2
BigChico	2	4	McCloud	1	3
Butte	2	5	Mill	1	3
Cache	3	6	Mokelumne	3	6
Calaveras	3	4	Paynes	1	2
Clear	2	4	Pit	3	6
Cosumnes	4	7	Putah	1	2
Cottonwood	2	6	Sacramento (P501)	2	5
Cow	1	3	Sacramento (P504)	4	7
Deer	1	3	Stony	4	9
Delta	2	3	Thomes	1	3
Dry	1	2	Trinity	2	5
DryofYuba	1	2	Yuba	12	23
Elder	1	4			
Total				**92**	**194**

Table 5-4. Model Regions

Model Region	Subwatersheds
Shasta	Clear, McCloud, Pit, Sacramento (01, 02), Trinity
Westside	Cache, Cottonwood, Elder, Putah, Stony, Thomes
Northeast Streams (NEStreams)	Antelope, Battle, Bear, Big Chico, Butte, Cow, Deer, Feather (06)[1], Little Chico, Mill, Paynes, Sacramento (96, 97, 98, 99)
Feather	Feather, Dry of Yuba
CABY	Cosumnes (all but 99), American, Bear, Yuba
Eastside	Calaveras, Cosumnes (99), Dry, Jackson, Littlejohns, Mokelumne
Delta	Delta, Marsh

Note:
[1] The Feather_06 subwatershed was included in both the Northeast Streams and Feather regions to model a transbasin transfer.

5.1.5 Land Cover

Land cover data are National Land Cover Database (NLCD) 2011. Most NLCD classes correspond to a single WEAP class, except for low-, medium-, and high-intensity developed land. Low-intensity developed land is subdivided in WEAP to include a residential landscape class so that the user can control the portion of residential lots that is pervious, thus allowing for a more accurate simulation of runoff from these areas. Similarly, portions of medium- and high-intensity area are designated as commercial-industrial landscape. Proportions of low-, medium-, and high intensity developed land are stored in *Other\Urban Outdoor\SAC\Area Factors*.

The NLCD 2011 raster for the coterminous United States was clipped to the Sacramento Basin with a 100-m buffer with ‘Maintain Clipping Extent’ unchecked to disallow resampling. This was output to a **land-use tif**. Raster-to-Polygon converted the tif to a polygon layer, which was then clipped to the upper watersheds extent, with ‘simplify polygons’ unchecked. WEAP level 1 and 2 fields were added to facilitate calculation of areas for the land-use classes used as input in WEAP (Table 5-5).

The catchment-NLCD intersections were dissolved on the WEAP1 and catchment fields, resulting in one polygon per catchment–land use combination in seven **simplified NLCD** files. Land use areas by catchment were exported and used in Excel lookup tables to produce area formulae (for low-, medium-, and high intensity urban; and residential and commercial/industrial landscape) and raw areas (for all other land use categories) for import into WEAP in square miles. Areas were rounded to three decimal places; this resulted in ‘0’ values for land uses that covered less than approximately 1300m^2. Data processing can be reviewed in the **catchment land use** file.

Table 5-5. National Land Cover Database Land Use Classes and Corresponding WEAP Classes

Gridcode	NLCD 2006	WEAP 1	WEAP_2
21	Developed, Open Space	OpenSpace	Urban
22	Developed, Low Intensity	Low Int	
		Res Landscape[1]	
23	Developed, Medium Intensity	Med Int	
		CommInd Landscape[1]	
24	Developed, High Intensity	Hi Int	
82	Cultivated Crops	Cultivated	Irrigated
81	Pasture/Hay	Pasture	
12	Perennial Ice/Snow	Barren	Non-Irrigated
31	Barren Land		
41	Deciduous Forest	Forest	
42	Evergreen Forest		
43	Mixed Forest		
11	Open Water	Open Water	
52	Shrub/Scrub	Non Forest	
71	Grassland/Herbaceous		
90	Woody Wetlands		
95	Emergent Herbaceous Wetlands		

Note:
[1] Commercial/Industrial Landscape and Residential Landscape are calculated as percentages of Low-, Medium-, and High Intensity Developed and are not assigned to specific pixels in the data files.

5.2 Upper Watershed Parameters

All values except for Initial Z1 and Initial Z2 can be reviewed in the **upper watershed parameterization** file. During calibration of the upper watershed scaling factors were created to adjust hydraulic parameters on a sub watershed scale such that all parameters for catchments contributing to a calibration point have the same value. The mapping of these groupings of catchments to calibration points is provided in the **upper watershed expressions** file.

5.2.1 Climate

5.2.1.1 Precipitation, Temperature, Humidity, Wind

Historical climate data were needed for the entire model domain for the period 1921 to 2015. In consultation with State Water Board staff and in reaction to advice from the peer review panel, the SacWAM development team developed two spatially interpolated, gridded datasets. One was based on data developed by Livneh et al. (2013), the other is the PRISM dataset (PRISM, 2016).

The Livneh dataset provides daily precipitation, maximum and minimum temperature, and wind speed (at 10m) for January 1, 1915, to December 31, 2011, on a 1/16-degree grid. The following steps were followed in developing the data:

1. The **Livneh grid** was intersected with the **water budget areas** boundaries.
2. A VBA macro in **valley floor processor** was used to calculate the average of the maximum and minimum daily temperature, precipitation, and wind speed for all **Livneh grid** cells that intersected each WBA.
3. The spreadsheet **Daily CIMIS RH Analysis** was used to calculate an average maximum and minimum daily relative humidity time series based on CIMIS data.
4. Data from steps 2 and 3 were combined to create the input files found in **WEAP Input Data**.

The wind data in the Livneh et al. (2013) dataset is provided as wind speed at 10 m above the ground. These data were modified to represent wind speed at 2 m above the ground using the following relationship (Neitsch et al., 2005):

$$wind_2 = wind_{10} * (2/10)^{0.2} \qquad \text{Equation 5-1}$$

where:

$wind_2$ is the wind speed at 2 m above the ground;

$wind_{10}$ is the wind speed at 10 m above the ground.

The PRISM dataset is a combination of daily data (1981 – 2015) and monthly average data (1922-1980). The data set contains precipitation and maximum and minimum temperature on a 4-km grid. The following steps were followed in developing the data:

1. For 1922-1980, the daily Livneh precipitation, maximum temperature, and minimum temperature were scaled on a monthly basis so that the monthly average values matched the

monthly PRISM data. Wind data were taken from the Livneh data set and the relative humidity described above for the Livneh dataset were used.

2. For 1981 – 2015, the daily PRISM precipitation, maximum temperature, and minimum temperature were used. The wind data were taken from the Livneh data set and the relative humidity described above for the Livneh dataset were used. For dates after 2011, the daily average wind speed values from the Livneh dataset were used.

3. Spatial processing that involved averaging PRISM grid data for each SacWAM catchment is described in **Prism spatial processing**.

4. The process utilized to scale the PRISM data and develop the input files read by SacWAM is provided in **SacWAM_PRISM_Data_Processor** and **SacWAM_UpperWatershed_PRISM_Data_Processor**.

SacWAM users can choose which data set to use. To do so, enter either ';Livneh' or ';PRISM' in *Key/Climate* in the data tree. A third option is available, PRISMLivneh2, in which the valley floor data are from the PRISM data and the upper watersheds are from the Livneh data. In the results presented in the appendix of this document, the PRISM data were used as climate inputs.

5.2.1.2 Cloudiness Fraction

No data were input for the *Cloudiness Fraction*. It was assumed that errors introduced by this assumption are minimal since there is little cloudiness during the period of highest ET (Apr – Oct).

5.2.1.3 Latitude

Centroids were calculated in ArcGIS for all catchments. Latitudes were calculated for these points in decimal degrees in WGS1984 UTM Zone 11 N. **Latitudes** were rounded to three decimal places and imported into WEAP.

5.2.1.4 Freezing Point and Melting Point

Freezing and melting points are regionally calibrated values. The regions are defined and further discussed in Section 7.10.1 of Chapter 7 on Other Assumptions.

5.2.1.5 Albedo

Default WEAP values were used for *Albedo Upper Bound* (0.25) and *Albedo Lower Bound* (0.15), No value was set for *Albedo*, resulting in WEAP calculating this value based on snow accumulation.

5.2.1.6 Initial Snow

No initial snow data were entered. The model runs begin with the assumption that no snow is on the ground.

5.2.1.7 Snow Accumulation Gauge

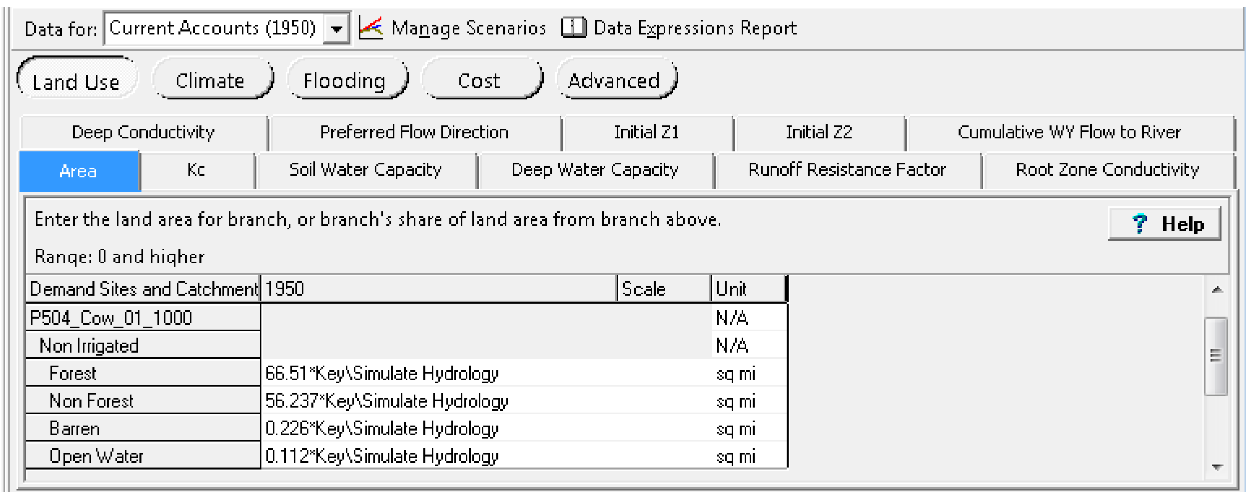
Snow water equivalent data were downloaded from DWR's CDEC (www.cdec.water.ca.gov). Snow gauge locations were spatially joined with the catchments layer so that the elevation of the snow gauge could be compared with the average elevation of the catchment it falls in. Only stations within 100 m of the average elevation of their respective catchment were considered. If more than one station met the elevation criterion, the one with more complete data was chosen to represent the catchment.

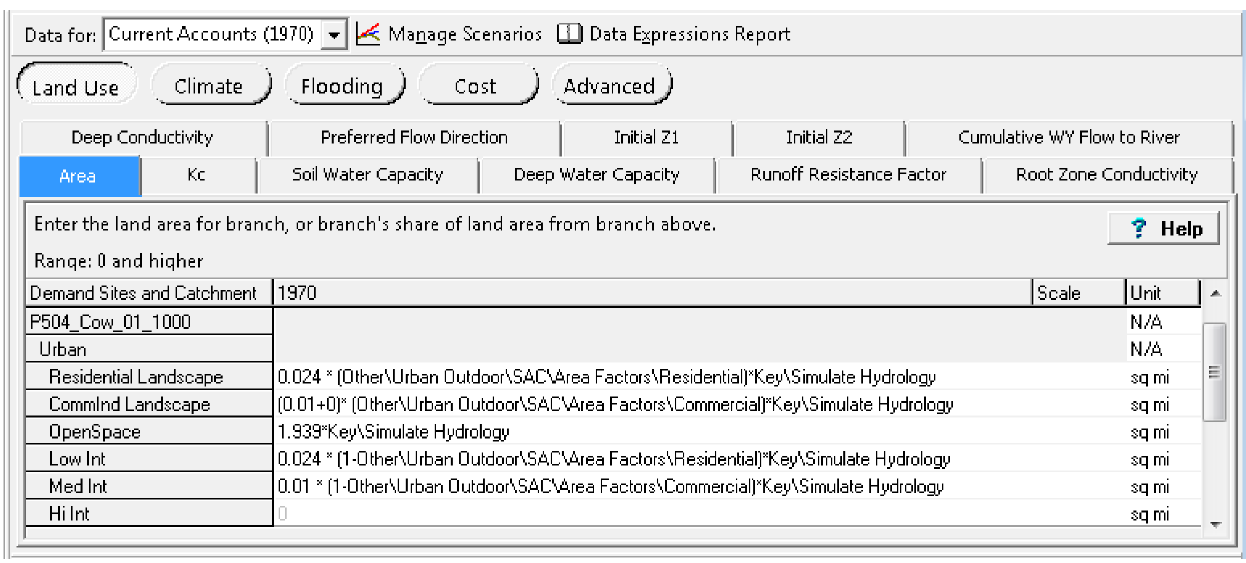
Adjusted snow equivalent data were used as available; raw data were used for dates lacking adjusted data. Data from 26 snow gauges were entered. However, the data were not used during calibration beacuse it was found the 500-meter elevation bands represent too large a range of elevation to have meaningful comparisons between observed and simulated snow accumulation.

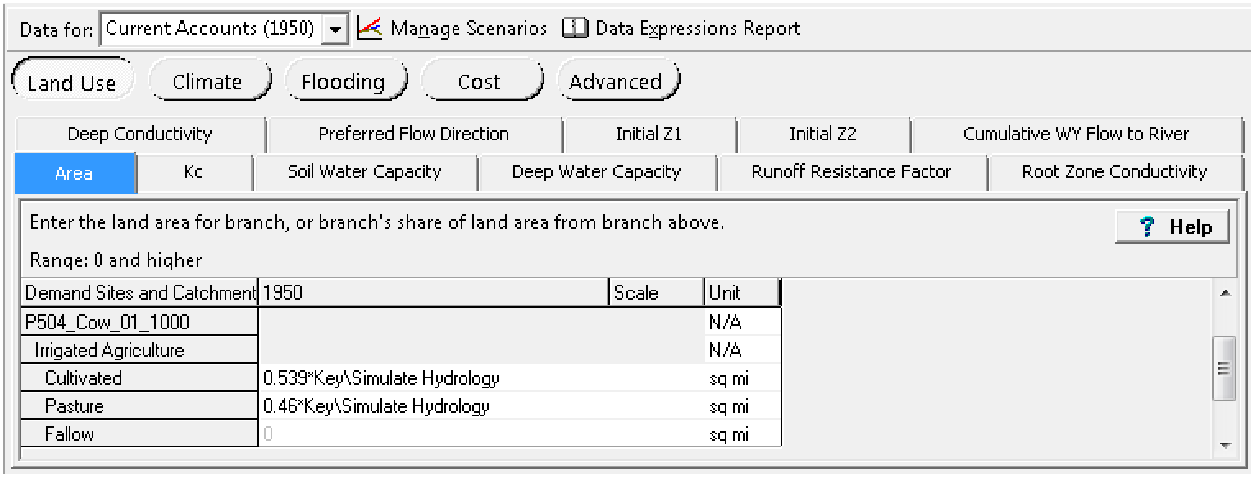
5.2.2 Land Use

5.2.2.1 Area

Land-use areas for upper watershed catchments were calculated based on the procedure outlined in Section 5.1.5. All area values from the GIS analysis can be found in **catchment land use**. Each area expression has the additional multiplier **Key\Simulate Hydrology* which sets the area value to zero if the DWR inflow time series are being used (see Section 9-10).

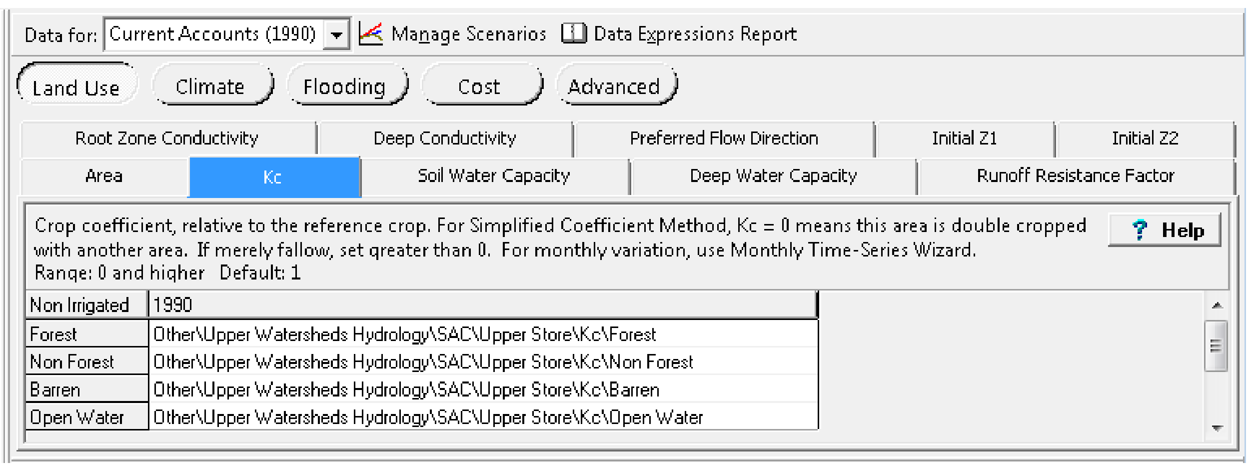


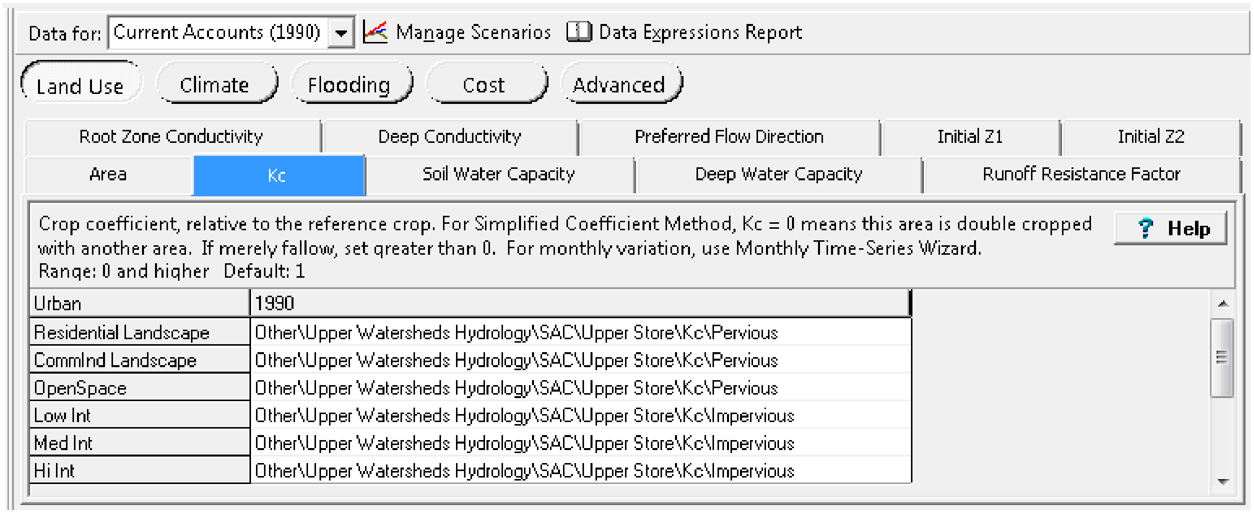


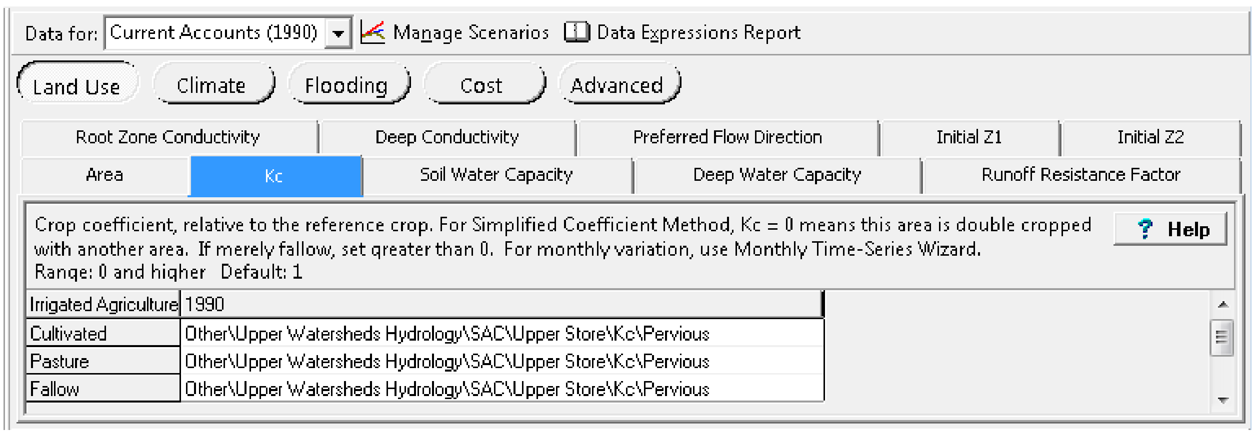


5.2.2.2 Kc

The crop coefficient (Kc) is used to scale the potential ET (ETo) calculated by WEAP to a level appropriate for the land cover type of interest. In SacWAM, land use–specific values from the CVPA model were used. These values range from 0.7 for impervious land classes to 1.2 for forested areas. In SacWAM, these values do not vary in time. See **upper watershed parameterization** and **upper watershed expressions** for details.

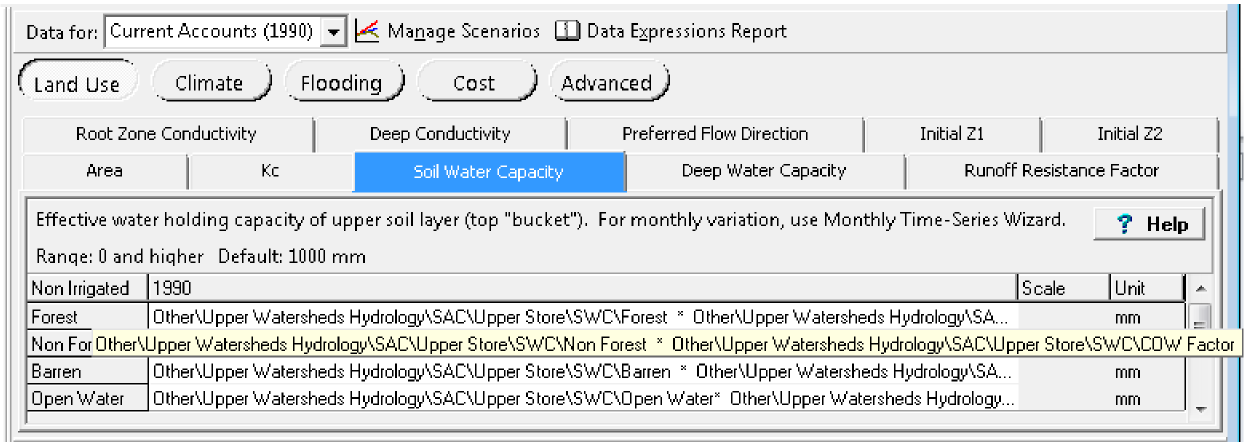


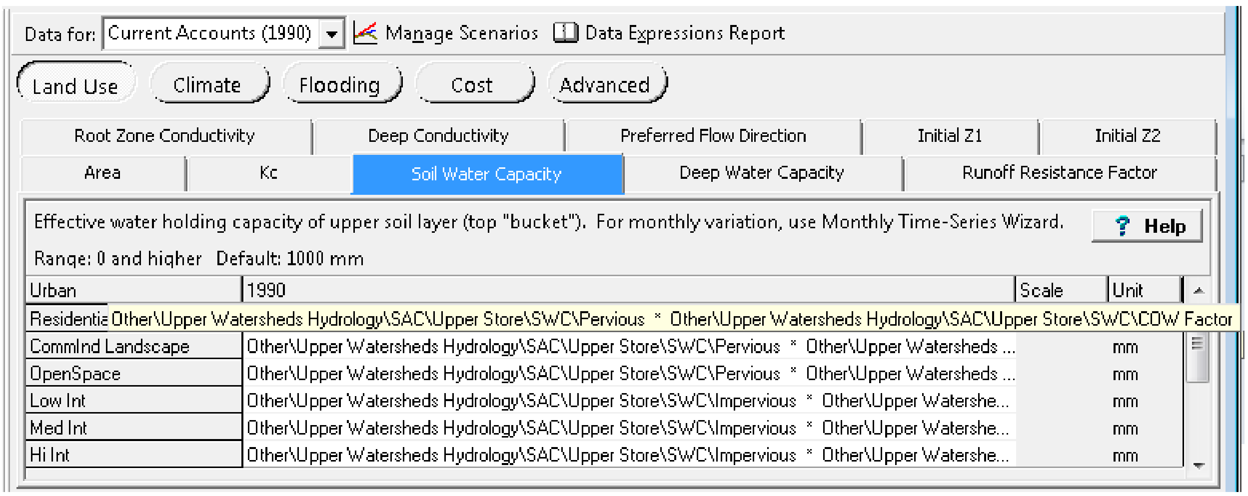


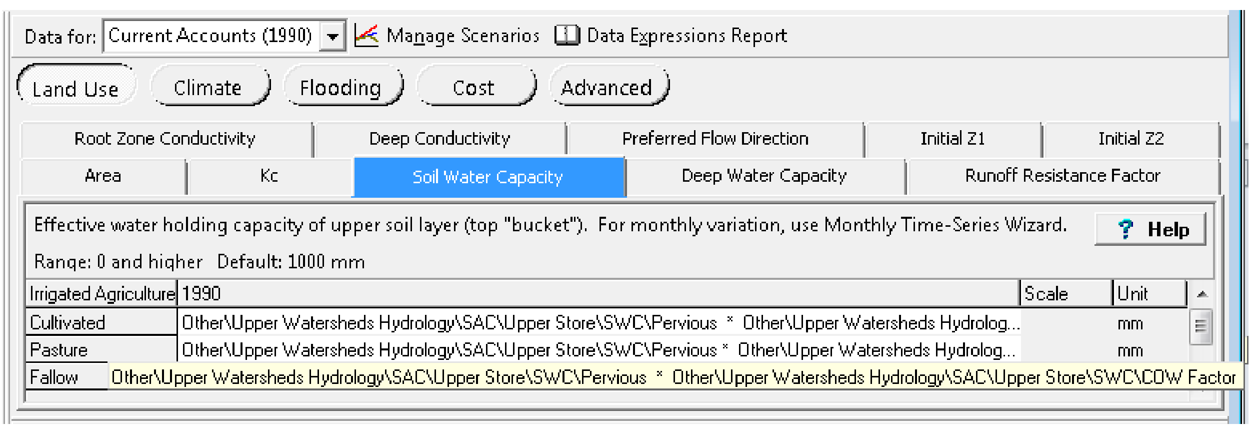


5.2.2.3 Soil Water Capacity

The soil water capacity is the maximum amount of water that can be stored in the upper compartment of the Soil Moisture Model. This is effectively the root zone soil water capacity. Soil water capacity was specified through two parameters—a land use–specific value multiplied by a subwatershed-specific multiplier. The land use–specific parameter was taken from the CVPA model. During calibration of SacWAM, subwatershed scaling factors were utilized to scale the soil water capacity values for all catchments that contribute to a specific flow calibration point. The scaling factors are located in *Other Assumptions\Upper Watershed Hydrology\SAC\Upper Store\SWC*. See **upper watershed parameterization** and **upper watershed expressions** for details.

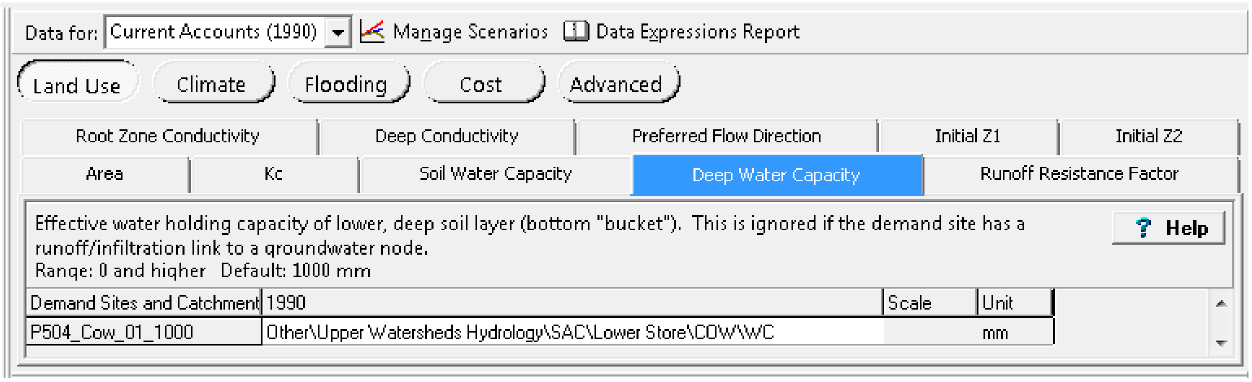






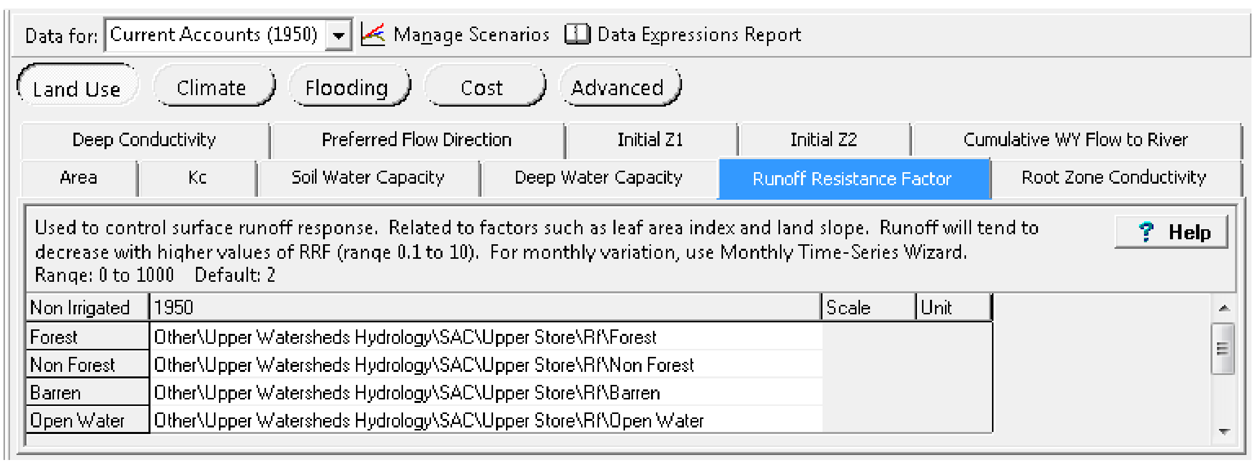
5.2.2.4 Deep Water Capacity

The *Deep Water Capacity* is the maximum amount of water that can be stored in the second compartment of the Soil Moisture Model. Deep water capacity (WC) was initially given a value of 1000 mm for all catchments. During calibration of the baseflow portion of the hydrograph for some sub watersheds it was necessary to alter the value. These values are located in *Other Assumptions\Upper Watershed Hydrology\SAC\Lower Store* under the parameter name WC. All values are provided in **upper watershed parameterization**.



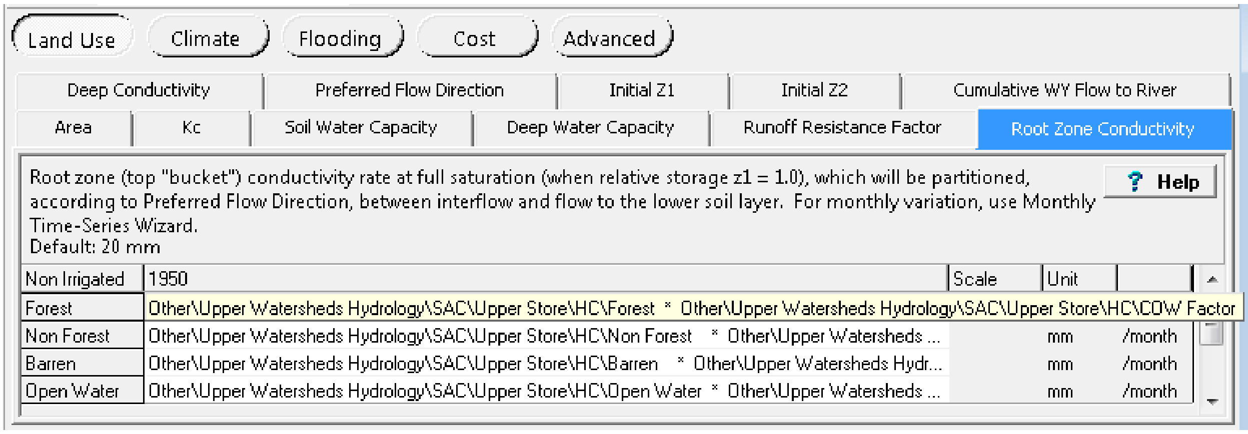
5.2.2.5 *Runoff Resistance Factor*

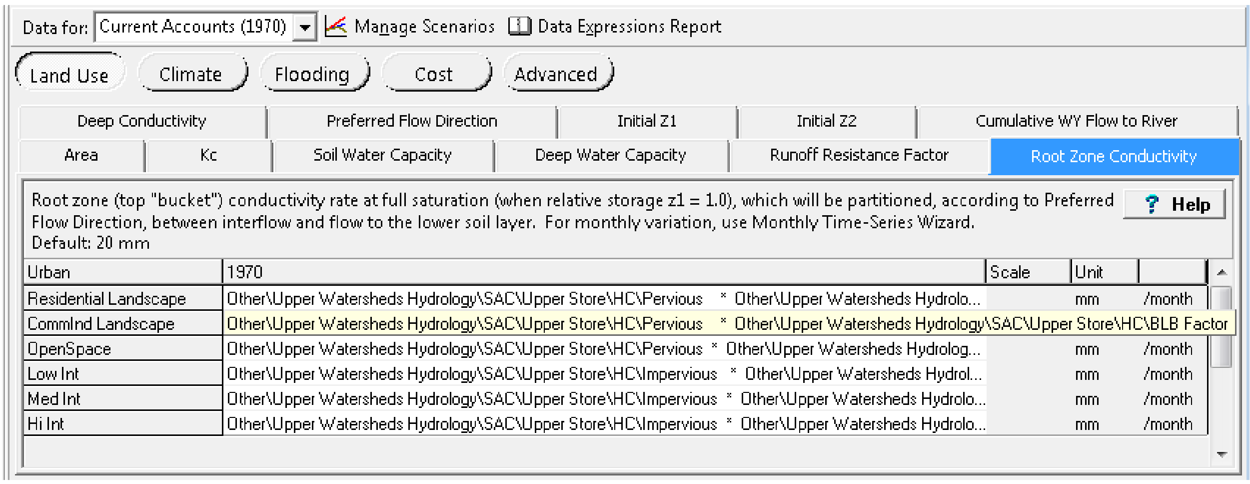
The runoff resistance factor reduces the rapidity of surface runoff thereby increasing the potential for water to infiltrate into the soil. In SacWAM, the runoff resistance factor (Rf) is based on land use class with smaller values for more pervious land cover types such as barren soil and impervious surfaces in urban areas. Higher values were assigned to areas with denser vegetation cover such as forests and pervious surfaces in urban areas. These values are located in *Other Assumptions\Upper Watershed Hydrology\SAC\Upper Store\Rf.* All values are provided in the **upper watershed parameterization** file.

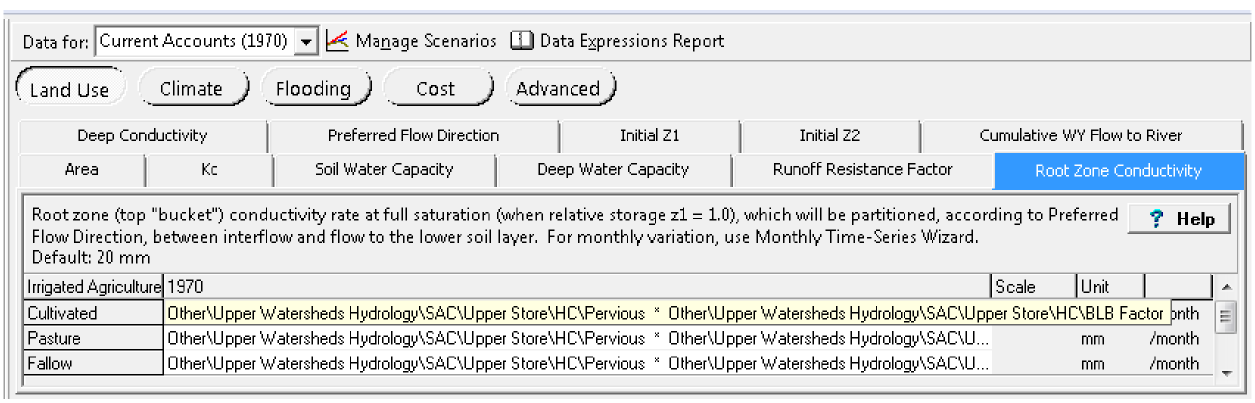


5.2.2.6 *Root Zone Conductivity*

The root zone conductivity specifies the hydraulic conductivity in the root zone. Root zone conductivity (HC) is specified through two parameters—a land use–specific value multiplied by a sub watershed-specific multiplier. The land use–specific parameters were obtained from the CVPA model. During calibration, these values were modified on a subwatershed basis. These values are located in *Other Assumptions\Upper Watershed Hydrology\SAC\Upper Store\HC.* See **upper watershed parameterization** and **upper watershed expressions** for details.

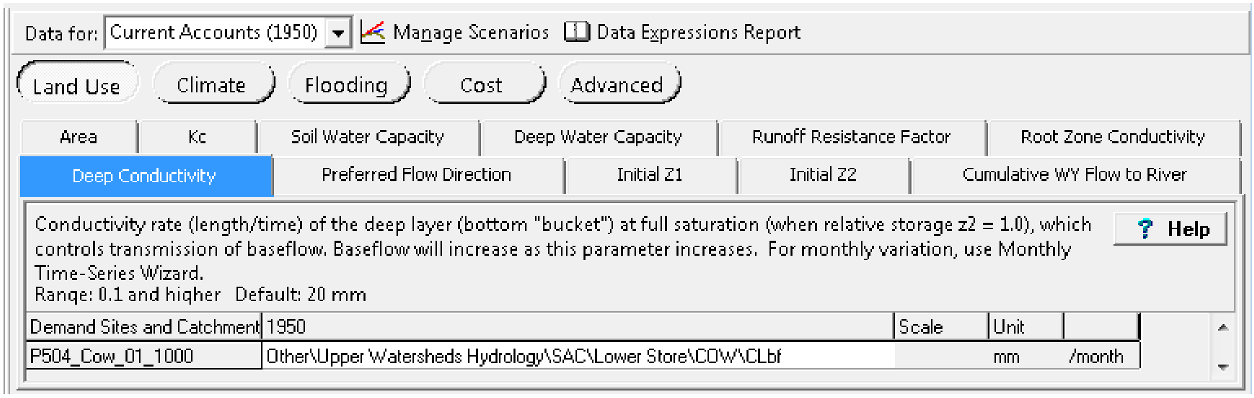






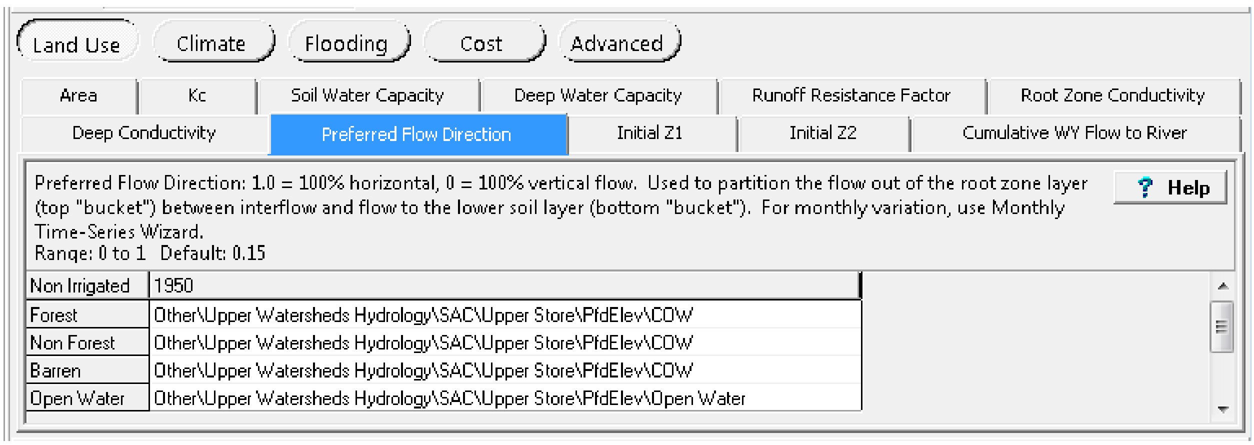
5.2.2.7 Deep Conductivity

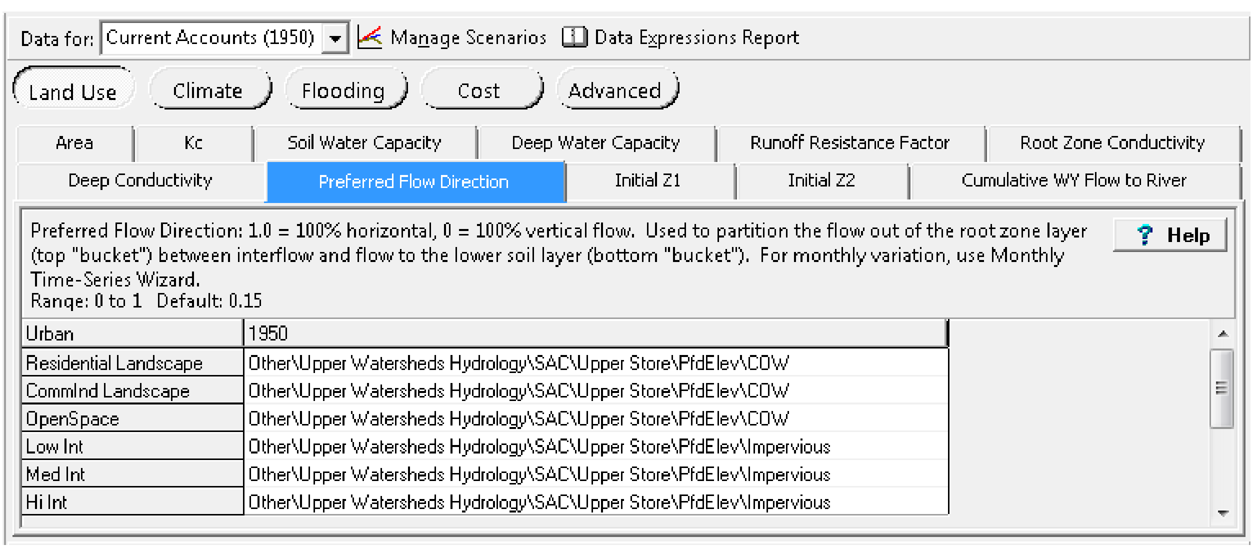
The deep conductivity parameter specifies the conductivity of the second, deep, compartment of the Soil Moisture Model. This parameter was initially set to a value of 500 mm/month, similar the CVPA. During calibration, it was adjusted on a sub watershed basis. These values are located in *Other Assumptions\Upper Watershed Hydrology\SAC\Lower Store* under the parameter name CLbf. See **upper watershed parameterization** and **upper watershed expressions** for details.

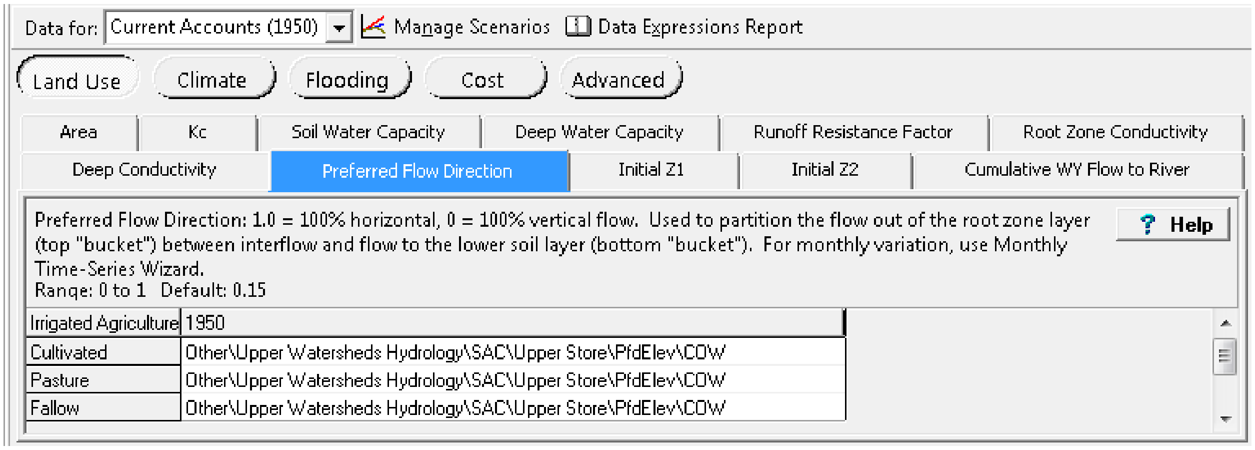


5.2.2.8 Preferred Flow Direction

The preferred flow direction is used to specify the division of flow from the root zone into interflow or deep percolation into the second compartment. Initially, land-use specific values were obtained from the CVPA model. During calibration, it was adjusted on a sub watershed basis. These values are located in *Other Assumptions\Upper Watershed Hydrology\SAC\PfdElev.* See **upper watershed parameterization** and **upper watershed expressions** for details.

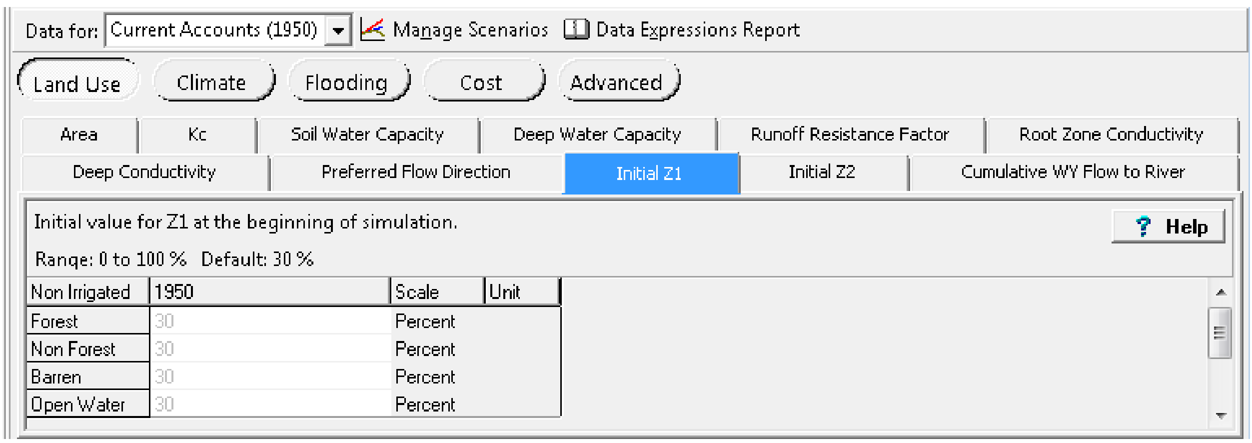






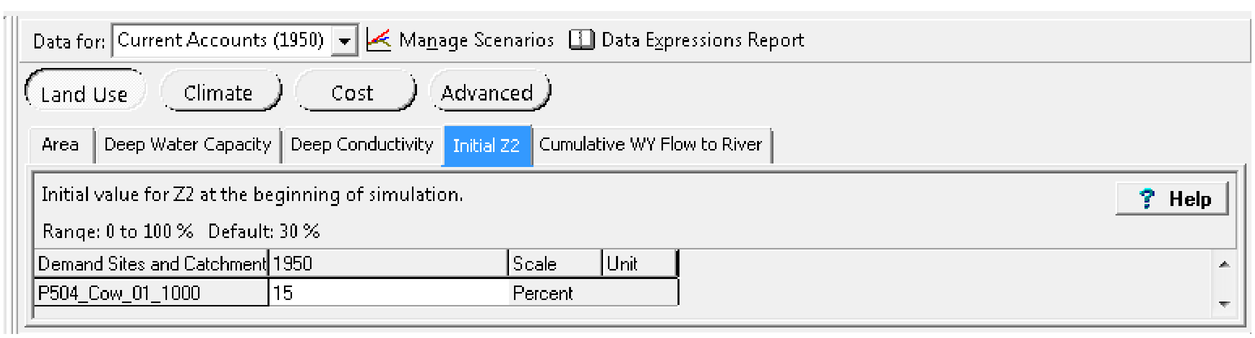
5.2.2.9 Initial Z1

The initial Z1 value is the initial soil moisture condition for the top compartment in the Soil Moisture Model. The default value for initial Z1 is 30%.



5.2.2.10 Initial Z2

The initial Z2 value is the initial soil moisture condition for the top compartment in the Soil Moisture Model. The value for initial Z2 has been set to 15%.



5.3 Data Directory

Table 5-6 provides location information in the SacWAM data directory for the datasets referenced in Chapter 5.

Table 5-6. File Location Information for Upper Watersheds Demand Sites and Catchments

Referenced Name	File Name(s)	File Location
Catchment analysis	catchments.xlsx	Data\Demand_Sites_and_Catchments\Upper_Watershed_Catchments
Catchment land use	nlcd_all.xlsx	Data\Demand_Sites_and_Catchments\Upper_Watershed_Catchments
Catchments	catchments_final	GIS\Boundaries
Climate dataset	*individual files by coordinates*	Livneh Data
Flow accumulation	nhdplusfac18b, nhdplusfac18c	GIS\Hydrology
Flow direction grid	nhdplusfdr18b, nhdplusfdr18c	GIS\Hydrology
Latitudes	catchment_and_du_latitudes.xlsx	Data\Demand_Sites_and_Catchments
Land-use tif	2011_sacwam.tif	GIS\Landuse
Livneh grid	livneh_grid_coords_utm11.shp	GIS\Climate
Nedsnapshot	elev_cm_18b, elev_cm_18c	GIS\Elevation
Pour point grid	upws_pts_grd	GIS\Hydrology
Pour points	upws_ppts	GIS\Hydrology
Reclassified elevation grid	ned_m_18b, ned_m_18c	GIS\Elevation
Reclassified elevation shapefile	ned_m_upws	GIS\Elevation
Simplified NLCD	nlcd_[*region*]_dissolve	GIS\Landuse
Upper watershed expressions	upperwshed_expressions.xlsx	Data\Demand_Sites_and_Catchments\Upper_Watershed_Catchments
Upper watershed parameterization	upper_ws_parameterization.xlsx	Data\Other_Assumptions\Upper_Watersheds
Upper watershed processor	upperwshed_livneh_data_processor.xlsm	Data\Demand_Sites_and_Catchments\Climate\Upper Watersheds
Upper watershed rasters	upws_18b, upws_18c, losvaq	GIS\Boundaries
Upper watersheds	upws_final	GIS\Boundaries
WEAP input data	*individual files by catchment*	Data\Demand_Sites_and_Catchments\Climate\WEAP Input Data

6 Supply and Resources

The *Supply and Resources* branch of the SacWAM data tree includes parameters relating to transmission arcs, rivers and diversions, groundwater, runoff and infiltration, return flows, and other water supply objects. These objects and their properties are described in this chapter, which is organized using headings that mimic the structure of the data tree in the WEAP software. Screenshots of the WEAP interface for each parameter are provided where possible to help the user understand where parameter values are entered into the model.

- Key Assumptions
- Demand Sites and Catchments
- Hydrology
- Supply and Resources
  - River
  - Groundwater
  - Other Supply
  - Transmission Links
  - Runoff and Infiltration
  - Return Flows
- Water Quality
- Other Assumptions
- User Defined LP Constraints

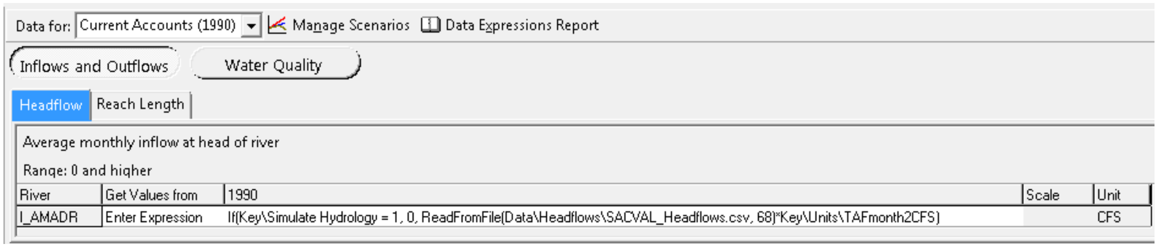
6.1 River

The *River* branch of the WEAP tree includes both 'river' arcs for natural streams and rivers (shown in blue in the WEAP schematic) and 'diversion' arcs for man-made channels and tunnels. However, parameterization of river and diversion objects differ. Diversions are discussed under Section 6.2. Table 3-1 provides a complete list of rivers and other natural waterways represented in SacWAM. The definition of river objects occurs at multiple levels. The head of a river branch includes *Inflows and Outflow* and *Water Quality* features. The WEAP *Water Quality* features for rivers is not used. The *Inflows and Outflows* feature is described below. Additionally, a river may contain reservoirs, flow requirements, reaches, and streamflow gauges, as shown below.

- Supply and Resources
  - River
    - Pit and Upper Sacramento River
    - Sacramento River
      - Reservoirs
      - Flow Requirements
      - Reaches
      - Streamflow Gauges

6.1.1 Inflows and Outflows

6.1.1.1 Headflow



SacWAM can be run in two modes with respect to the upper watershed hydrology. The first mode uses WEAP catchment objects to simulate snow accumulation, snow melt, and rainfall-runoff processes. The creation of these catchments is described in Section 3.7 and Chapter 5. The second mode uses time series data of historical unimpaired flows developed by DWR to represent flows from the upper watersheds into the stream network. The model user can choose between these two modes of simulation using the parameter *Key\Simulate Hydrology.* Currently, the option to simulate hydrology using the catchment objects is not available.

The WEAP 'Headflow' is the inflow to the first node on a stream. Headflows can be specified either as originating from a WEAP catchment object, or with values directly input using the Read from File Method. Historical streamflow data were obtained for the Sacramento Valley Hydrologic Region from DWR, and for the San Joaquin Hydrologic Region from Reclamation. The data are stored in the csv file *Data/Headflows/SacVal_Headflows.csv* as monthly time series data. The first row in this file denotes the name of the time series data used in SacWAM. Inflow names contain the prefix 'I_' followed by a five or six letter string. The five-letter string is an acronym for inflows to reservoirs or lakes. The six-letter string denotes the river followed by the river mile. For example, I_SHSTA represents the inflow to Shasta Lake, and I_NFY029 represents inflow to the North Fork Yuba River at RM 29. Table 6-1 lists all historical inflows used in SacWAM and their average annual flow (water years 1922-2015).

Table 6-1. Upper Watershed Inflows

Inflow Arc	Description	Type[1]	Average Annual Flow (TAF)[2]
I_ALD002	Alder Creek near Whitehall	Stream accretion	4
I_ALD004	Alder Creek at proposed dam site	Stream inflow	24
I_ALMNR	Lake Almanor	Reservoir inflow	489
I_ALOHA	Lake Aloha	Reservoir inflow	16
I_AMADR	Amador Reservoir	Reservoir inflow	29
I_ANT011	Antelope Creek near Red Bluff	Stream inflow	99
I_ANTLP	Antelope Reservoir	Reservoir inflow	33
I_BCC014	Big Chico Creek near Chico	Stream inflow	101
I_BCN010	Bear Creek (North) near Millville	Stream inflow	59
I_BLKBT	Black Butte Lake	Local reservoir inflow	210
I_BOWMN	Bowman Lake	Reservoir inflow	77
I_BRC003	Bear Creek above Holsten Chimney	Stream inflow	33
I_BRR023	Camp Far West Reservoir	Local reservoir inflow	90
I_BRYSA	Lake Berryessa	Reservoir inflow	357
I_BSH003	Brush Creek at Brush Creek Dam	Stream inflow	9
I_BTC048	Butte Creek near Chico	Stream inflow	241
I_BTL006	Battle Creek near Cottonwood	Stream inflow	347
I_BTVLY	Butt Valley Reservoir	Reservoir inflow	72
I_BUCKS	Bucks Lake	Reservoir inflow	85
I_CAPLS	Caples Lake	Reservoir inflow	29
I_CCH053	Cache Creek above Rumsey	Stream accretion	54
I_CLR011	Clear Creek near Igo	Stream accretion	45
I_CLRLK	Clear Lake	Reservoir inflow	443
I_CLV026	Calaveras River at Bellota	Stream inflow	8
I_CMBIE	Combie Reservoir	Local reservoir inflow	30
I_CMCHE	Camanche Reservoir	Local reservoir inflow	11
I_CMP001	Camp Creek near Somerset	Stream inflow	12
I_CMP014	Camp Creek at Camp Creek Diversion Tunnel	Stream inflow	31
I_CMPFW	Camp Far West Reservoir	Local reservoir inflow	15
I_COL003	Cole Creek near Salt Springs	Stream inflow	46
I_COW014	Cow Creek near Millville	Stream inflow	413
I_CSM035	Cosumnes River at Michigan Bar	Stream accretion	302
I_CWD018	North Fork and Middle Fork Cottonwood Creek near Olinda	Stream inflow	292
I_CYN009	Canyon Creek at Towle Canal Diversion Dam	Stream inflow	2
I_DAVIS	Lake Davis	Reservoir inflow	30
I_DCC010	Duncan Canyon Creek at Diversion Dam	Stream inflow	27
I_DEE023	Deer Creek	Stream inflow	33
I_DER001	Deer Creek near Smartville	Stream accretion	30
I_DER004	Deer Creek at Wildwood Dam	Stream accretion	34
I_DHC021	Dry Creek and Hutchinson Creek	Stream inflow	53
I_DRC012	Deer Creek near Vina	Stream inflow	228
I_DSC035	Dry and Sutter Creeks	Stream inflow	63
I_EBF001	East Branch of North Fork Feather River near Rich Bar	Stream accretion	609
I_ELD027	Elder Creek near Paskenta	Stream inflow	67
I_ELIMP	Echo Lake Conduit	Inter-basin import	2
I_ENGLB	Englebright Reservoir	Stream inflow	122
I_EPARK	East Park Reservoir inflow	Reservoir inflow	65
I_FOLSM	Folsom Lake	Local reservoir inflow	160
I_FRDYC	Fordyce Lake	Reservoir inflow	91
I_FRMAN	Lake Frenchman	Reservoir inflow	23
I_FRMDW	French Meadows Reservoir	Reservoir inflow	113
I_FRNCH	French Lake	Reservoir inflow	16
I_GERLE	Gerle Reservoir	Local reservoir inflow	47

Inflow Arc	Description	Type[1]	Average Annual Flow (TAF)[2]
I_GZL009	Grizzly Creek at Diversion Dam	Stream inflow	51
I_HHOLE	Hell Hole Reservoir	Local reservoir inflow	206
I_HON021	South Fork Honcut Creek near Bangor	Stream inflow	24
I_ICEHS	Ice House Reservoir	Reservoir inflow	56
I_INDVL	Indian Valley Reservoir	Reservoir inflow	107
I_JKSMD	Jackson Meadows Reservoir	Reservoir inflow	75
I_JNKSN	Jenkinson Lake	Reservoir inflow	17
I_LCBRF	Lindsey, Culberstson, Blue, Rucker, and Feeley Lakes	Reservoir inflow	60
I_LCC038	Little Chico Creek near Chico	Stream inflow	22
I_LDC029	Little Dry Creek	Stream inflow	26
I_LGRSV	Little Grass Valley Reservoir	Reservoir inflow	78
I_LJC022	Littlejohn and Rock Creek at Farmington Reservoir	Reservoir Inflow	48
I_LKVLY	Lake Valley Reservoir	Reservoir inflow	6
I_LNG012	Long Creek Canyon near French Meadows	Stream inflow	14
I_LOONL	Loon Lake	Reservoir inflow	24
I_LOSVQ	Los Vaqueros Reservoir	Reservoir inflow	1
I_LRB004	Little Rubicon River Inflow to Bucks Island Lake	Reservoir inflow	19
I_LWSTN	Lewiston Lake	Local reservoir inflow	39
I_MERLC	Merle Collins Reservoir	Reservoir inflow	48
I_MFA001	Middle Fork American River near Auburn	Stream accretion	47
I_MFA023	Middle Fork American River near Foresthill	Stream accretion	7
I_MFA025	Middle Fork American River at Ralston Afterbay	Stream accretion	43
I_MFA036	Middle Fork American River at Interbay Diversion Dam	Stream accretion	50
I_MFF019	Middle Fork Feather River near Merrimac	Stream accretion	751
I_MFF087	Middle Fork Feather River near Portola	Stream accretion	132
I_MFM008	Middle Fork Mokelumne near West Point	Stream inflow	46
I_MFY013	Middle Fork Yuba River above Our House Diversion Dam	Stream accretion	210
I_MLC006	Mill Creek near Los Molinos	Stream inflow	215
I_MNS000	Minor northeast streams	Stream inflow	234
I_MOK079	Mokelumne River at Mokelumne Hill	Stream accretion	99
I_MSH015	Marsh Creek near Byron	Stream inflow	14
I_MTMDW	Mountain Meadows	Reservoir inflow	241
I_NBLDB	New Bullards Bar Reservoir	Local reservoir inflow	383
I_NFA016	North Fork American River at Auburn Dam site	Stream accretion	15
I_NFA022	North Fork American River at North Fork Dam	Stream accretion	213
I_NFA054	North Fork American River	Stream inflow	347
I_NFF029	North Fork Feather River at Pulga	Stream accretion	658
I_NFM010	North Fork Mokelumne below Tiger Creek Reservoir	Stream accretion	115
I_NFY029	North Fork Yuba River below Goodyears Bar	Stream inflow	532
I_NHGAN	New Hogan Reservoir	Reservoir inflow	154
I_NLC003	North Fork Long Canyon Creek at Diversion Dam	Stream inflow	5
I_NMA003	North Fork of Middle Fork American River	Stream Inflow	175
I_NNA013	North Branch North Fork American River at Diversion Dam	Stream accretion	7
I_OGN005	Oregon Creek at Log Cabin Diversion Dam	Stream inflow	52
I_OROVL	Lake Oroville	Local reservoir inflow	520
I_PARDE	Pardee Reservoir	Local reservoir inflow	11
I_PLC007	Pilot Creek at Georgetown Divide Diversion Dam	Stream accretion	9
I_PLM001	Plum Creek Inflow	Stream inflow	7
I_PYN001	Paynes Creek and Sevenmile Creek	Stream inflow	52
I_PYR001	Pyramid Creek at Twin Bridges	Stream accretion	26
I_RCK001	Rock Creek near Placerville	Stream inflow	48
I_RLLNS	Rollins Reservoir natural inflow	Local reservoir inflow	158
I_RUB002	Rubicon River near Foresthill	Stream accretion	128
I_RUB047	Rubicon Lake	Stream inflow	74

Inflow Arc	Description	Type[1]	Average Annual Flow (TAF)[2]
I_RVPHB	Round Valley and Philbrook Lakes	Reservoir inflow	20
I_SCOTF	Scotts Flat Reservoir	Local reservoir inflow	34
I_SCW008	South Fork Cottonwood Creek near Olinda	Stream inflow	175
I_SFA030	South Fork American River near Placerville	Stream accretion	64
I_SFA040	South Fork American River near Camino	Stream accretion	92
I_SFA066	South Fork American River at Kyburz	Stream accretion	95
I_SFA076	South Fork American River at Proposed Diversion Dam	Stream accretion	55
I_SFD003	South Fork Deer Creek at Wildwood Dam	Stream inflow	8
I_SFF008	South Fork Feather at Enterprise	Stream accretion	21
I_SFF011	South Fork Feather River at Ponderosa Dam	Stream accretion	91
I_SFM005	South Fork Mokelumne near West Point	Stream inflow	55
I_SFR006	South Fork Rubicon River Inflow	Stream inflow	32
I_SFY007	South Fork Yuba River at Jones Bar	Stream accretion	172
I_SFY048	South Yuba near Cisco	Stream inflow	142
I_SGRGE	Stony Gorge Reservoir	Local reservoir inflow	162
I_SHSTA	Shasta Lake	Reservoir inflow	5,589
I_SILVR	Silver Lake	Reservoir inflow	29
I_SLC003	South Fork Long Canyon Creek	Stream inflow	9
I_SLF009	Silver Fork American River at proposed diversion dam	Stream accretion	63
I_SLT009	Slate Creek at Slate Creek Diversion Dam	Stream inflow	138
I_SLTSP	Salt Springs Reservoir	Reservoir Inflow	327
I_SLV006	Silver Creek at Junction Diversion Dam[3]	Stream accretion	27
I_SLV015	Silver Creek at Camino Diversion Dam	Stream accretion	45
I_SLYCK	Sly Creek Reservoir	Reservoir inflow	73
I_SPLDG	Lake Spaulding	Local reservoir inflow	111
I_STMPY	Stumpy Meadows	Reservoir Inflow	22
I_TGC003	Tiger Creek at Regulator Dam	Stream inflow	9
I_THM028	Thomes Creek at Paskenta	Stream inflow	213
I_TRNTY	Trinity Lake	Reservoir inflow	1,236
I_UBEAR	Upper Bear Reservoir	Reservoir inflow	72
I_UNVLY	Union Valley Reservoir	Reservoir inflow	158
I_WBF006	West Branch Feather River near Yankee Hill	Stream accretion	68
I_WBF015	West Branch Feather River at Miocene Diversion Dam	Stream accretion	146
I_WBF030	West Branch Feather River at Hendricks Diversion Dam	Stream accretion	95
I_WBR001	Weber Creek near Salmon Falls	Stream inflow	57
I_WKYTN	Whiskeytown Lake	Reservoir inflow	279
I_WLF013	Wolf Creek at Tarr Ditch Diversion Dam	Stream inflow	19

Notes:
[1] 'Reservoir inflow' is the total natural inflow to a reservoir or lake.
'Local reservoir inflow' is the natural inflow to a reservoir or lake from a portion of the watershed adjacent to the water body.
'Stream inflow' is the total natural flow/unimpaired flow at the stream location.
'Stream accretion' is the accretion to a stream or river between the upstream inflow location and this location.
[2] Flows averaged over water years 1992-2015.

Key:
TAF=thousand acre-feet

Only in limited cases are streamflow records available for the entire period of simulation. For most streams, historical time series data have been extended using various statistical methods assuming stationarity over the historical period. Methods used to develop each inflow are summarized in Table 6-2. Data Sources and Calculation Methods for Upper Watershed Inflows. These methods are as follows:

- **Direct gauge measurement**: Stream gauge data exist at the watershed outflow point for water years 1922 through 2015.

- **Streamflow correlation**: Stream gauge data exist at the watershed outflow point for only a limited period. Gauge data are extended through linear correlation of annual flows with streamflow records from an adjacent watershed. Double mass plots of monthly flows are used to check that a constant (and linear) relationship exists between the dependent and independent variables. Annual synthetic flows are disaggregated to a monthly time step based on the cumulative fraction of annual runoff that has occurred by the end of month for the independent variable, while attempting to preserve the shape of the hydrograph of the dependent watershed.
- **Proportionality**: No gauge data exist for the watershed. It is assumed that runoff is proportional to the product of drainage area and average annual precipitation depth over the watershed.[24] Outflow is determined through association of the watershed with a similar, but gauged watershed at similar elevation and the use of multiplicative factors representing the ratio of watershed areas and ratio of precipitation depths.
- **Mass balance**: Typically, this method is used when watersheds have significant storage regulation. Reservoir operating records of dam releases and reservoir storage, together with estimated reservoir evaporation, are used to estimate inflows to the reservoir.

[24] Determined using PRISM data of the 30-year average annual precipitation for 1971-2000 (PRISM, 2013).

Table 6-2. Data Sources and Calculation Methods for Upper Watershed Inflows

SacWAM Inflow	Observed Period	Agency	Gauge ID	Flow Correlation	Propor-tionality	Mass Balance
I_ALD002	10/22 - 09/81	USGS	11440000	•		
I_ALD004						
I_ALMNR	10/21 - present	USGS	11399500			•
I_ALOHA						
I_AMADR	–	–	–		•	
I_ANT011	10/40 - 09/82	USGS	11379000	•		
I_ANTLP	10/30 - 09/93	USGS	11401500	•		•
I_BCC014	10/21 - 09/86	USGS	11384000	•		•
I_BCN010	10/59 - 09/67	USGS	11374100	•		
I_BLKBT	01/53 - present	USACE	Res. Report of Operations	•		•
I_BOWMN	02/27 - present	USGS	11416500	•		•
I_BRC003	10/98 - present	USGS	11451715	•	•	
I_BRR023	10/21 - 10/27 11/27 - present	USGS USGS	11423500 11424000	•	•	•
I_BRYSA	01/57 - present	Reclamation	Res. Report of Operations	•		•
I_BSH003						
I_BTC048	10/30 - present	USGS	11390000			•
I_BTL006	10/40 - 09/61	USGS	11376500	•		
	10/61 - present	USGS	11376550			
I_BTVLY	10/36 - present	USGS	11400500	•	•	•
I_BUCKS	10/80 - present1	USGS	11403530	•		•
I_CAPLS	10/22 - 09/92	USGS	11437000	•		•
	10/92 - present	USGS	11436999			
I_CCH053	10/60 - 09/831 10/92 - present	USGS CDEC	11451760 RUM	•	•	•
I_CLR011	10/40 - present	USGS	11372000	•		•
I_CLRLK	10/44 - present	USGS	11451000			•
I_CLV026	–	–	–		•	
I_CMBIE	10/21-10/27 11/27-present	USGS USGS	11423500 11424000	•	•	•
I_CMCHE	–	–	–		•	
I_CMP001	10/56 - 09/04	USGS	11333000	•		
I_CMP014	10/49 - 09/54	USGS	11331500	•	•	
I_CMPFW	10/21 - 10/27 11/27 - present	USGS USGS	11423500 11424000	•	•	•
I_COL003						
I_COW014	10/49 - present	USGS	11374000	•	•	
I_CSM035	10/21 - present	USGS	11335000			•
I_CWD018	09/71 - 09/86	USGS	11375810	•		
I_CYN009						
I_DAVIS	10/25 - 09/801 12/67 - present	USGS, DWR	11391500 Res. Report of Operations	•	•	•
I_DCC010	09/60 - present 10/64 - present	USGS USGS	11427700 11427750	•		•
I_DEE023	10/60 - 09/77	USGS	11335700	•	•	

SacWAM Inflow	Observed Period	Agency	Gauge ID	Flow Correlation	Propor-tionality	Mass Balance
I_DER001	10/35 - present	USGS	1418500			
I_DER004	–	–	–		●	
I_DHC021	–	–	–		●	
I_DRC012	10/21 - present	USGS	11383500	Data for all years		
I_DSC035	10/61 - 09/70 10/35 - 09/41	USGS USGS	11326300 11327000	●	●	
I_ELD027	10/48 - present	USGS	11379500	●		
I_ELIMP	08/23 - present	USGS	11434500	●		
I_EBF011	10/50 - 09/60	USGS	11403000	●		●
I_ENGLB	10/21 - 09/41 10/41 - present	USGS USGS	11418000 11419000	●		●
I_EPARK	10/21 - present	Reclamation	Res. Report of Operations			●
I_FOLSM	10/21 - present 02/55 - present	USGS Reclamation	USGS Res. Report of Operations			●
I_FRDYC	07/66 - present	USGS	11414100	●		●
I_FRMAN	10/65 - present	DWR	Res. Report of Operations	●		●
I_FRMDW	10/64 - present	USGS	11427500	●		●
I_FRNCH						
I_GERLE						
I_GZL009	10/85 - present	USGS	11404300	●		●
I_HHOLE	10/85 - present	USGS	11428800	●		●
I_HON021	10/50 - 09/86	USGS	11407500	●		
I_ICEHS	10/23 - present	USGS	11441500	●		●
I_INDVL	10/74 - present	USGS	11451300	●		●
I_JKSMD	10/26 - present	USGS	11407900	●		●
I_JNKSN	10/46 - 09/54	USGS	11332500	●		
I_LCBRF						
I_LCC038	02/59 – present	DWR	A04910	●		●
I_LDC029	–	–	–		●	
I_LGRSV	10/63 - present	USGS	11395030	●		●
I_LJC022	10/51 - 09/95	USACE	multiple data sources	●		●
I_LKVLY	–	–	–		●	
I_LNG012	10/66 - 09/92	USGS	11433100	●		●
I_LOONL	10/62 - present	USGS	11429500	●		●
I_LOSVQ	10/97 - present	CCWD		●		
I_LRB004	11/90 – present1	USGS	11428400	●		●
I_LWSTN	10/21 - present	USGS	11525500	●		●
I_MERLC	10/63 - present	BVID	Res. Report of Operations	●		●
I_MFA001	10/21 - 09/85	USGS	11433500	●		●
I_MFA023						
I_MFA025						
I_MFA036	10/65 - present	USGS	11427770	●		●
I_MFF019	10/51 - 09/86	USGS	11394500	●		
I_MFF087	10/68 - 09/80	USGS	11329100	●		●

SacWAM Inflow	Observed Period	Agency	Gauge ID	Flow Correlation	Propor-tionality	Mass Balance
I_MFM008	10/21 - present	USGS	11317000			
I_MFY013	10/68 - present	USGS	11408870			●
I_MLC006	10/28 - present	USGS	11381500	●		
I_MNS000	–	–	–		●	
I_MOK079	10/27 - present	USGS	11319500			●
I_MSH015	04/53 - 09/83	USGS	11337500			
I_MTMDW	10/21 - present	USGS	11399500		●	●
I_NBLDB	10/66 - 09/40	USGS	11413520	●		●
I_NFA016						
I_NFA022	10/21 - 09/41 10/41 - present	USGS USGS	11426500 11427000		●	●
I_NFA054	10/21 - 09/41 10/41 - present	USGS USGS	11426500 11427000		●	●
I_NFF029	10/21 - present	USGS	11404500	●		●
I_NFM010	09/84-present	USGS	11316700	●		●
I_NFY029	10/30 - present	USGS	11413000	●	●	
I_NHGAN	10/21 - 09/66 10/63 - present	USGS USACE	11309500 Res. Report of Operations	●	●	●
I_NLC003						
I_NMA003	08/65 - 09/84	USGS	11433260	●		
I_NNA013						
I_OGN005	10/21 - 09/69, 09/68 - present	USGS USGS	11409500	●	●	●
I_OROVL	10/21 - present 10/67 - present	USGS, DWR	11407000 Res. Report of Operations			●
I_PARDE	–	–	–	●	●	●
I_PLC007						
I_PLM001	10/22 - 09/39	USGS	11440500	●		
I_PYN001	10/49 - 09/66	USGS	11377500	●	●	
I_PYR001						
I_RCK001						
I_RLLNS	04/50 - present	USGS	11422500	●	●	●
I_RUB002	12/65 - present	USGS	11433200	●		●
I_RUB047	10/91 - present	USGS	11427960	●		●
I_RVPHB	–	–	–	●	●	●
I_SCOTF	–	–	–		●	●
I_SCW008	12/76 - 09/86	USGS	11375870	●		
I_SFA030	10/64 - present	USGS	11444500	●		●
I_SFA040	10/22 - present	USGS	11443500	●		●
I_SFA066	10/22 - present	USGS	11439500	●		●
I_SFA076						
I_SFD003	–	–	–		●	
I_SFF008	10/21 - 09/66	USGS	11397000	●		●
I_SFF011	10/21 - 09/66	USGS	11397000	●		●
I_SFM005	10/21 - present	USGS	11317000	●		
I_SFR006	10/62 - present	USGS	11430000	●		●
I_SFY007	10/40 - present	USGS	11417500	●		

SacWAM Inflow	Observed Period	Agency	Gauge ID	Flow Correlation	Propor-tionality	Mass Balance
I_SFY048						
I_SGRGE	11/28 - present	Reclamation	Res. Report of Operations			●
I_SHSTA	10/25 - 09/42 01/44 - present	USGS Reclamation	11369500 Res. Report of Operations		●	●
I_SILVR	10/22 - present	USGS	11436000	●		●
I_SLC003						
I_SLF009						
I_SLT009	10/60 - present	USGS	11413300	●		●
I_SLTSP	10/27 - present	USGS	11314500	●		●
I_SLV006						
I_SLV015	10/87 - present	USGS	11441800	●		●
I_SLYCK	10/73 - present	USGS	11396000	●		●
I_SPLDG	12/65 - present	USGS	11414250	●		●
I_STMPY	04/46 - 09/60	USGS	11432500	●		
I_TGR003						
I_THM028	10/21 - 09/96	USGS	11382000	●		
I_TRNTY	10/21 - present 10/61 - present	USGS Reclamation	11525500 Res. Report of Operations	●		●
I_UNVLY	10/61 - present	USGS	11441002			
I_UBEAR	–	–	–		●	
I_WBF006	10/30 - 09/63	USGS	11406500	●	●	●
I_WBF015	10/30 - 09/63	USGS	11406500	●	●	●
I_WBF030	10/30 - 09/63	USGS	11406500	●	●	●
I_WBR001						
I_WKYTN	10/64 - present	Reclamation	Res. Report of Operations	●	●	
I_WLF013	–	–	–	●	●	●

Key:
CDEC=California Data Exchange Center, DWR=California Department of Water Resources, Reclamation=US Department of Interior, Bureau of Reclamation, Res=Reservoir, USGS=United States Geological Survey.

6.1.2 Reservoirs

The following sections apply to most reservoirs in SacWAM. However, the smaller reservoirs are not operated in the model and therefore have blank expressions for many of the parameters. These reservoirs include Gerle Creek Reservoir, Lake Amador, Buck Island Reservoir, Farmington Reservoir, Poe Reservoir, Cresta Reservoir, Rock Creek Reservoir, Belden Reservoir, Clifton Court Forebay, Rubicon Reservoir, Camino Reservoir, Junction Reservoir, Chili Bar Reservoir, and Slab Creek Reservoir. The purpose of these reservoirs in SacWAM is solely to orient model users in the schematic view. Reservoir operations are discussed in greater detail in Section 6.1.2.3.

In SacWAM, two reservoir objects are used to represent San Luis Reservoir, *CVP_San Luis* and *SWP_San Luis*, in order to represent and simulate the CVP and SWP share of this joint use facility. Operational logic for San Luis Reservoir is discussed in detail in Section 7.4.

6.1.2.1 Reservoir Evaporation

For SacWAM, a user-defined set of parameters was added to the model to calculate the reservoir evaporation. These parameters are in the Reservoir Evaporation tab of the Reservoirs interface. The calculation of reservoir evaporation is made using the Modified Hargreaves Equation (Droogers and Allen, 2002):

$$0.0013*D*S_o*(T_{ave}[C]+17.0)*(T_{max}[C]-T_{min}[C]-0.0123*P\ [mm])^{0.76} \qquad \text{Equation 6-1}$$

where:

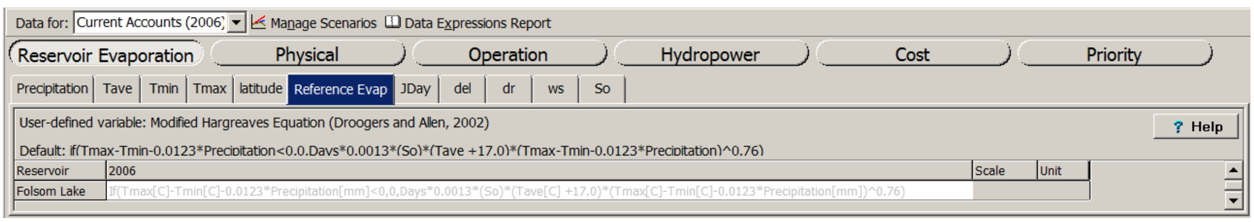
D = days in the time step

S_o = extra-terrestrial solar radiation

T_{ave} = average temperature for the time step

T_{max} = maximum temperature for the time step, 1.4 x T_{ave}

T_{min} = minimum temperature for the time step, 0.6 x T_{ave}



6.1.2.1.1 Precipitation, Tave, Tmin, and Tmax

Values of monthly precipitation and average monthly temperature for the reservoirs are stored in the csv files 'SACVAL_ReservoirPrecipitationData' and 'SACVAL_ReservoirTemperatureData' in the data\reservoir\ directory. These values were obtained from gridded PRISM climate data and correspond approximately to the dam centerline.

6.1.2.1.2 Latitude

Latitudes for each reservoir were determined using GIS.

6.1.2.1.3 Reference Evap

The reference evaporation is calculated using Equation 3-2.

6.1.2.1.4 JDay

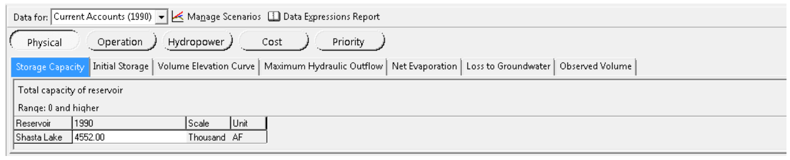
The Julian Day for the mid point of the month. This value is used in calculating the solar declination (del) and the relative distance between the Earth and Sun (dr).

6.1.2.1.5 del, dr, ws, and So

Solar declination (*del*), the relative distance between Earth and the Sun (*dr*), the sunset hour angle (*ws*), and solar radiation (S_o) affect reference evaporation; these parameters use default WEAP expressions.

6.1.2.2 Physical

6.1.2.2.1 Storage Capacity



Storage Capacity data for reservoirs were obtained from multiple sources, including the SWP Handbook (DWR, 1992), FERC relicensing application documents, and CDEC (DWR, 2014d). These values are entered in SacWAM (*Supply and Resources**Rivers**Reservoirs**Physical**Storage Capacity*). Table 6-3 lists all simulated storage capacities of SacWAM reservoirs. For more information, see **reservoir storage capacity.**

Table 6-3. Reservoirs Represented in SacWAM

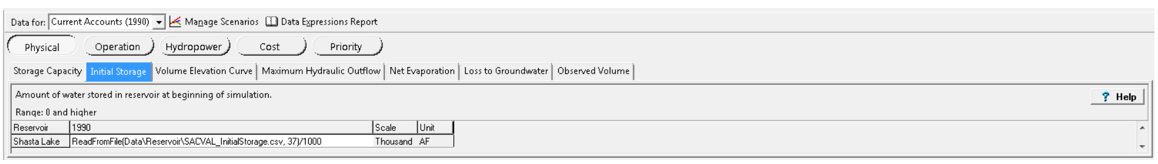
Reservoir	SacWAM River	Owner/Operator	Simulated Capacity (TAF)[1]
Antelope Reservoir	Indian Creek	DWR	22.6
Belden Reservoir	North Fork Feather River	PG&E	2.4
Black Butte Reservoir	Stony Creek	Reclamation/CVP	143.7
Bowman Lake	Canyon Creek	Nevada Irrigation District	68.5
Buck Island	Little Rubicon River	Sacramento Municipal Utility District	1.1
Bucks Lake	Bucks Creek	PG&E	103.0
Butt Valley Reservoir	Butt Creek	PG&E	49.9
Camanche Reservoir	Mokelumne River	EBMUD	417.1
Camino Reservoir	Silver Creek	Sacramento Municipal Utility District	0.8
Camp Far West	Bear River	South Sutter WD	104.5
Caples Lake	Caples Creek	PG&E	22.3
Chili Bar Reservoir	South Fork American River	PG&E	3.0
Clear Lake	Cache Creek	Yolo County FC&WCD	1,155.0
Clifton Court Forebay	Old and Middle River	DWR/SWP	31.26
Cresta Reservoir	North Fork Feather River	PG&E	4.1
CVP San Luis Reservoir	Offstream	Reclamation/CVP	973.0
East Park Reservoir	Little Stony Creek	Reclamation/Orland WUA	50.9
EBMUD Terminal Reservoirs	Mokelumne Aqueduct	EBMUD	155.2
Englebright Reservoir	Yuba River	USACE	70.0
Farmington Reservoir	Littlejohns Creek	USACE	52.0
Folsom Lake	American River	Reclamation/CVP	977.0
French Meadows Reservoir	Middle Fork American River	Placer County Water Agency	135.0
Frenchman Lake	Little Last Chance Creek	DWR/SWP	55.4
Gerle Creek Reservoir	Gerle Creek	Sacramento Municipal Utility District	1.3
Grizzly Reservoir	Grizzly Creek	Sacramento Municipal Utility District	1.1
Hell Hole Reservoir	Rubicon River	Sacramento Municipal Utility District	207.6
Ice House Reservoir	South Fork Silver Creek	Sacramento Municipal Utility District	43.5
Indian Valley Reservoir	North Fork Cache Creek	Yolo County FC&WCD	301.0
Jackson Meadows Reservoir	Middle Yuba River	Nevada Irrigation District	69.2
Jenkinson Lake	Sly Park Creek	El Dorado Irrigation District	41.0
Junction Reservoir	Silver Creek	Sacramento Municipal Utility District	3.3
Keswick Reservoir	Sacramento River	Reclamation/CVP	23.8
Lake Almanor	North Fork Feather River	PG&E	1,143.0
Lake Amador	Jackson Creek	Jackson Valley Irrigation District	22.0
Lake Berryessa	Putah Creek	Reclamation/Solano Project	1,602.0
Lake Combie	Bear River	Nevada Irrigation District	5.6
Lake Davis	Middle Fork Feather River	DWR/SWP	84.4
Lake Fordyce	Fordyce Creek	PG&E	49.4
Lake Natoma	American River	Reclamation/CVP	8.8
Lake Spaulding	South Fork Yuba River	PG&E	75.9
Lake Valley	North Fork of North Fork American River	PG&E	10.3
Lewiston Lake	Trinity River	Reclamation/CVP	14.7
Little Grass Valley Reservoir	South Fork Feather River	South Feather Water & Power Agency	93.0
Loon Lake	Gerle Creek	Sacramento Municipal Utility District	69.3
Los Vaqueros Reservoir	Kellogg Creek	Contra Costa Water District	160.0
Lower Bear Reservoir	Bear River (Mokelumne Watershed)	PG&E	52.0
Lower Bucks Lake	Bucks Creek	PG&E	5.8
Merle Collins Reservoir	French Dry Creek	Browns Valley Irrigation District	57.0
Mountain Meadows Reservoir	Hamilton Branch	PG&E	23.9
New Bullards Bar Reservoir	Yuba River	Yuba County Water Agency	969.6
New Hogan Reservoir	Calaveras River	Reclamation/Stockton East WD	317.0
Lake Oroville	Feather River	DWR/SWP	3,538.1
Pardee Reservoir	Mokelumne River	EBMUD	210.0
Philbrook Round Valley	West Branch Feather River	PG&E	6.2
Poe Reservoir	North Fork Feather River	PG&E	0.0
Rock Creek Reservoir	North Fork Feather River	PG&E	4.4
Rollins Reservoir	Bear River	Nevada Irrigation District	66.0
Rubicon Lake	Rubicon River	Sacramento Municipal Utility District	1.5
Salt Springs Reservoir	North Fork Mokelumne River	PG&E	141.9
Schaads Reservoir	Middle Fork Mokelumne	Calaveras Public Utility District	0

Reservoir	SacWAM River	Owner/Operator	Simulated Capacity (TAF)[1]
Scotts Flat Reservoir	Deer Creek (Yuba River tributary)	Nevada Irrigation District	48.5
Shasta Lake	Sacramento River	Reclamation/CVP	4,552.2
Silver Lake	Silver Fork American	PG&E	8.6
Slab Creek Reservoir	South Fork American River	Sacramento Municipal Utility District	16.6
Sly Creek Reservoir	Lost Creek	South Feather Water and Power Agency	65.1
Stony Gorge Reservoir	Stony Creek	Reclamation/Orland WUA	50.4
Stumpy Meadows Reservoir	Pilot Creek	Georgetown Divide PUD	20.0
SWP San Luis Reservoir	Offstream	DWR/SWP	1,067.0
Thermalito Afterbay	Power Canal	DWR/SWP	57.0
Trinity Lake	Trinity River	Reclamation/CVP	2,447.7
Union Valley Reservoir	Silver Creek	Sacramento Municipal Utility District	266.3
Upper Bear Rerservoir	Bear Creek (Mokelumne River tributary)	PG&E	7.3
Whiskeytown Reservoir	Clear Creek	Reclamation/CVP	241.1

Note:
[1] Values are rounded to one decimal place.

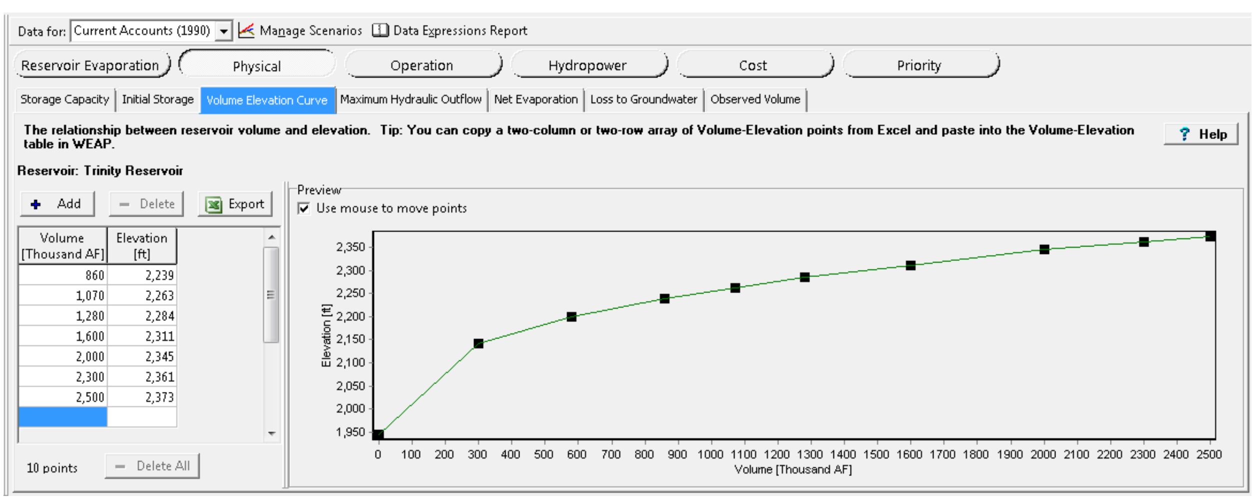
Key:
CVP=Central Valley Project, DWR=Department of Water Resources, EBMUD=East Municipal Utility District, FC&WCD=Flood Control and Water Conservation District, PG&E=Pacific Gas and Electric, PUD=Public Utility District, SWP=State Water Project, TAF=thousand acre-feet USACE=U.S. Army Corps of Engineers, WD=Water District, WUA=Water Users' Association.

6.1.2.2.2 Initial Storage



Initial Storage data for reservoirs were obtained from USGS and/or CDEC (DWR, 2014d) and represent historical September 30th storage volumes. These values are given in TAF (*Supply and Resources\Rivers\Reservoirs\Physical \Initial Storage*). For more information, see **reservoir storage capacity**.

6.1.2.2.3 Volume Elevation Curve



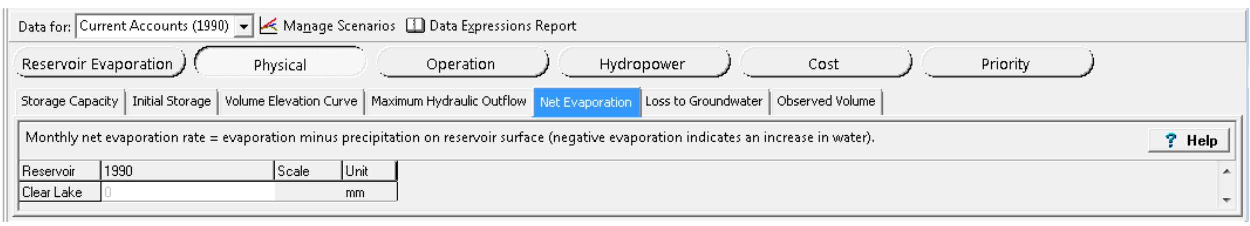
Volume Elevation Curve data for reservoirs were obtained from a variety of sources. They relate reservoir volume in TAF to reservoir water surface elevation in feet (*Supply and*

Resources\Rivers\Reservoirs\Physical\Volume Elevation Curve). This information is used to simulate reservoir evaporation. Table 6-4 lists reservoirs where volume-elevation data were used. Evaporation is not simulated for the smaller reservoirs with constant storage in the model. For further information on the volume-elevation dataset, see **volume elevation curve**.

Table 6-4. Reservoirs with Simulated Evaporation using Volume Elevation Curves

Lake/Reservoir Name	Lake/Reservoir Name	Lake/Reservoir Name
Black Butte Reservoir	Indian Valley Reservoir	Los Vaqueros Reservoir
Bowman Lake	Jackson Meadows Reservoir	Merle Collins Reservoir
Bucks Lake	Jenkinson Lake	New Bullards Bar Reservoir
Butt Valley	Keswick Reservoir	New Hogan Reservoir
Camanche Reservoir	Lake Almanor	Lake Oroville
Camp Far West	Lake Amador	Pardee Reservoir
Clear Lake	Lake Berryessa	Rollins Reservoir
CVP San Luis Reservoir	Lake Combie	Scotts Flat Reservoir
East Park Reservoir	Lake Davis	Shasta Lake
Englebright Reservoir	Lake Fordyce	Sly Creek Reservoir
Folsom Lake	Lake Natoma	Stony Gorge Reservoir
French Meadows	Lake Spaulding	Thermalito Afterbay
Frenchman Lake	Lewiston Lake	Trinity Lake
Hell Hole	Little Grass Valley Reservoir	Union Valley Reservoir
Ice House	Loon Lake	Whiskeytown Reservoir

6.1.2.2.4 Net Evaporation

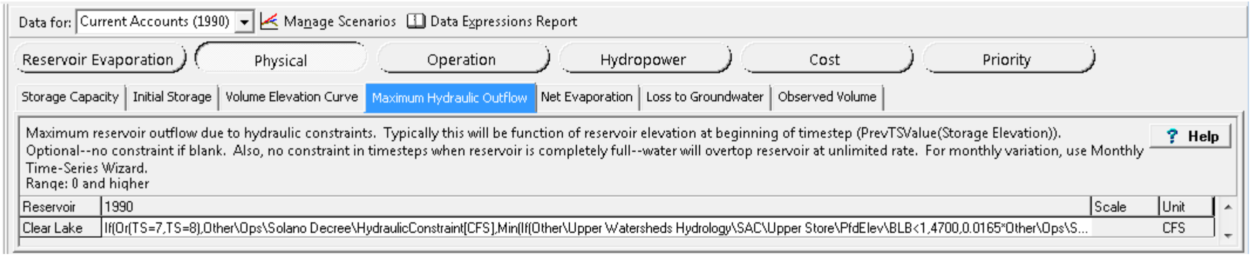


Net evaporation refers to the evaporation from the water surface of a reservoir less the precipitation falling on the surface. In WEAP, this parameter is often treated as the net of evaporation and precipitation. However, in SacWAM, the catchment objects contain the area of the reservoirs and therefore account for the precipitation that falls on the reservoir. For this reason, the *Net Evaporation* parameter only contains the estimated evaporation calculated in the *Reference Evaporation* parameter under the Reservoir Evaporation tab.[25]

Calculations of net evaporation for San Luis Reservoir are contained under the *Other\Ops\CVPSWP\San Luis\Evaporation* branch. Total evaporation for San Luis Reservoir is calculated as a volume and subsequently disaggregated between the CVP (*Evap_CVP*) and SWP (*Evap_SWP*) based on beginning-of-month storage in the two accounts. These volumetric evaporative losses are converted to depths using the San Luis Reservoir volume-elevation curve and passed back to the Net Evaporation property of the CVP and SWP San Luis Reservoir objects.

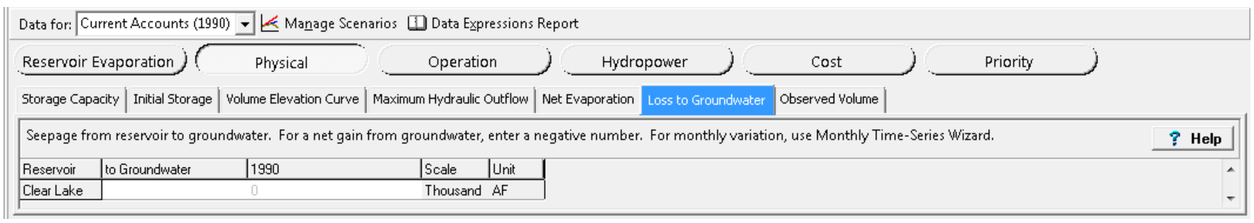
[25] This is consistent with how inflows to reservoirs are calculated by DWR and Reclamation. Precipitation on the reservoir surface is included in the natural inflow to the reservoir.

6.1.2.2.5 Maximum Hydraulic Outflow



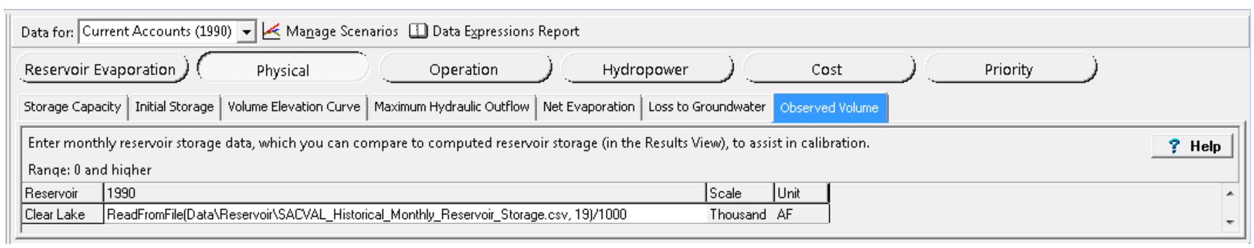
The *Maximum Hydraulic Outflow* parameter restricts the outflow of water from a reservoir. In SacWAM this has been implemented on Clear Lake as part of the Solano Decree logic, and on Los Vaqueros Reservoir to restrict releases to Kellogg Creek.

6.1.2.2.6 Loss to Groundwater



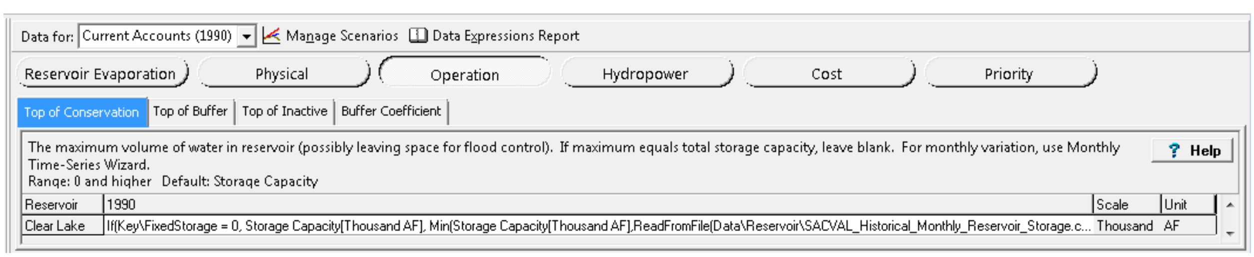
No reservoir losses to groundwater are simulated in SacWAM.

6.1.2.2.7 Observed Volume



Historical *Observed Volumes* for reservoirs are read from the file Data/Reservoir/SACVAL_HistoricalMonthlyReservoirStorage.csv stored in the WEAP model directory. These data were taken from USGS and/or CDEC and can be found in **reservoir storage capacity**.

6.1.2.3 Operation



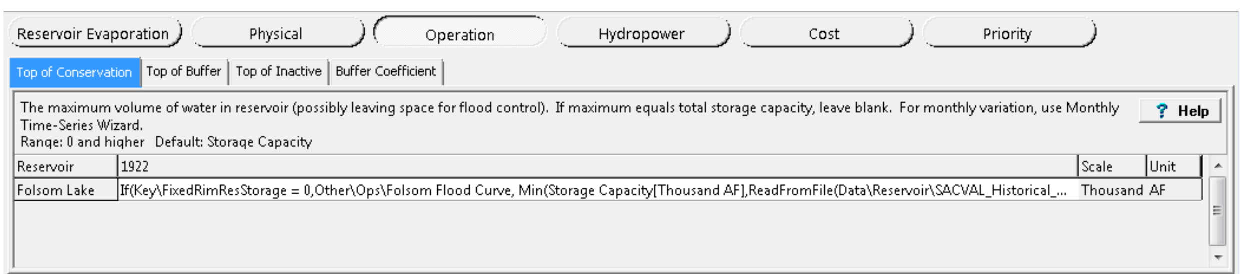
As previously described in Section 2.4, reservoir storage is divided into four zones: flood control, conservation, buffer, and inactive. These zones and associated priorities on conservation storage and buffer storage dictate reservoir operations. The zones are defined by the four parameters: *Total*

Storage, *Top of Conservation*, *Top of Buffer*, and *Top of Inactive*. WEAP always leaves the flood control zone empty, therefore, reservoir storage can never exceed *Top of Conservation*. WEAP will release water from a reservoir's conservation zone to meet downstream demands for water supply, instream flow requirements, and hydropower generation. Once a reservoir's storage drops into the buffer pool, releases are restricted by the buffer coefficient, since the reservoir has less water available for allocation.[26] In WEAP, water in the inactive zone cannot be released and is only drained through evaporation. Reservoirs simulated in SacWAM can be grouped into three categories based on their operational logic, as summarized in Table 6-5. The three groups are 'Constant Storage', 'Average Monthly Historical Storage', and 'Fully Operational' reservoirs and are simulated as follows:

- **Constant Storage** reservoirs are those that are not operated in SacWAM. The *Top of Conservation* and *Top of Inactive* parameters are set equal to the same constant value.
- **Average Monthly Historical Storage** reservoirs are those that follow a pre-determined monthly pattern that is implemented by setting the *Top of Conservation* and *Top of Inactive* parameters equal to the same set of 12 monthly values. These values are based on historical storage data for water years 1970 to 2009.
- **Fully Operational** reservoirs are simulated in one of two ways. The first is a reservoir without a buffer zone, the second is a reservoir with a buffer zone. In SacWAM, the buffer zone is used to limit deliveries to downstream users or to differentiate between discretionary and non-discretionary releases. For multi-purposes reservoirs that are operated for hydropower purposes, hydropower generation is typically restricted to releases from conservation storage through the relative priorities on conservation storage, buffer storage, and IFR objects placed on powerhouse penstocks.

Parameters relating to reservoir operations can be turned off and on using the *Simulate Operations* Key Assumption.

6.1.2.3.1 *Top of Conservation*



The *Top of Conservation* parameter is used to place an upper limit on conservation storage in a reservoir. WEAP leaves the flood control zone (above the top of conservation) evacuated. The two zones from which water can be released to meet demands are the conservation zone and buffer zone. The State Water Board's eWRIMS database (2014) was used to identify diversion to storage water rights

[26] In SacWAM, the buffer coefficient is typically set to zero and reservoir-specific allocation logic used to control releases for water supply purposes.

including the purpose of diversion, annual diversion amount, period of diversion, and maximum diversion rate. Information on these water rights is displayed in Table 6-7. The *Top of Conservation* property is used to impose period-of-diversion constraints where the right to divert to storage is not year-round. For these reservoirs, outside of the period of diversion the *Top of Conservation* is set equal to the previous month's end-of-month storage.

Table 6-5. Reservoir Operational Logic

Owner/Operator (FERC Project No.)	Reservoir (River)	Operational Logic	Flood Control	Variable TOC	Buffer Storage	Instream Flow	Water Supply	Hydro-Power
BVID	Merle Collins (French Dry Creek)	TOB = average monthly historical		●	●	●	●	
CaPUD	Schaads (MF Mokelumne River)	Constant storage						
CCWD	Los Vaqueros (Kellogg Creek)	Pre-operated[8]					●	
DWR/SWP	Clifton Court Forebay (Offstream[4])	Constant storage						
DWR/SWP	SWP San Luis (Offstream[2])	Defined in Other Assumptions/UDCs			●		●	[14]
DWR/SWP	Antelope (Indian Creek)	TOB = average monthly historical		●	●	●		
DWR/SWP	Lake Davis (Big Grizzly Creek)	TOB = average monthly historical		●	●	●		
DWR/SWP (P-2100)	Oroville (Feather River)	Defined in Other Assumptions/UDCs	●	●	●	●	●	[14]
DWR/SWP (P-2100)	Thermalito Afterbay (Offstream)	Fluctuates with Oroville storage						[14]
DWR/SWP	Frenchman (Little Last Chance Creek)	TOB = average monthly historical		●	●	●		
EBMUD	Camanche (Mokelumne River)	Defined in Other Assumptions/UDCs	●	●		●	●	
EBMUD	Pardee (Mokelumne River)	Defined in Other Assumptions/UDCs	●	●		●	●	
EBMUD	EBMUD Terminal Res. (Various[6])	Average Monthly Values		●			●	
EID (P-184)	Aloha (Pyramid Creek)	Constant storage						
EID (P-184)	Caples (Caples Creek)	TOB = min FERC storage level		●	●	●	●	●
EID (P-184)	Silver (Silver Fork American)	TOB = min FERC storage level		●	●	●	●	●
EID	Jenkinson (Sly Park Creek)	No additional logic					●	
GDPUD	Stumpy Meadows (Pilot Creek)	No additional logic		●		●	●	
JVID	Amador (Jackson Creek)	No additional logic		●			●	●
NID	Scotts Flat (Deer Creek)	TOC = TOI = average monthly historical		●				
NID	Combie (Bear River)	TOC = TOI = average monthly historical		●				
NID (P-2266)	Bowman (Canyon Creek)	TOB = average monthly historical			●	●	●	●[12]
NID (P-2266)	French (Canyon Creek)	Constant storage						
NID (P-2266)	Jackson Meadows (Middle Yuba River)	TOB = average monthly historical			●	●	●	●[12]
NID (P-2266)	Rollins (Bear River)	TOC = TOI = average monthly historical		●	●	●	●	●
PG&E	Mountain Meadows (Hamilton Branch)	TOB = function of Oroville FNF and month	●		●			●
PG&E (P-137)	Lower Bear (Bear River)	Defined in Other Assumptions/UDCs	[9]	●	●	●	●	●
PG&E (P-137)	Salt Springs (NF Mokelumne River)	Defined in Other Assumptions/UDCs	[9]	●	●	●	●	●
PG&E (P-137)	Upper Bear (Bear River)	Defined in Other Assumptions/UDCs		●	●	●	●	●
PG&E (P-1962)	Cresta (North Fork Feather River)	Constant Storage						
PG&E (P-1962)	Rock Creek (North Fork Feather River)	Constant Storage						
PG&E (P-2105)	Belden (North Fork Feather River)	Constant Storage						
PG&E (P-2105)	Butt Valley (Butt Creek)	TOB = average monthly historical			●			●
PG&E (P-2105)	Almanor (North Fork Feather River)	TOB = function of Oroville FNF and month			●	●		●
PG&E (P-2107)	Poe (North Fork Feather River)	Constant Storage						
PG&E (P-2155)	Chili Bar (SF American River)	Constant Storage						
PG&E (P-2310)	Lake Valley (NF of NF American River)	TOC = TOI = average monthly historical		●				

Owner/Operator (FERC Project No.)	Reservoir (River)	Operational Logic	Flood Control	Variable TOC	Buffer Storage	Instream Flow	Water Supply	Hydro-Power
PG&E (P-2310)	Lake Fordyce (Fordyce Creek)	TOB = average monthly historical			●	●	●	●[12]
PG&E (P-2310)	Lake Spaulding (SF Yuba River)	TOB = average monthly historical			●	●	●	●[12]
PG&E (P-619)	Bucks (Bucks Creek)	TOB = average monthly historical			●	●		●
PG&E (P-619)	Grizzly (Grizzly Creek)	Constant Storage						
PG&E (P-619)	Lower Bucks (Bucks Creek)	Constant Storage						
PG&E (P-803)	Philbrook/Round Valley (WB Feather[5])	TOC = TOI = average monthly historical		●				
PCWA (P-2079)	French Meadows (MF American River)	TOB = function of Folsom FNF and month	[10]	●		●	●	●
PCWA (P-2079)	Hell Hole (Rubicon River)	TOB = function of Folsom FNF and month	[10]	●		●	●	●
Reclamation/CVP	Black Butte (Stony Creek)	No additional logic	●			●	●	
Reclamation/CVP	Trinity (Trinity River)	Defined in Other Assumptions/UDCs	●	●				●
Reclamation/CVP	Whiskeytown (Clear Creek)	Fluctuates with Shasta storage	●	●		●	●	●
Reclamation/CVP	CVP San Luis (Offstream[3])	Defined in Other Assumptions/UDCs			●			[14]
Reclamation/CVP	Folsom (American River)	Defined in Other Assumptions/UDCs	●	●	●			[14]
Reclamation/CVP	Keswick (Sacramento River)	Constant storage						[14]
Reclamation/CVP	Lake Natoma (American River)	Fluctuates with Folsom storage						[14]
Reclamation/CVP	Lewiston (Trinity River)	Constant storage						[14]
Reclamation/CVP	Shasta (Sacramento River)	Defined in Other Assumptions/UDCs	●	●				[14]
Reclamation/OP	East Park (Little Stony Creek)	No additional logic	●	●		●	●	
Reclamation/OP	Stony Gorge (Stony Creek)	No additional logic	●	●		●	●	
Reclamation/SP	Lake Berryessa (Putah Creek)	No additional logic		●		●	●	
SMUD (P-2101)	Ice House (SF Silver Creek)	TOB = function of Folsom FNF and month		●	●	●		●
SMUD (P-2101)	Union Valley (Silver Creek)	TOB = function of Folsom FNF and month	[10]	●	●	●		●
SMUD (P-2101)	Buck Island (Little Rubicon River)	Constant storage						
SMUD (P-2101)	Camino (Silver Creek)	Constant storage						
SMUD (P-2101)	Gerle Creek (Gerle Creek)	Constant storage						
SMUD (P-2101)	Junction (Silver Creek)	Constant storage						
SMUD (P-2101)	Rubicon (Rubicon River)	Constant storage						
SMUD (P-2101)	Slab Creek (SF American River)	Constant storage						
SMUD (P-2101)	Loon (Gerle Creek)	TOB = function of Folsom FNF and month				●		●
SFWPA (P-2088)	Little Grass Valley (SF Feather River)	TOC = TOI = average monthly historical		●				
SFWPA (P-2088)	Sly Creek (Lost Creek)	TOC = TOI = average monthly historical		●				
SSWD (P-2997)	Camp Far West (Bear River)	Buffer Coefficient = 0.15			●	●	●	
USACE	Farmington (Littlejohns Creek)	Constant Storage[1]						
USACE	Englebright (Yuba River)	TOC = TOI = average monthly historical		●				
USACE/SEWD	New Hogan (Calaveras River)	No additional logic.	●	●		●	●	
YCFC&WCD	Indian Valley (NF Cache Creek)	No additional logic.	●	●		●	●	
YCFC&WCD[7]	Clear (Cache Creek)	TOB = constant	[13]		●		●	
YCWA (P-2246)	New Bullards Bar (Yuba River)	TOB = constant	●	●		●	●	

Owner/Operator (FERC Project No.)	Reservoir (River)	Operational Logic	Flood Control	Variable TOC	Buffer Storage	Instream Flow	Water Supply	Hydro-Power

Notes:

[1] Farmington Reservoir is a flood detention basin and at a monthly time step, the reservoir is maintained empty.

[2] For modeling purposes, the SWP share of San Luis Reservoir is represented as a separate reservoir located on an artificial stream, named SWP San Luis Conveyance.

[3] For modeling purposes, the CVP share of San Luis Reservoir is represented as a separate reservoir located on an artificial stream, named CVP San Luis Conveyance.

[4] For modeling purposes, Clifton Court Forebay is located at the head of the California Aqueduct.

[5] For modeling purposes, Philbrook Reservoir located on Philbrook Creek, and Round Valley located on the West Branch Feather River have been combined into a single reservoir.

[6] For modeling purposes, Briones, Chabot, Lafayette, San Pablo, and Upper San Leandro reservoirs are represented as a single reservoir located on the Mokelumne Aqueduct.

[7] Clear Lake is a natural lake. Yolo County FC&WCD operate a dam built at the natural outlet of the lake to increase its storage capacity.

[8] Simulated storage in Los Vaqueros Reservoir is driven by IFR objects located on reservoir fill and release arcs. The flow requirements associated with these objects consist of time series data read from a CSV file. The time series data are developed using a WRIMS-based model of Contra Costa Water District's facilities.

[9] Salt Springs and Lower Bear reservoirs are not operated for flood control. However, available flood space is credited to Pardee and Camanche reservoirs.

[10] French Meadows, Hell Hole, and Union Valley reservoirs are not operated for flood control. However, available flood space is credited to Folsom Lake.

[11] Reservoir evaporation for diversion dams (simulated with constant storage) is set to zero.

[12] PG&E Drum-Spaulding Project (P-2310) and NID Yuba-Bear Project (P-2266) are operated to meet flow requirements through Drum Powerhouse and Deer Creek Powerhouse for power purposes.

[13] In winter, Clear Lake is operated to meet the requirements of the Gopcevic Decree.

[14] Hydropower operations are not simulated in SacWAM. It is assumed storage releases are dictated by flood control, water supply, and instream flow requirements.

Key:
BVID=Browns Valley Irrigation District, CCWD=Contra Costa Water District, CVP=Central Valley Project, DWR=Department of Water Resources, EBMUD=East Bay Municipal Utility District
EID=El Dorado Irrigation District, FNF=Full Natural Flow, GDPUD=Georgetown Divide Public Utility District, JVID=Jackson Valley Irrigation District, NID=Nevada Irrigation District
OP=Orland Project, PCWA=Placer County Water Agency, PG&E=Pacific Gas & Electric, PUD=Public Utility District, eclamation=U.S Department of Interior, Bureau of Reclamation
SEWD=Stockton East Water District, SFWPA=South Feather Water and Power Agency, SMUD=Sacramento Municipal Utility District, SP=Solano Project, SSWD=South Sutter Water District
SWP=State Water Project, TOB=Top of Buffer, TOC=Top of Conservation, TOI=Top of Inactive, UDC=User-defined constraint, USACE=U.S. Army Corps of Engineers, WB=West Branch,
YCFC&WCD=Yolo County Flood Control and Water Conservation District, YCWA=Yuba County Water Agency.

Table 6-6. Reservoir Top of Conservation Data

Reservoir	Description
Almanor	Constant value representing reservoir capacity (1,142.96 TAF)
Amador	Nov-May equal to storage capacity, Jun-Oct equal to previous month's storage
Antelope	Oct-Jun equal to storage capacity, Jul-Sep equal to previous month's storage
Belden	Constant value representing reservoir capacity (2.40 TAF)
Berryessa	Nov-May equal to storage capacity, Jun-Oct equal to previous month's storage
Black Butte	12 monthly values representing flood control requirements.
Bowman	Constant value representing reservoir capacity (68.51 TAF)
Buck Island	Constant value representing reservoir capacity (1.07 TAF)
Bucks	Storage capacity varies according to flashboard installation (101.93/106.61)
Butt Valley	Constant value representing reservoir capacity (49.93 TAF)
Camanche	Monthly values representing flood control requirements and dynamic accounting of upstream available flood space
Camino	Constant value representing storage capacity (0.83 TAF)
Camp Far West	Constant value representing reservoir capacity (93.74 TAF)
Caples	Storage capacity varies according to flashboard installation (20.49/22.34)
Chili Bar	Constant value representing reservoir capacity (3.00 TAF)
Clear Lake	Constant value representing active storage capacity (1,155 TAF)
Clifton Court Forebay	Constant value representing storage capacity (31.26 TAF)
Combie	12 monthly values based on average historical end-of-month storage
Cresta	Constant value representing reservoir capacity (4.14 TAF)
CVP San Luis	Constant value representing storage capacity (972.0 TAF)
Davis	Oct-Jun equal to storage capacity, Jul-Sep equal to previous month's storage
East Park	12 monthly values representing flood control requirements
EBMUD Terminal	12 monthly values based on district simulation model
Englebright	12 monthly values based on average historical end-of-month storage
Farmington	Set to zero as flood detention reservoir
Folsom	Monthly values representing flood control requirements and dynamic accounting of upstream available flood space
Fordyce	Constant value representing reservoir capacity (49.43 TAF)
French Meadows	Nov-Jun varies according to gated spillway operation (111.60/134.99), Jul-Oct previous month's storage
Frenchman	Nov-Jun equal to storage capacity, Jul-Oct equal to previous month's storage
Gerle Creek	Constant value representing reservoir capacity (1.26 TAF)
Hell Hole	Nov-Jun equal to storage capacity, Jul-Oct equal to previous month's storage
Ice House	Storage capacity varies according to gated spillway operation (34.90/41.54)
Indian Valley	12 monthly values representing flood control requirements
Jackson Meadows	Constant value representing reservoir capacity (69.21 TAF)
Jenkinson	Constant value representing storage capacity (41.00 TAF)
Junction	Constant value representing storage capacity (3.25 TAF)
Keswick	Constant value representing reservoir capacity (22.0 TAF)
Lake Valley	12 monthly values based on average historical end-of-month storage

Reservoir	Description
Lewiston	Constant value representing reservoir capacity (14.66 TAF)
Little Grass Valley	12 monthly values based on average historical end-of-month storage
Loon	Constant value representing reservoir capacity (69.31 TAF)
Los Vaqueros	Constant value representing storage capacity (160.0 TAF)
Lower Bear	Nov-Jul equal to storage capacity, Aug-Oct equal to previous month's storage
Merle Collins	Oct-Apr equal to storage capacity, May-Sep equal to previous month's storage – based on diversion fir irrigation purposes
Mountain Meadows	Oct-Jun equal to storage capacity, Jul-Sep equal to previous month's storage
Natoma	Fluctuates with Folsom storage
New Bullards Bar	12 monthly values representing flood control requirements.
New Hogan	Monthly time series representing flood control requirements, which vary based on antecedent moisture conditions.
Oroville	Monthly time series representing flood control requirements, which vary based on antecedent moisture conditions.
Pardee	Monthly values representing flood control requirements and dynamic accounting of upstream available flood space
Philbrook/Round Valley	12 monthly values based on average historical end-of-month storage
Poe	Constant value representing reservoir capacity (1.20 TAF)
Rock Creek	Constant value representing reservoir capacity (2.40 TAF)
Rollins	Constant value representing storage capacity (65.99 TAF)
Rubicon	Constant value representing reservoir capacity (1.45 TAF)
Salt Springs	Dec-Jul equal to storage capacity, Aug-Nov equal to previous month's storage
Scotts Flat	Constant value representing reservoir capacity (48.55 TAF)
Shasta	Monthly time series representing flood control requirements, which vary based on antecedent moisture conditions.
Silver	Storage capacity varies according to flashboard installation (3.76/8.64)
Slab Creek	Constant value representing reservoir capacity (16.60 TAF)
Sly Creek	12 monthly values based on average historical end-of-month storage
Spaulding	Constant value representing reservoir capacity (75.91 TAF)
Stony Gorge	12 monthly values representing flood control requirements.
Stumpy Meadows	Nov-Jul equal to storage capacity, Aug-Sep equal to previous month's storage
SWP San Luis	Constant value representing storage capacity (1,067.0 TAF)
Thermalito Afterbay	Constant value representing storage capacity (38.08 TAF)
Trinity	12 monthly values representing flood control requirements
Union Valley	Storage capacity varies according to gated spillway operation (225.35/257.90)
Upper Bear	12 monthly values based on average historical end-of-month storage
Whiskeytown	12 monthly values based on average historical end-of-month storage

Table 6-7. Diversion to Storage Water Rights

Owner/ Operator	Reservoir (River)	Year Comp.	Application ID	Permit ID	License ID	Period	Amount (AF/year)	Purpose
Browns Valley ID	Merle Collins (French Dry Creek)	1963	A013130	008649	013608	10/1-4/30	20,000	Domestic, Irrigation, Recreation
			A013873	009703	013609	10/1-4/30	31,900	Domestic, Irrigation, Recreation
			A027302	018861	N/A	10/1-6/01	57,000	Power
Contra Costa WD	Los Vaqueros (Kellogg Creek)	1997	A020245	020749	N/A	10/1-6/30	95,850	M&I, Domestic, Irrigation, Recreation, Water Quality
			A025516A	020750	N/A	10/1-9/30	9,640	
DWR/SWP	Clifton Court (Old River)	1969	No information gathered as part of the SacWAM modeling effort					
DWR/SWP	SWP San Luis (offstream)	1967	No information gathered as part of the SacWAM modeling effort					
DWR/SWP	Antelope (Indian Creek)	1964	A016951	014587	009389	10/1-6/30	18,200	Recreation and Streamflow Enhancement
			A020117	014588	010975	10/1-5/31	3,400	
DWR/SWP	Davis (Middle Fork Feather)	1964	A021443	015255	N/A	10/1-6/30	34,000	Recreation, Streamflow Enhancement, Municipal, Irrigation
			A016950	015254	N/A	10/1-6/30	49,000	
DWR/SWP	Oroville (Feather River)	1967	A005630	016478	N/A	9/1-7/31	380,000	Irrigation, domestic, M&I, salinity control, recreational, fish
			A014443	016479	N/A	9/1-7/31	3,500,000	
DWR/SWP	Thermalito Afterbay (Offstream)	1968	No information gathered as part of the SacWAM modeling effort					
DWR/SWP	Frenchman (Little Last Chance Creek)	1961	A016952	012945	009182	11/1-6/1	30,000	Irrigation, Domestic, Stockwatering and Recreational
			A018844	012946	009928	11/1-6/1	4,962	Recreation
EBMUD	Camanche (Mokelumne River)	1963	A025056	017378	N/A	12/1-7/1	353,000	Power
EBMUD	Terminal reservoirs (Mokelumne Aq.)	varies	No information gathered as part of the SacWAM modeling effort					
EBMUD		1929	A004228	002459	011109	10/1-7/15	209,950	M&I and recreation

Owner/ Operator	Reservoir (River)	Year Comp.	Application ID	Permit ID	License ID	Period	Amount (AF/year)	Purpose
	Pardee (Mokelumne River)		A015201	014079	N/A	12/1-7/1	353,000	Hydroelectric power and Incidental domestic
			A013156	010478	N/A	12/1-7/1	353,000	Fish and wildlife preservation and Enhancement, recreation, M&I
			A005128	003587	006062	10/1-12/31	28,702	Power
			A025056	017378	N/A	12/1-7/1	353,000	Power
			A004768	002529	001388	1/1-7/31	198,965	Power
El Dorado ID	Caples (Caples Creek)[1]	1922	A005645B	021112	N/A	11/1-7/31	21,581	Domestic, irrigation, M&I
El Dorado ID	Silver (Silver Fork American) [1]	1876	A005645B	021112	N/A	11/1-7/31	6,000	Domestic, irrigation, M&I
El Dorado ID	Jenkinson (Sly Park Creek)	1955	A002270	002631	001835	11/15-6/1	7,000	Irrigation, industrial, municipal, domestic, recreation, Fish, and wildlife enhancement
			A005645A	012258	011836	11/1-6/30	5,400	
Georgetown Divide PUD	Stumpy Meadows (Pilot Creek)	1960	A005644A	012827	N/A	11/1-8/1	20,000	Irrigation, domestic and stockwatering
Jackson Valley ID	Lake Amador (Jackson Creek)	1965	A012342A	011589	N/A	11/1-5/31	6,000	Irrigation, domestic, industrial, Recreation, fish, wildlife propagation, incidental power
			A017605	011224	N/A	11/1-5/31	30,000	
Nevada ID	Scotts Flat (Deer Creek)	1948	A027132	018608	N/A	1/1-12/31	60,000	Power
			A001614	001481	N/A	1/1-12/31	60,000	Irrigation
Nevada ID	Combie (Bear River)	1928	A002652A	005803	010350	11/30-6/1	5,555	Irrigation, domestic and recreational
Nevada ID	Bowman (Canyon Creek)	1927	A001270	002082	012795	1/1-12/31	58,829	Irrigation, municipal, domestic and mining
Nevada ID	Jackson Meadows (Middle Yuba River)	1965	A020072	013773	N/A	10/1-6/30	50,000	Power
			A005193	013770	N/A	10/1-12/1 1/1-6/30	50,000	Irrigation and incidental domestic
			A002276	002085	012797	12/1-7/15	60,000	Irrigation, municipal, domestic and mining
			A002275	002084	012796	1/1-12/31	60,000	Power
Nevada ID	Rollins (Bear River)	1965	A025652A	005803	010350	11/30-6/1	6,945	Irrigation, domestic and recreation
			A002652B	011626	N/A	11/30-6/1	87,500	Irrigation
			A024983	016953	N/A	11/30-6/1	62,080	Power
PG&E	Mountain Meadows (Hamilton Branch)	1924	A026651	020606		10/1-6/30	24,000	Power
PG&E (P-137)	Lower Bear (Bear River)	1952	A006032	003452	004242	11/1-7/15	49,000	Power
PG&E (P-137)	Salt Springs	1931	A005240	003191	002855	12/1-7/15	85,000	Power

Owner/ Operator	Reservoir (River)	Year Comp.	Application ID	Permit ID	License ID	Period	Amount (AF/year)	Purpose
	(NF Mokelumne River)		A002751	003189	009276	12/1-6/30	9,412	
			A005161	003190	009369	12/1-6/30	9,412	
			A002100	002100	001916	2/1-7/15	60,000	
			A002534	003188	003292	12/1-7/15	85,000	
PG&E (P-2105)	Butt Valley (Butt Creek)	1924	Pre-1914				49,897	
PG&E (P-2105)	Almanor (NF Feather River)	1927	Pre-1914				1,142,964	
			A030257	021151	N/A	10/1-6/30	500,000	Power
PG&E (P-2310)	Lake Valley (NF of NF American River)	1911	Pre-1914					Power, irrigation, domestic
PG&E (P-2310)	Fordyce (Fordyce Creek)	1926	Pre-1914					Power, irrigation, municipal
PG&E (P-2310)	Spaulding (South Yuba River)	1954	Pre-1914					Power, irrigation, domestic
PG&E (P-619)	Bucks Lake (Bucks Creek)	1928	A004441	002292	001921	11/1-7/15	40,000	Power
			A003889	002291	001920	11/1-7/15	23,000	Power
			A002186	003390	009570	10/1-7/1	70,000	Irrigation
			A002195	002290	001919	12/1-7/1	55,000	Power
PG&E (P-803)	Round Valley (WB Feather River)	1926	Pre-1914				1,196	Power
PG&E (P-803)	Philbrook (Philbrook Creek)	1926	A002755	002006	000988	10/20-7/1	5,060	Power
PG&E (P-1403)[2]	Englebright Yuba River	1941	A008794	005775	006388	10/1-3/1	45,000	Power
PCWA	French Meadows (MF American River)	1965	A018084	013855	N/A	11/1-7/1	95,000	Power and recreation.
			A018085	013856	N/A	11/1-7/1	95,000	Irrigation, incidental domestic, recreation, M&I
			A018086	013857	N/A	11/1-7/1	10,000	Power and recreation
			A018087	013858	N/A	11/1-7/1	10,000	Irrigation and incidental domestic, recreation, M&I
PCWA	Hell Hole (Rubicon River)	1965	A018084	013855	N/A	11/1-7/1	129,000	Power and recreation
			A018085	013856	N/A	11/1-7/1	129,000	Irrigation, incidental domestic, recreation, M&I
			A018086	013857	N/A	11/1-7/1	36,000	Power and recreation
			A018087	013858	N/A	11/1-7/1	36,000	Irrigation, incidental domestic, recreation, M&I
Reclamation/CVP	Black Butte (Stony Creek)	1963	A018115	013776	N/A	1/1-12/31	160,000	Domestic, irrigation, M&I, flood control, recreation
Reclamation/CVP		1960	A005628	011967	N/A	1/1-12/31	1,540,000	Irrigation, navigation, fish

Owner/ Operator	Reservoir (River)	Year Comp.	Application ID	Permit ID	License ID	Period	Amount (AF/year)	Purpose
	Trinity (Trinity River)		A016767	011971	N/A	1/1-12/31	700,000	Irrigation, domestic, water quality control
			A015374	011968	N/A	1/1-12/31	200,000	M&I
Reclamation/CVP	Whiskeytown (Clear Creek)	1963	A017375	012365	N/A	11/1-4/1	250,000	Power
			A017376	012364	N/A	11/1-4/1	250,000	Irrigation, domestic, navigation, water quality control, recreation
Reclamation/CVP	CVP San Luis (Offstream)	1968	No information gathered as part of the SacWAM modeling effort					
Reclamation/CVP	Folsom (American River)	1956	A013370	012365	N/A	11/1-7/1	1,000,000	Irrigation
			A013371	011316	N/A	11/1-8/1	300,000	M&I, domestic, recreation
Reclamation/CVP	Keswick (Sacramento River)	1950	No information gathered as part of the SacWAM modeling effort					
Reclamation/CVP	Natoma (American River)	1955	No information gathered as part of the SacWAM modeling effort					
Reclamation/CVP	Lewiston Lake (Trinity River)	1963	No information gathered as part of the SacWAM modeling effort					
Reclamation/CVP	Shasta Lake (Sacramento River)	1945	A005626	012721	N/A	10/1-7/1	3,190,000	Irrigation, incidental domestic, stockwatering and recreational uses.
Reclamation/Orland Project	East Park (Little Stony Creek)	1911	Pre-1914					
Reclamation/ Orland Project	Stony Gorge (Stony Creek)	1928	A002212	002339	002652	11/1-5/1	50,200	Irrigation
Reclamation/ Solano Project	Berryessa (Putah Creek)	1957	A019934	014186	N/A	11/1-5/31	7,500	Municipal, domestic and stockwatering
			A012716	010659	N/A	11/1-5/31	320,000	Domestic, M&I, irrigation, frost protection
Reclamation/Stockton East WD	New Hogan (Calaveras River)	1963	A018812	014434	N/A	11/1-5/1	325,000	Irrigation, M&I, domestic, recreation
			A006522	003652	002021	11/1-6/1	11,500	Irrigation and domestic uses
SMUD	Ice House (SF Silver Creek)	1959	A012323	107093	011073	10/1-7/31	49,700	Power and recreation
			A026768	019025	N/A	10/1-7/31	60,000	Power
SMUD	Union Valley (Silver Creek)	1963	A012323	010703	011073	10/1-7/31	195,000	Power and recreation
			A012624	010704	011074	10/1-7/31	141,500	Power, recreation, fish and wildlife protection/enhancement
SMUD	Buck Island (Little Rubicon River)	1963	A012624	010704	011074	10/1-7/31	440	Power, recreation, fish and wildlife protection/enhancement
SMUD	Camino (Silver Creek)	1961	A012624 A031596	010704 021262	011074 N/A	10/1-7/31 10/1-9/30	1,400	Power, recreation, fish and wildlife protection/enhancement
SMUD	Gerle Creek (Gerle Creek)	1963	A012624	010704	011074	10/1-7/31		Power, recreation, fish and wildlife protection/enhancement

Owner/ Operator	Reservoir (River)	Year Comp.	Application ID	Permit ID	License ID	Period	Amount (AF/year)	Purpose
SMUD	Junction Reservoir (Silver Creek)	1962	A012624 A031596	010704 021262	011074 N/A	10/1-7/31 10/1-9/30	6,300	Power, recreation, fish and wildlife protection/enhancement
SMUD	Rubicon (Rubicon River)	1963	A012624	010704	011074	10/1-7/31	450	Power, recreation, fish and wildlife protection/enhancement
SMUD	Slab Creek (SF American River)	1967	A012624 A031596	010704 021262	011074 N/A	10/1-7/31 10/1-9/30	17,000	Power, recreation, fish and wildlife protection/enhancement
SMUD	Loon Lake (Gerle Creek)	1963	A031595 A012624	021261 010704	N/A 011074	10/1-9/30 10/1-7/31	1,200 92,000	Power, recreation, fish and wildlife Protection/enhancement
South Feather Water and Power Agency	Little Grass Valley (SF Feather River)	1961	A001651	001267	010939	10/1-7/1	109,012	Recreation, domestic, M&I, irrigation
			A013676	011514	N/A	11/1-7/1	77,300	Power
South Feather Water and Power Agency	Sly Creek (Lost Creek)	1961	A013676	001271	N/A	11/1-7/1	24,100	Power
			A002778	002492	N/A	10/1-6/1	25,000	Recreation, domestic, M&I, irrigation
South Sutter WD	Camp Far West (Bear River)	1963	A010221	014871	011120	10/1-6/30	40,000	Irrigation and domestic
			A014804	011297	011118	10/1-6/30	58,370	Irrigation and domestic
			A026162	018360	N/A	10/1-6/30	103,100	Power
USACE	Farmington (Littlejohns Creek)		No information gathered as part of the SacWAM modeling effort					Flood control
USACE	Englebright (Yuba River)	1941	No information gathered as part of the SacWAM modeling effort					Debris control
Yolo County FC&WCD	Indian Valley (NF Cache Creek)	1976	A011389	012848	N/A	10/1-6/30	250,000	Irrigation, flood control, domestic, and recreation
			A015975	012849	N/A	10/1-6/30	1,480,000	None specified
			A026469	018295	N/A	1/1-6/30	300,000	Power
Yolo County FC&WCD	Clear Lake (Cache Creek)	1914	Governed by the Gopcevic and Solano decrees					Irrigation, flood control, Hydropower
Yuba County Water Agency	New Bullards Bar Reservoir (NF Yuba River)	1970	A015563	015029	011567	10/15-6/30	177,400	Power
			A015205	015028	011566	5/1-6/30	3,900	Power
			A015204	015027	N/A	10/1-6/30	240,000	Irrigation, flood control, domestic, industrial and recreation
			A005631	015025	011565	10/15-6/30	490,000	Power
			A005632	015026	N/A	10/1-6/30	490,000	Power
			A002197	001154	000435	12/15-7/15	5,000	Power
			A003026	001354	000436	12/15-7/15	10,000	Power
			A005004	002694	000777	12/15-7/15	15,000	Power
			A010282	008330	005544	10/1-3/1	5,335	Power
			A015574	015030	N/A	10/1-6/30	150,000	Irrigation, flood control, domestic, Industrial and recreation

Owner/ Operator	Reservoir (River)	Year Comp.	Application ID	Permit ID	License ID	Period	Amount (AF/year)	Purpose

Notes:

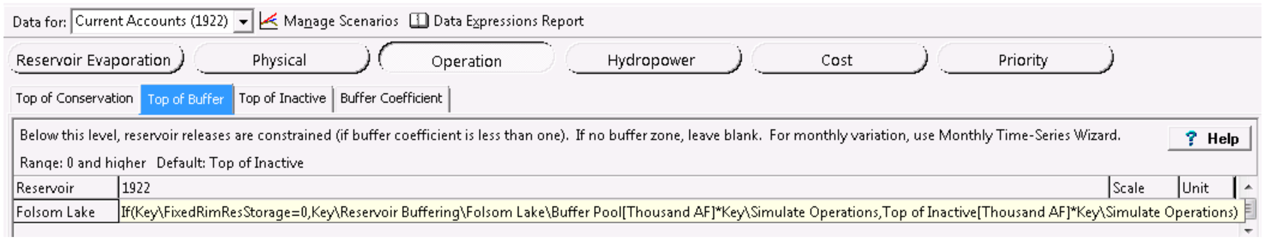
[1] Additional pre-1914 water rights not quantified in table.

[2] Englebright Dam is owned by USACE. PG&E holds a license in association with the Narrows No. 1 Powerhouse.

Key:

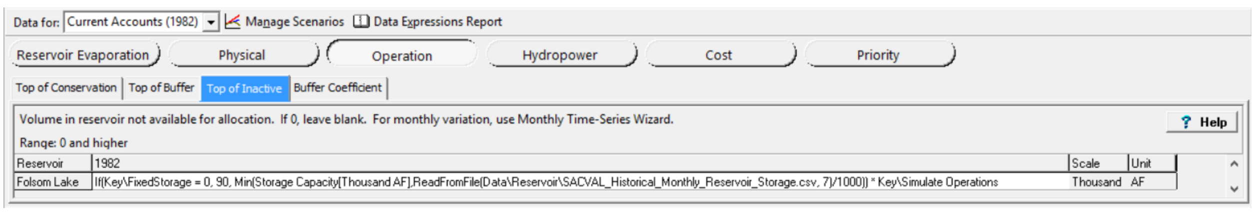
CVP = Central Valley Project, DWR = Department of Water Resources, EBMUD = East Bay Municipal Utility District, FC&WCD = Flood Control and Water Conservation District, ID = Irrigation District, MF = Middle Fork, NF = North Fork, PG&E = Pacific Gas and Electric Company, PUD = Public Utility District, SMUD = Sacramento Municipal Utility District, SF = South Fork, SWP = State Water Project, USACE = U.S. Army Corps of Engineers, WB = West Branch, WD = Water Districy.

6.1.2.3.2 Top of Buffer



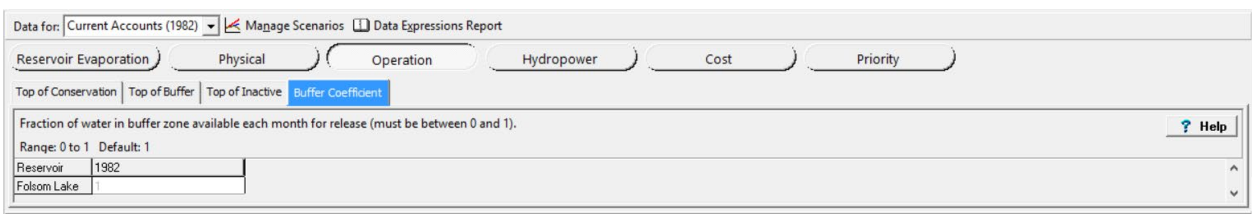
The *Top of Buffer* parameter is used to set the upper limit of the buffer pool. If the reservoir is operating in the buffer pool, then the reservoir will release only the volume of water available multiplied by the buffer coefficient.

6.1.2.3.3 Top of Inactive



The *Top of Inactive* parameter is used to specify the upper limit of the dead pool storage. Like the top of conservation, some reservoirs have this parameter constrained to average historical storage in order to simulate operations. The remainder have a fixed volume of dead pool storage. For more information, see **reservoir storage capacity**.

6.1.2.3.4 Buffer Coefficient



The *Buffer Coefficient* parameter is used to specify the fraction of the buffer pool that is available to meet demands. Similar to *Top of Buffer*, there is an option to set this parameter for the major rim reservoirs using *Key Assumptions\Reservoir Buffering* (see Section 9.8). Reservoirs with a buffer coefficient defined in key assumptions include Black Butte, Camanche, Camp Far West, Clear Lake, Folsom, Berryessa, New Bullards Bar, New Hogan, Oroville, Pardee, Shasta, and Stony Gorge. This list of reservoirs partly results as a legacy of model development – initially WEAP's buffer coefficient was used to control reservoir operations, but latterly reservoir-specific allocation logic was developed.

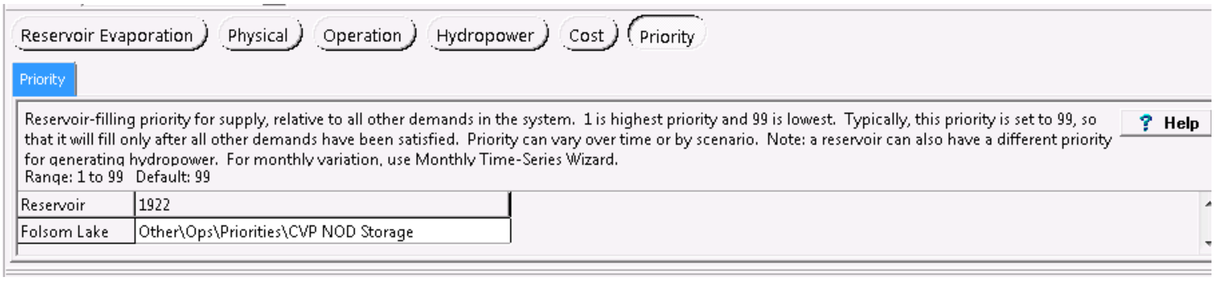
6.1.2.4 Hydropower

The WEAP *Hydropower* feature is not used in SacWAM.

6.1.2.5 Cost

The WEAP *Cost* feature is not used in SacWAM.

6.1.2.6 Priority



Priorities for reservoir objects, demand sites, catchment objects, and IFR objects are discussed in Section 7.12. Priorities are assigned to reservoir storage, consumptive demands, and non-consumptive (i.e., instream flow requirements, hydropower) demands. Priorities are relative rather than absolute. For example, WEAP will prefer to store surface water if the storage priority is higher (i.e., has a lower numeric value) than other demands. When releasing water from storage to meet downstream demands, WEAP will release first from reservoirs with lower demand priority. If reservoirs share the same priority, WEAP will attempt to balance storage in these reservoirs as a percentage of their total active storage (i.e., top of conservation storage less inactive storage). Expressions of reservoir priority and their associated values are presented in Table 6-8

Table 6-8. SacWAM Reservoir Priority Structure

Reservoir	Conservation Storage		Buffer Storage	
	Expression[6]	Priority	Expression[6]	Priority
Almanor	PGE Feather River Conservation Storage	15	PGE Feather River Buffer Storage	9
Aloha	N/A	N/A	N/A	N/A
Amador	JVID Conservation Storage	15	N/A	N/A
Antelope	SWP NOD Local Reservoirs Conservation Storage	19	SWP NOD Local Reservoirs Buffer Storage	12
Belden	N/A	N/A	N/A	N/A
Berryessa	NonProject Trib Storage	33	Key\Reservoir Buffering\Lake Berryessa\Buffer Priority	N/A
Black Butte	CVP Stony Creek Storage	34	Key\Reservoir Buffering\Black Butte\Buffer Priority	N/A
Bowman	NID Conservation Storage Yuba River	21	NID Buffer Storage Yuba River	21
Buck Island	SMUD Conservation Storage	15	SMUD Buffer Storage	9
Bucks	PGE Feather River Conservation Storage	15	PGE Feather River Buffer Storage	9
Butt Valley	PGE Feather River Conservation Storage	15	PGE Feather River Buffer Storage	9
Camanche	EBMUD Storage Camanche	35	Key\Reservoir Buffering\Camanche\Buffer Priority	34
Camino	N/A	N/A	N/A	N/A
Camp Far West	NonProject Trib Storage	33	Key\Reservoir Buffering\Camp Far West\Buffer Priority	N/A
Caples	EID Conservation Storage	14	EID Buffer Storage	8
Chili Bar	N/A	N/A	N/A	N/A
Clear	YCFCWCD Storage Clear Lake	34	Key\Reservoir Buffering\Clear Lake\Buffer Priority	N/A
Clifton Court Forebay	N/A	N/A	N/A	N/A
Combie	Upper Watershed Reservoirs	12	N/A	N/A
Cresta	N/A	N/A	N/A	N/A
CVP San Luis	CVP SOD storage ab Rule Curve using Delta surplus	83	CVP SOD Storage bw Rule Curve	74
Davis	SWP NOD Local Reservoirs Conservation Storage	19	SWP NOD Local Reservoirs Buffer Storage	12
East Park	NonProject Trib Storage	33	Key\Reservoir Buffering\East Park\Buffer Priority	N/A
EBMUD Terminal	EBMUD Storage Terminal Reservoirs	21	N/A	N/A
Englebright	Upper Watershed Reservoirs	12	N/A	N/A
Farmington	N/A	N/A	N/A	N/A
Folsom	CVP NOD Storage	95	Key\Reservoir Buffering\Folsom Lake\Buffer Priority	66
Fordyce	PGE YubaBear Conservation Storage	21	PGE YubaBear Buffer Storage	21
French	N/A	N/A	N/A	N/A
French Meadows	PCWA Conservation Storage	27	PCWA Buffer Storage	21
Frenchman	SWP NOD Local Reservoirs Conservation Storage	19	SWP NOD Local Reservoirs Buffer Storage	12

Reservoir	Conservation Storage		Buffer Storage	
	Expression[6]	Priority	Expression[6]	Priority
Gerle	N/A	N/A	N/A	N/A
Grizzly	N/A	N/A	N/A	N/A
Hell Hole	PCWA Conservation Storage	27	PCWA Buffer Storage	21
Ice House	SMUD Conservation Storage	15	SMUD Buffer Storage	9
Indian Valley	YCFCWCD Storage Indian Valley	33	Key\Reservoir Buffering\Indian Valley\Buffer Priority	N/A
Jackson Meadows	NID Conservation Storage Yuba River	21	NID Buffer Storage Yuba River	21
Jenkinson	EID Cosumnes River Storage	15	N/A	N/A
Junction	N/A	N/A	N/A	N/A
Keswick	N/A	N/A	N/A	N/A
Lake Valley	Upper Watershed Reservoirs	12	N/A	N/A
Lewiston	N/A	N/A	N/A	N/A
Little Grass Valley	Upper Watershed Reservoirs	12	N/A	N/A
Loon	SMUD Conservation Storage	15	SMUD Buffer Storage	9
Los Vaqueros[1]	Default value	99	N/A	N/A
Lower Bear	PGE NF Mokelumne Conservation Storage	21	N/A	N/A
Lower Bucks	N/A	N/A	N/A	N/A
Merle Collins	BrownsValleyID Conservation Storage	21	Key\Reservoir Buffering\Merle Collins\Buffer Priority	15
Mountain Meadows	PGE Feather River Conservation Storage	15	PGE Feather River Buffer Storage	9
Natoma	N/A	N/A	N/A	N/A
New Bullards Bar	NonProject Trib Storage	33	YCWA Buffer Storage	30
New Hogan	NonProject Trib Storage	33	Key\Reservoir Buffering\New Hogan\Buffer Priority	N/A
Oroville[2]	SWP NOD Oroville Buffer Storage/Conservation Storage	45-86	Key\Reservoir Buffering\Oroville\Buffer Priority	45
Pardee	EBMUD Storage Pardee	34	Key\Reservoir Buffering\Pardee\Buffer Priority	N/A
PhilbrookRoundValley	N/A	N/A	N/A	N/A
Poe	N/A	N/A	N/A	N/A
Rock Creek	N/A	N/A	N/A	N/A
Rollins[3]	NID Conservation Storage Bear River	20-22	Key\Reservoir Buffering\Rollins\Buffer Priority	N/A
Rubicon	SMUD Conservation Storage	15	N/A	N/A
Salt Springs	PGE NF Mokelumne Conservation Storage	21	N/A	N/A
Scotts Flat	NID Conservation Storage Deer Creek	21	NID Buffer Storage Deer Creek	19
Schaads	N/A	N/A	N/A	N/A
Shasta	CVP NOD Storage	95	Key\Reservoir Buffering\Shasta\Buffer Priority	N/A

Reservoir	Conservation Storage		Buffer Storage	
	Expression[6]	Priority	Expression[6]	Priority
Silver[4]	EID Conservation Storage	14	EID FERC Minimum Storage/EID Buffer Storage	6-8
Slab Creek	SMUD Conservation Storage	15	N/A	N/A
Sly Creek	Upper Watershed Reservoirs	12	N/A	N/A
Spaulding	PGE YubaBear Conservation Storage	21	PGE YubaBear Buffer Storage	21
Stony Gorge	NonProject Trib Storage	33	Key\Reservoir Buffering\Stony Gorge\Buffer Priority	33
Stumpy Meadows	GDPUD Conservation Storage	15	N/A	N/A
SWP San Luis	SWP SOD storage ab Rule Curve using Delta surplus	84	SWP SOD Storage bw Rule Curve	79
Thermalito Afterbay	N/A	N/A	N/A	N/A
Trinity	CVP Trinity River Storage	58	N/A	N/A
Union Valley	SMUD Conservation Storage	15	SMUD Buffer Storage	9
Upper Bear	PGE NF Mokelumne Conservation Storage	21	N/A	N/A
Whiskeytown	CVP NOD Storage	95	N/A	N/A

Notes:

[1] Storage in Los Vaqueros Reservoir is controlled by IFR objects placed on the fill and release arcs. The priority on reservoir conservation storage has not been defined and has the WEAP default value of 99.

[2] The priority assigned to conservation storage in Lake Oroville varies depending on the previous end-of-month storage.

[3] The priority assigned to conservation storage in Rollins Reservoir varies by month.

[4] The priority assigned to buffer storage in Silver Lake varies by month.

[5] Rows shaded grey indicate that reservoir operations are constrained to a fixed storage; the top of conservation storage is set equal to to the top of inactive storage.

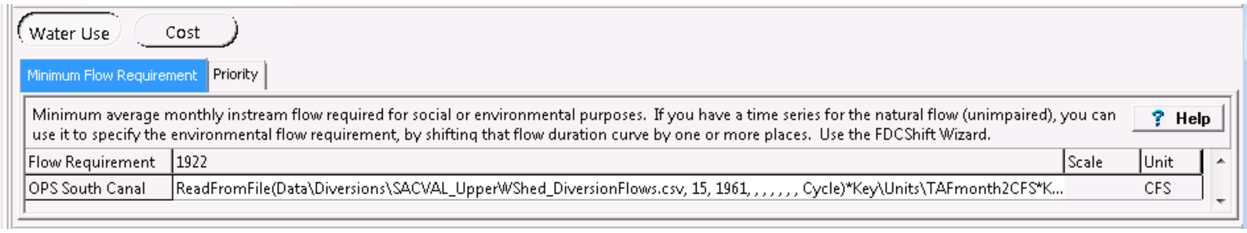
[6] Unless shown otherwise, all expressions for priority are located in the SacWAM data tree under Other Assumptions\Water Allocation Priorities

Key:

ab = above, bw = below, CVP = Central Valley Project, EBMUD = East Bay Municipal Utility District, EID = El Dorado Irrigation District, GDPUD = Georgetown Divide Public Utility District, IFR = instream flow requirement, N/A = not applicable, NID = Nevada Irrigation District, NOD = north of Delta, PCWA = Placer County water Agency, PGE = Pacific Gas and Electric Company, SOD = south of Delta

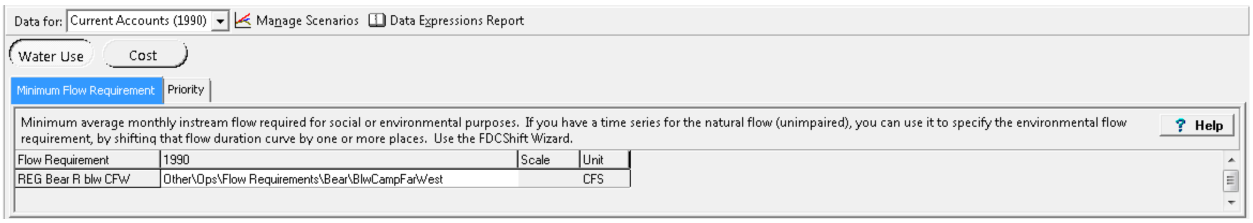
SMUD = Sacramento Municipal Utility District, SWP = State Water Project, YCFCWCD = Yolo County Water Conservation and Flood Control District.

6.1.3 Flow Requirements



6.1.3.1 Water Use

6.1.3.1.1 Minimum Flow Requirement



SacWAM considers flow requirements for water quality, fish and wildlife, navigation, recreation, and other purposes using a flow requirement object associated with points on a river. Flow requirements are treated as a demand and are satisfied in accordance with the user-defined priority structure. Many requirements vary seasonally and are adjusted depending on water year type.

There are three categories of flow requirements in SacWAM. The first category is regulatory in nature, and these flow requirements are indicated with the prefix 'REG' at the start of their name. An example of a regulatory requirement is *REG American River at Fair Oaks*, on the American River. This flow requirement is based on regulations set under the lower American River Flow Management Standard. Flow requirements with the prefix 'REG' are listed and described in Table 6-9. The second category of flow requirement is used to drive simulated operations of upstream reservoirs, or diversions through tunnels, canals, and pipelines. These flow requirements, which are operational in nature, are designated using the prefix 'OPS' at the start of their name. An example of an operational requirement is *OPS Duncan Creek Tunnel* that conveys water from Duncan Creek to French Meadows Reservoir on the Middle Fork American River. This flow requirement is set equal to the tunnel capacity. Its purpose is to divert all creek water, over and above the downstream flow requirement, into the reservoir. For more details, see upper **watershed diversion flows** and Table 6-10. The third type of flow requirement is designated using the prefix 'SWRCB'; these flow requirements have been included in the schematic, but no flow requirement is specified under the Current Account or 'Existing' scenario. These flow requirements allow model users to set and test new regulatory flow requirements where the flow requirement is specified as a fraction of the unimpaired flow. Flow requirements in this category are listed in Table 6-11.

In WEAP, a flow requirement is usually added to the model by setting the flow requirement expression either to a fixed value or to 12 monthly values using the WEAP 'Monthly Values' expression. In SacWAM, more complicated flow requirements are expressed as conditional on hydrological conditions or other variables defined under the *Other Assumptions\Ops\Flow Requirements* branch.

6.1.3.1.2 *Priority*

Priorities for flow requirements, demand sites and catchments, and reservoirs are discussed in Section 4.5.8.

6.1.3.2 *Cost*

The WEAP *Cost* feature for Flow Requirements is not used in SacWAM.

Table 6-9. Regulatory Instream Flow Requirements Represented in SacWAM

River	Name	Description
American River	REG American River at Fair Oaks	Lower American River Flow Management Standard
American River	REG D893 St	1958 WRD-893
Bear River	REG Bear River blw Bear River Canal	FERC P-2266 license (issued June 24, 1963), NID Yuba-Bear Project
Bear River	REG Bear River blw Canal Wasteway	FERC P-2310 license (issued June 24, 1963), PG&E Drum-Spaulding Project
Bear River	REG Bear River blw CFW Diversion Dam	FERC P-2997 license (issued July 2, 1981), SSWD Camp Far West Hydroelectric Project 2000 Settlement Agreement between DWR, South Sutter WD, and Camp Far West ID
Bear River	REG Bear River blw Combie Dam	FERC P-2266 license (issued June 24, 1963), NID Yuba-Bear Project
Bear River	REG Bear River blw Drum Afterbay	FERC P-2310 license (issued June 24, 1963), PG&E Drum-Spaulding Project
Bear River (Mokelumne Watershed)	REG Bear River blw Lower Bear Dam	FERC P-137 license (issued October 11, 2001) for the North Fork Mokelumne Project
Big Grizzly Creek	REG Big Grizzly Creek blw Davis	Water Right License 9182 (Permit 12945, A16952)
Brush Creek	REG Brush Creek blw Dam	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Bucks Creek	REG Bucks Creek blw Bucks Dam	FERC P-619 license (issued December 19, 1974), PG&E Bucks Creek Project
Canyon Creek	REG Canyon Creek blw Bowman Diversion Dam	FERC P-2266 license (issued June 24, 1963), NID Yuba-Bear Project
Caples Creek	REG Caples Creek blw Caples Lake	FERC P-184 El Dorado Relicensing Settlement Agreement
Clear Creek	REG Clear Creek blw Igo	Combination of 1960 MOA between DWR and CDFG, (b)2 actions, and 2009 NMFS BiOp
Cole Creek	REG Cole Creek below Diversion Dam	
Deer Creek	REG Deer Creek near Smartville	
Duncan Creek	REG Duncan Creek blw Diversion Dam	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project
Feather River	REG Feather River nr Verona	1986 MOU between CDFG and DWR
Feather River	REG HighFlow Channel	1986 MOU between CDFG and DWR
Feather River	REG LowFlowChannel	1986 MOU between CDFG and DWR
Fordyce Creek	REG Fordyce Creek blw Fordyce	FERC P-2310 license (issued June 24, 1963), PG&E Drum-Spaulding Project
French Dry Creek	REG French Dry Creek	CDFG Agreement, August 10, 1972
Gerle Creek	REG Gerle Creek blw Gerle Reservoir	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Gerle Creek	REG Gerle Creek blw Loon Lake	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Grizzly Creek	REG Grizzly Creek blw Diversion Dam	FERC P-619 license (issued December 19, 1974), PG&E Bucks Creek Project
Kellogg Creek	REG Kellogg Creek blw Los Vaqueros	SWRCB D-1629: Los Vaqueros Project
Little Last Chance Creek	REG Little Last Chance Creek blw Frenchman	Water Right License 9182 (Permit 12945, A16952)

River	Name	Description
Little Rubicon River	REG Little Rubicon blw diversion	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Little Stony Creek	REG Stony Creek blw East Park Dam	Agreement with CDFG
Middle Fork American River	REG MF American blw French Meadows Dam	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project
Middle Fork American River	REG MF American blw Interbay Dam	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project
Middle Fork American River	REG MF American blw Oxbow Powerhouse	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project
Middle Yuba River	REG Middle Yuba blw Jackson Meadows Dam	FERC P-2266 license (issued June 24, 1963), NID Yuba-Bear Project
Middle Yuba River	REG Middle Yuba blw Milton Dam	FERC P-2266 license (issued June 24, 1963), NID Yuba-Bear Project
Middle Yuba River	REG Middle Yuba blw Our House Dam	FERC P-2246 license (issued May 16, 1963) YCWA Yuba River Development Project
Mokelumne River	REG blw Camanche	1998 Joint Settlement Agreement and FERC license for the Lower Mokelumne Hydroelectric Project (FERC Project No. 2916)
Mokelumne River	REG Mokelumne blw Woodbridge	1998 Joint Settlement Agreement and FERC license for the Lower Mokelumne Hydroelectric Project (FERC Project No. 2916)
N and S Fork Canyon Creek	REG NS Fork Long Canyon Creek blw Dam	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project
North Fork American River	REG NF American blw American River Pump Station	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project
North Fork Feather River	REG NF Feather blw Almanor	FERC P-2105 license (issued January 24, 1955) PG&E Upper North Fork Feather River Project
North Fork Feather River	REG NF Feather blw Belden Dam	FERC P-2105 license (issued January 24, 1955) PG&E Upper North Fork Feather River Project
North Fork Feather River	REG NF Feather blw Cresta Dam	FERC P-1962 license Rock Creek-Cresta Project (issued October 24, 2001)
North Fork Feather River	REG NF Feather blw Poe Dam	FERC P-2107 license (issued October 26, 1953), PG&E Poe Project
North Fork Feather River	REG NF Feather blw Rock Creek Dam	FERC P-1962 license Rock Creek-Cresta Project (issued October 24, 2001)
North Fork Mokelumne River	REG NF Mokelumne blw Electra Dam	FERC P-137 license (issued October 11, 2001) for the North Fork Mokelumne Project
North Fork Mokelumne River	REG NF Mokelumne blw Salt Spring Dam	FERC P-137 license (issued October 11, 2001) for the North Fork Mokelumne Project
North Fork Mokelumne River	REG NF Mokelumne blw Tiger Creek Afterbay	FERC P-137 license (issued October 11, 2001) for the North Fork Mokelumne Project
North Fork of North Fork American River	REG NF American blw Lake Valley Canal	FERC P-2310 license (issued June 24, 1963), PG&E Drum-Spaulding Project
Oregon Creek	REG Oregon Creek blw Log Cabin Dam	FERC P-2246 license (issued May 16, 1963) YCWA Yuba River Development Project
Pilot Creek	REG Pilot Creek blw Diversion Dam	Water Right Permit 11304 (A016212)
Putah Creek	REG Lower Putah Diversion Dam	2000 Putah Creek Accord/Settlement Agreement flow requirements below Putah Diversion Dam
Putah Creek	REG Lower Putah I80 Bridge	2000 Putah Creek Accord/Settlement Agreement flow requirements at I80 Road Bridge
Putah Creek	REG Putah Creek Outfall to Toe Drain	2000 Putah Creek Accord/Settlement Agreement flow requirements at Outfall to Toe Drain
Rubicon River	REG Rubicon blw Rubicon Dam	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Rubicon River	REG Rubicon River blw Hell Hole	FERC P-2079 license (issued March 13, 1963) PCWA Middle Fork American River Project

River	Name	Description
Sacramento River	REG Delta Salinity GModel	Delta outflow to meet D-1641 flow requirements using G-model
Sacramento River	REG MRDO	Delta outflow to meet D-1641 flow requirements
Sacramento River	REG Sac at Rio Vista	SWRCB D-1641 flow requirement
Sacramento River	REG Sac blw Keswick	April 5, 1960 MOA between Reclamation and CDFG, SWRCB WR 90-5, 1993 NMFS BO, and predetermined CVPIA 3406(b)(2) flows, and NMFS BO (Jun 2009) Action I.2.2v
Sacramento River	REG X2	Delta outflow to meet D-1641 X2 requirements and USFWS 2009 BO Fall X2 requirement
San Joaquin River	REG Vernalis	Not active
Silver Creek	REG Silver Creek blw Camino Dam	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Silver Creek	REG Silver Creek blw Junction Dam	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
Silver Fork American	REG Silver Creek blw Oyster Creek	FERC P-184 El Dorado Relicensing Settlement Agreement
Slate Creek	REG Slate Creek blw Slate Creek Dam	FERC P-2088 license (issued July 21, 1952) SFWPA South Feather Power Project
South Fork American River	REG SF American blw Kyburz	FERC P-184 El Dorado Relicensing Settlement Agreement
South Fork American River	REG SF American blw Slab Creek Dam	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
South Fork American River	REG SF American nr Placerville	FERC P-2155 license (issued August 20, 2014), PG&E Chili Bar Project
South Fork Rubicon River	REG SF Rubicon blw Robbs Peak Dam	
South Fork Silver Creek	REG Silver Creek blw Ice House	FERC P-2101 license (issued July 23, 2014), SMUD Upper American River Project
South Yuba River	REG South Yuba blw Spaulding Dam	FERC P-2310 license (issued June 24, 1963), PG&E Drum-Spaulding Project
Stony Creek	REG Stony Creek blw Black Butte	Agreement with CDFG
Stony Creek	REG Stony Creek blw Northside Dam	Agreement with CDFG
Stony Creek	REG Stony Creek blw Stony Gorge	Agreement with CDFG
Trinity River	REG Trinity River blw Lewiston	2001 Trinity River Record of Decision
West Branch Feather River	REG WB Feather blw Hendricks Dam	FERC P-803 license PG&E DeSabla-Centerville Project
Yuba River	REG North Yuba blw New Bullards Bar Dam	FERC P-2246 license (issued May 16, 1963) YCWA Yuba River Development Project
Yuba River	REG Yuba River nr Marysville	Lower Yuba River Accord/SWRCB Revised WRD-1644
Yuba River	REG Yuba River nr Smartville	Lower Yuba River Accord/SWRCB Revised WRD-1644

Key:
abv = above, blw = below, BiOp = Biological Opinion, CFW = Camp Far West, CVPIA = Central Valley Improvement Act, DWR = Department of Water Resources, FERC = Federal Energy Regulatory Commission, ID = Irrigation District, IFR = instream flow requirement, MF = Middle Fork MOU = Memorandum of Understanding, NF = North Fork, nr = near, SMUD = Sacramento Municipal Utility District, SWRCB = State Water Resources Control Board, WB = West Branch, WD = Water District, WRD = Water Right Decision.

Table 6-10. Operational Flow Requirements Represented in SacWAM

Canal/Tunnel/Pipeline	Name	Priority		Description
		Variable	Value	
Auburn Tunnel	OPS American River Pump Station	N/A	N/A	Deactivated. Model legacy.
Bear River Canal	OPS Halsey PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Bear River Canal NID Wheeling	OPS Bear River Canal NID Wheeling	Upper Watershed Demand	18	Canal capacity available to Nevada ID.
Belden Tunnel	OPS Belden PH	PGE Feather River Operational Objectives	12	Powerhouse capacity for power generation.
Bowman Spaulding Conduit	OPS NID Spill Prevention Bowman Spaulding	NID Operational Objectives	20	Not active
Bowman Spaulding Conduit	OPS PGE Power Contract	NID Operational Objectives	20	Target flows under 1963 Power Contract between PG&E-Nevada ID.
Brush Creek Tunnel	OPS Brush Creek Tunnel	RouteThruPowerhouse	99	9,999 cfs. Preferentially route water through Camino powerhouse.
Buck Grizzly Tunnel	OPS Grizzly Creek PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Bucks Creek Powerhouse	OPS Bucks Creek PH	PGE Feather River Operational Objectives	12	Powerhouse capacity for power generation.
California Aqueduct	OPS CA Health and Safety	SWP Export Pumping Health and Safety	35	Minimum flow for Health and Safety
CalSim II Hydrology Adjustment Outflow	OPS Bias Correction Freeport Outflow	Headflow Adjustment	1	Time series of outflows to adjust SacWAM hydrology to that of CalSim II.
Camino Conduit	OPS Camino Conduit PH	SMUD Power Generation	12	Powerhouse capacity for power generation.
Camp Creek	OPS Camp Creek blw Div Dam	RouteThruStream	98	Bypass flow.
Camptonville Tunnel	OPS Camptonville Tunnel	N/A	N/A	Deactivated. Model legacy.
Caribou PH 1 and 2	OPS Caribou PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Chalk Bluff Canal	OPS Deer Creek PH	N/A	N/A	Deactivated. Model legacy.
Chicago Park Flume	OPS Chicago Park PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Clear Creek Tunnel	OPS Baseline Trinity Imports		1	Equal to baseline simulation when key assumption Use Baseline Trinity Imports = 1
Clear Creek Tunnel	OPS Trinity Import for Reservoir Balancing	CVP Trinity River Imports Base	48	Used to balance storage in Trinity and Shasta reservoirs
Clear Creek Tunnel	OPS Import Spills for Power	CVP Trinity River Imports Additional	49	Import of Trinity Lake spills for power purposes
Clear Creek Tunnel	OPS Trinity Import for Clear Creek IFR	CVP Trinity River Imports Base	48	Import to meet Clear Creek flow requirements
Colgate Powerhouse	OPS Colgate PH	YCWA Power Generation	32	Powerhouse capacity for power generation.
Cresta Tunnel	OPS Cresta PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
CVP Exp 1	OPS CVP Exp 1	Water Accounting	99	CVP use of unused Sate share under COA accounting.
Delta Depletion 1	Ops DD1	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net consumptive use. Otherwise zero.
Delta Depletion 2	Ops DD2	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net

Canal/Tunnel/Pipeline	Name	Priority		Description
		Variable	Value	
				consumptive use. Otherwise zero.
Delta Depletion 3	Ops DD3	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net consumptive use. Otherwise zero.
Delta Depletion 4	Ops DD4	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net consumptive use. Otherwise zero.
Delta Depletion 5	Ops DD5	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net consumptive use. Otherwise zero.
Delta Depletion 6	Ops DD6	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net consumptive use. Otherwise zero.
Delta Depletion 7	Ops DD7	Delta Consumptive Use	35	If Calibration Switches\Simulate Delta Demands=0, pre-processed time series of Delta net consumptive use. Otherwise zero.
Delta-Mendota Canal	OPS DMC Health and Safety	CVP Export Pumping Health and Safety	35	Minimum flow for Health and Safety
Drum Canal	OPS Drum Canal	PGE Drum Spaulding Power Objective	24	Powerhouse capacity for power generation.
Drum Canal	OPS PGE Spill Prevention Drum	PGE YubaBear Operational Objectives	15	Upstream reservoir releases to prevent future spills.
Duncan Creek Tunnel	OPS Duncan Creek Tunnel	RouteThruPowerhouse	99	Tunnel capacity. Preferentially route water to French Meadows Reservoir.
Dutch Flat Flume	OPS Dutch Flat PH No 2	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Dutch Flat Powerhouse No 1	OPS Dutch Flat PH No 1	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Echo Lake Conduit	OPS Echo Lake Conduit	EID Operational Objectives	13	Time series of historical flows.
El Dorado Akin Powerhouse	OPS El Dorado Akin PH	EID Operational Objectives	13	Powerhouse capacity for power generation.
Electra Tunnel	OPS Electra PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
French Meadows Hell Hole Tunnel	OPS French Meadows PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Hamilton Branch Powerhouse	OPS Hamilton Branch PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Headflow Adjustment Bend Bridge Outflow	OPS Headflow adjustment Bend Bridge outflow	Headflow Adjustment	1	Time series of outflows as bias correction on upstream inflows
Headflow Adjustment Butte City Outflow	OPS Headflow adjustment Butte City outflow	Headflow Adjustment	1	Time series of outflows as bias correction on upstream inflows
Hell Hole Tunnel	OPS Middle Fork PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.

Canal/Tunnel/Pipeline	Name	Priority		Description
		Variable	Value	
Jaybird Conduit	OPS Jaybird Conduit PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Jones Fork Tunnel	OPS Jones Fork Tunnel	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Kelly Ridge Powerhouse	OPS Kelly Ridge PH	Upper Watershed Diversions	18	Time series of historical flows.
Knights Landing Ridge Cut	OPS Knights Landing Ridge Cut	N/A	N/A	Deactivated. Model legacy.
Lake Valley Canal	OPS Lake Valley Canal	PGE YubaBear Operational Objectives	15	Repeating 12-month time series of average monthly historical diversions.
Lohman Ridge Tunnel	OPS Lohman Ridge Tunnel	N/A	N/A	Repeating 12-month time series of average monthly historical diversions. Deactivated.
Long Canyon Creek Diversion Tunnel	OPS Long Canyon Creek Diversion Tunnel	Upper Watershed IFRs	6	No flow requirement specified.
Loon Lake Powerplant	OPS Loon Lake PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Los Vaqueros Transfer Pipeline	OPS LVToTransfer	Contra Costa WD Operational Objectives	35	Pre-processed time series data from stand-alone WRIMS-based Los Vaqueros Model
Los Vaqueros Transfer Pipeline	OPS TransferToLV	Contra Costa WD Operational Objectives	35	Pre-processed time series data from stand-alone WRIMS-based Los Vaqueros Model
Lower Boardman Canal	OPS Lower Boardman Canal	N/A	N/A	Deactivated. Model legacy.
Middle Yuba River	OPS StreamFlowPreservation	RouteThruStream	98	Capacity of Camptonvile Tunnel.
Milton Bowman Tunnel	OPS NID Spill Prevention Milton Bowman	NID Operational Objectives	20	Not active.
Mokelumne Aqueduct	OPS Mokelumne Aqueduct	Upper Watershed Diversions	18	Deactivated. Model legacy.
Mokelumne Los Vaqueros Intertie	OPS Mokelumne Intertie	NonProject Trib Demand	30	Not simulated – flow requirement set to zero.
Mokelumne River	OPS Mokelumne blw Electra PH Base	Upper Watershed IFRs	6	Lodi Decree flow requirements
Mokelumne River	OPS Mokelumne blw Electra PH Add	PGE NF Mokelumne Operational Objectives	18	Lodi Decree storage requirements
Mokelumne River	OPS Thermal Stratification	EBMUD Operational Objectives	33	Pardee Dam release requirement to avoid thermal stratification in Camanche Reservoir.
Narrows Powerhouse I and II	OPS NarrowPH	YCWA Power Generation	32	Powerhouse capacity for power generation.
Oak Flat Powerhouse	OPS Oak Flat PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Old River Pipeline	OPS OR Pipeline	N/A	N/A	Deactivated. Model legacy.
Oxbow Powerhouse	OPS Oxbow PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Palermo Canal	OPS Palermo Canal	Urban NonProject	36	Repeating 12-month time series of average monthly historical diversions.
Pardee to Amador	OPS Pardee to Amador	Upper Watershed Diversions	18	Pardee to Lake Amador transfer constrained by capacity and water rights.
Poe Tunnel	OPS Poe PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Power Canal	OPS Power Canal	RouteThruPowerhouse	99	15,000 cfs. Used to route water through Power Canal rather than low flow channel.

Canal/Tunnel/Pipeline	Name	Priority		Description
		Variable	Value	
Prattville Tunnel	OPS Butt Valley PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Ralston Tunnel	OPS Ralston Tunnel	PCWA Operational Objectives	varies	Powerhouse capacity for power generation.
Robbs Peak Tunnel	OPS Robbs Peak Tunnel	SMUD Transwatershed Imports	18	Powerhouse capacity for power generation.
Rock Creek Tunnel	OPS Rock Creek PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Rock Slough Intake	OPS RS pumping	Contra Costa WD Operational Objectives	35	Pre-processed time series data from stand-alone WRIMS-based Los Vaqueros Model
Sacramento River	OPS Headflow adjustment Bend Bridge outflow	Headflow Adjustment	1	Time series of outflows as bias correction on upstream inflows
Sacramento River	OPS Headflow adjustment Butte City outflow	Headflow Adjustment	1	Time series of outflows as bias correction on upstream inflows
Sacramento River	OPS Navigation Control Point	Project Trib IFR	42	Flow requirement to maintain sufficient river stage for upstream diversion pumps.
Slate Creek Tunnel	OPS Slate Creek Tunnel	Upper Watershed Diversions	18	Repeating 12-month time series of average monthly historical diversions.
South Canal	OPS Newcastle PH	PGE Drum Spaulding Power Objective	24	Powerhouse capacity for power generation.
South Fork Tunnel	OPS South Fork Tunnel	Upper Watershed Diversions	18	Repeating 12-month time series of average monthly historical diversions.
South Yuba Canal	OPS PGE Spill Prevention SY	PGE YubaBear Operational Objectives	15	Upstream reservoir releases to prevent future spills.
Spring Creek Conduit	OPS Spring Creek Conduit	RouteThruPowerhouse	99	Equal to historical flows when Calibration Switches\Simulate Trinity Imports = 0. Otherwise powerhouse capacity for power generation.
SWP Exp 1	OPS SWP Exp 1	Water Accounting	99	SWP use of unused CVP water under COA accounting
Toadtown Canal	OPS Toadtown Canal	Upper Watershed Diversions	18	Repeating 12-month time series of average monthly historical diversions.
Union Valley Powerhouse	OPS Union Valley PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
West Point Powerhouse	OPS West Point PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
White Rock Tunnel	OPS Whiterock Tunnel	RouteThruPowerhouse	99	Powerhouse capacity for power generation.
Wise Canal	OPS Wise PH	RouteThruPowerhouse	99	Powerhouse capacity for power generation.

Table 6-11. State Water Board Potential Instream Flow Requirements Represented in SacWAM

River	Name	Description
American River	SWRCB American River	Confluence with Sacramento River
American River	SWRCB Folsom	Below Folsom Lake
American River	SWRCB Folsom Inflow	Inflow to Folsom Lake
Antelope Creek	SWRCB Antelope Creek	Confluence with Sacramento River
Battle Creek	SWRCB Battle Creek	Confluence with Sacramento River
Bear River	SWRCB Bear River	Confluence with Sacramento River
Bear River	SWRCB Camp Far West	Below Camp Far West Dam
Bear River	SWRCB Camp Far West Inflow	Inflow to Camp Far West Reservoir
Big Chico Creek	SWRCB Big Chico	Confluence with Sacramento River
Butte Creek	SWRCB Butte Creek	Confluence with Butte Slough
Cache Creek	SWRCB Cache Creek	Confluence with Yolo Bypass
Cache Creek	SWRCB Clear Lake	Below Clear Lake
Calaveras River	SWRCB Calaveras River	Confluence with San Joaquin River
Calaveras River	SWRCB New Hogan	Below New Hogan Dam
Canyon Creek	SWRCB Canyon Creek	Confluence with South Yuba River
Clear Creek	SWRCB Clear Creek	Confluence with Sacramento River
Cosumnes River	SWRCB Cosumnes River	Confluence with Mokelumne River
Cottonwood Creek	SWRCB Cottonwood Creek	Confluence with Sacramento River
Cow Creek	SWRCB Cow Creek	Confluence with Sacramento River
Deer Creek	SWRCB Deer Creek	Confluence with Sacramento River
Feather River	SWRCB Feather River	Confluence with Sacramento River
Feather River	SWRCB Oroville	Below Oroville Dam
Feather River	SWRCB Oroville Inflow	Inflow to Lake Oroville
Mill Creek	SWRCB Mill Creek	Confluence with Sacramento River
Mokelumne River	SWRCB Camanche	Below Camanche Dam
Mokelumne River	SWRCB Camanche Inflow	Inflow to Camanche Reservoir
Mokelumne River	SWRCB Mokelumne River	Upstream from confluence with Cosumnes River
Mokelumne River	SWRCB Pardee Inflow	Inflow to Pardee Reservoir
Putah Creek	SWRCB Lake Berryessa	Below Monticello Dam
Putah Creek	SWRCB Putah Creek	South Fork Putah near Davis
Sacramento River	SWRCB Delta	Net Delta outflow
Sacramento River	SWRCB Sac abv Bend Bridge	USGS Bend Bridge Gauge
Sacramento River	SWRCB Sac at Butte City	DWR Butte City Gauge
Sacramento River	SWRCB Sac at Colusa	Below Colusa Weir
Sacramento River	SWRCB Sac at Freeport	USGS Freeport Gauge
Sacramento River	SWRCB Sac at Hamilton	DWR Hamilton Gauge
Sacramento River	SWRCB Sac at Knights Landing	Below Colusa Basin Drain Outfall
Sacramento River	SWRCB Sac at Ord Ferry	DWR Ord Ferry Gauge
Sacramento River	SWRCB Sac at Rio Vista	Rio Vista Gauge
Sacramento River	SWRCB Sac at Verona	USGS Verona Gauge
Sacramento River	SWRCB Sac at Vina	DWR Vina Bridge Gauge
Sacramento River	SWRCB Sac blw Wilkins Slough	USGS Wilkins Slough Gauge
Sacramento River	SWRCB Shasta	Below Shasta Dam
Stony Creek	SWRCB Black Butte	Below Black Butte Reservoir
Stony Creek	SWRCB Black Butte Inflow	Inflow to Black Butte Reservoir
Stony Creek	SWRCB Stony Creek	Confluence with Sacramento River
Thomes Creek	SWRCB Thomes Creek	Confluence with Sacramento River
Trinity River	SWRCB Trinity	Below Trinity Dam
Yuba River	SWRCB Englebright	Below Englebright Dam
Yuba River	SWRCB Englebright Inflow	Inflow to Englebright Reservoir
Yuba River	SWRCB New Bullards Bar Inflow	Inflow to New Bullards Bar Reservoir
Yuba River	SWRCB Yuba River	Confluence with Sacramento River

Key: DWR = Department of Water Resources; SWRCB = State Water Resources Control Board; USGS = U.S. Geological Survey

6.1.4 Reaches

6.1.4.1 *Inflows and Outflows*

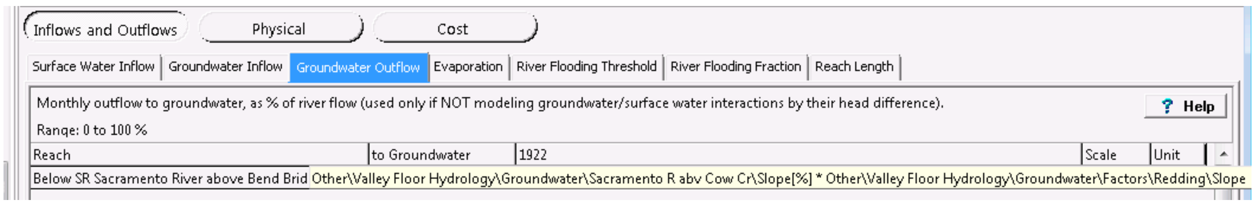
6.1.4.1.1 *Surface Water Inflow*

The WEAP *Surface Water Inflow* feature is not used in SacWAM.

6.1.4.1.2 *Groundwater Inflow*

The WEAP *Groundwater Inflow* feature is used to simulate surface water groundwater interactions. For further details see Section 6.3.1.2.

6.1.4.1.3 *Groundwater Outflow*



The *Groundwater Outflow* feature is used to simulate surface water groundwater interactions. For further details, see Section 6.3.1.2.

6.1.4.1.4 *Evaporation*

The WEAP *Evaporation* feature is not used in SacWAM.

6.1.4.1.5 *River Flooding Threshold*

The WEAP *River Flooding Feature* feature is not used in SacWAM.

6.1.4.1.6 *River Flooding Fraction*

The WEAP *River Flooding Fraction* feature is not used in SacWAM.

6.1.4.1.7 *Reach Length*

The WEAP *River Length* feature is not used in SacWAM.

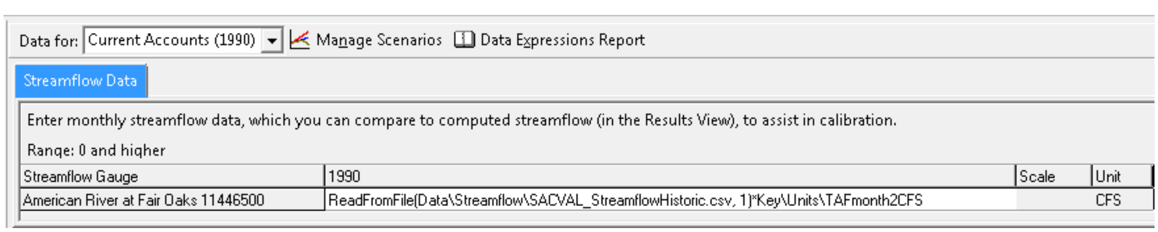
6.1.4.2 *Physical*

The *Physical* WEAP feature is not used in SacWAM.

6.1.4.3 *Cost*

The *Cost* WEAP feature is not used in SacWAM.

6.1.5 Streamflow Gauges



Streamflow gauges are used to provide comparisons between simulated and observed values of flow. In SacWAM, observed data are read from a SACVAL_StreamflowHistoric.csv file located in Data\Streamflow within the model area directory.

6.1.5.1 Streamflow Data

Streamflow gauge data are used in SacWAM to facilitate assessment of model performance. In some cases, the streamflow gauge objects in the model represent computed full natural flows or estimates of unimpaired flows. To differentiate between actual observed flow data, full natural flows, and estimated unimpaired flows each gauge has been assigned a prefix of 'HIS', 'FNF', or 'EST'. The streamflow gauges that are represented in SacWAM are listed in Table 6-12 by type.

6.1.5.1.1 Historical

Historical streamflow data were obtained from the USGS 'Current Water Data for the Nation' website (USGS, 2016a), DWR's Water Data Library (DWR, 2014c), DWR's CDEC (DWR, 2014d) and by contacting DWR directly. Historical streamflow data are saved in a csv file and contained in the SacWAM directory (Data\Streamflow\SACVAL_StreamflowHistoric.csv). For more information regarding streamflow data, refer to the **streamflow gauges**.

6.1.5.1.2 Full Natural Flow

SacWAM gauges that represent full natural flow (the calculated flow that would be in the river without any upstream infrastructure) are designated with the prefix 'FNF' and are equal to the sum of upstream inflow arc flows.

6.1.5.1.3 Estimated

Additional gauge objects have been added to SacWAM where historical flows can be reliably estimated from downstream gauges and/or reservoir releases. These gauge objects are designated with the prefix 'EST'.

Table 6-12. Streamflow Gauges Represented in SacWAM

River	Gauge	Gauge ID
Gauges estimated using water balance method (indicated by prefix 'EST')		
Jackson Creek	EST Amador Res inflow	N/A
Bear River	EST Camp Far West inflow	N/A
Cache Creek	EST Clear Lake Inflows	N/A
Cow Creek	EST COW014	N/A
Dry and Hutchinson Creeks	EST Dry and Hutchinson Ck	N/A
Dry Creek Mok	EST DSC035	N/A
Little Stony Creek	EST East Park Res Inflow	N/A
Littlejohns Creek	EST Farmington Res Inflow	N/A
American River	EST Folsom Res Inflow	N/A
Fordyce Creek	EST Fordyce Res Inflow	N/A
North Fork Cache Creek	EST Indian Valley Res inflow	N/A
Middle Yuba River	EST Jackson Meadows Res Inflow	N/A
Knights Landing Ridge Cut	EST KLRC	N/A
Putah Creek	EST Lake Berryessa Inflow	N/A
Little Chico Creek	EST LCC038	N/A
Little Dry Creek	EST Little Dry Ck	N/A
South Fork Feather River	EST Little Grass Valley Res Inflow	N/A
Kellogg Creek	EST Los Vaqueros Res Inflow	N/A
French Dry Creek	EST Merle Collins Res Inflow	N/A
Marsh Creek	EST MSH015	N/A
Calaveras River	EST New Hogan Res Inflow	N/A
Feather River	EST Oroville Res Inflow	N/A
Sacramento River	EST Shasta Lake Inflow	N/A
Trinity River	EST Trinity Res Inflow	N/A
Gauges where full natural flow data are available (indicated by prefix 'FNF')		
American River	FNF American at Fair Oaks	N/A
Bear River	FNF Bear at Camp Far West	N/A
Bear River	FNF Bear River nr Wheatland	N/A
Butte Creek	FNF Butte Ck nr Chico	N/A
Cache Creek	FNF Cache Ck at Rumsey	N/A
Calaveras River	FNF Calaveras nr Bellota	N/A
Mokelumne River	FNF Camanche Res Inflow	N/A
Canyon Creek	FNF Canyon Ck blw Bowman	N/A
Clear Creek	FNF Clear Ck nr Igo	N/A
Cosumnes River	FNF Cosumnes at Michigan Bar	N/A
Feather River	FNF Feather at Oroville	N/A
Middle Fork Feather River	FNF MF Feather nr Merrimac	N/A
Middle Yuba River	FNF MF Yuba blw Our House Dam	N/A
Mokelumne River	FNF Mokelumne at Mokelumne Hill	N/A
Mokelumne River	FNF Mokelumne at Pardee	N/A
Bear River	FNF Rollins Res Inflow	N/A
South Fork Feather River	FNF SF Feather at Ponderosa	N/A
South Yuba River	FNF SF Yuba at Jones Bar	N/A
Silver Creek	FNF Silver Cr at Union Valle	N/A
Stony Creek	FNF Stony Ck at Black Butte	N/A
Stony Creek	FNF Stony Ck at Stony Gorge	N/A
Trinity River	FNF Trinity at Lewiston	N/A
West Branch Feather River	FNF WB Feather nr Yankee Hill	N/A
Clear Creek	FNF Whiskeytown Res Inflow	N/A
Yuba River	FNF Yuba River at Smartville	N/A
Gauges where observed historical mean monthly flow data are available (indicated by prefix 'HIS')		
American River	HIS American at Fair Oaks	USGS 11446500
Antelope Creek	HIS Antelope Ck nr Red Bluff	USGS 11379000

River	Gauge	Gauge ID
California Aqueduct	HIS Banks PP	CDEC HRO
North Bay Aqueduct	HIS Barker Slough Pumping Plant	CDEC BKS
Battle Creek	HIS Battle Ck nr Cottonwood	USGS 11376550
Bear Creek	HIS Bear Ck nr Millville	USGS 11374100
Bear River	HIS Bear blw Drum Afterbay	USGS 11421750; 60; 70
Bear River	HIS Bear blw Rollins Dam	USGS 11422500
Bear River	HIS Bear bw Dutch Flat Afterbay	USGS 11421780; 11421790
Bear River	HIS Bear River blw Combie Dam	NID BR386
Bear River	HIS Bear River at Pleasant Grove Road	DWR A06535
Bear River (Mokelumne watershed)	HIS Bear River blw Diversion Dam	USGS 11316100
Bear River	HIS Bear nr Wheatland	USGS 11424000
Bear River Canal	HIS Bear River Canal at Intake	USGS 11422000
Belden Tunnel	HIS Belden Powerhouse	USGS 11403050
Big Chico Creek	HIS Big Chico Ck nr Chico	USGS 11384000
Stony Creek	HIS Black Butte Dam Release	USACE
Bowman Spaulding Conduit	HIS Bowman Spaulding Canal at Intake	USGS 11416000
Brush Creek	HIS Brush Ck blw Diversion Dam	USGS 11442700
Buck Loon Tunnel	HIS Buck Loon Tunnel	USGS 11428300
Bucks Creek	HIS Bucks Ck blw Diversion Dam	USGS 11403530
Bucks Creek Powerhouse	HIS Bucks Ck Powerhouse	USGS 11403700
Prattville Tunnel	HIS Butt Valley Powerhouse	USGS 11400600
Butte Creek	HIS Butte Ck nr Chico	USGS 11390000
Butte Creek	HIS Butte Ck nr Durham	USGS 11390010
Butte Slough	HIS Butte Slough nr Meridian	DWR A02972
Butte Slough Outfall Gates	HIS Butte Slough Outfall Gates	DWR A02967
Cache Creek	HIS Cache Ck abv Rumsey	USGS 11451760
Cache Creek	HIS Cache Ck at Yolo	USGS 11452500
Cache Creek	HIS Cache Ck nr Lower Lake	USGS 11451000
Camptonville Tunnel	HIS Camptonville Tunnel at Intake	USGS 11409350
Canyon Creek	HIS Canyon Ck blw Bowman	USGS 11416500
Caribou PH 1 and 2	HIS Caribou Powerhouse	USGS 11401110
Chicago Park Powerhouse	HIS Chicago Park PH	USGS 11421780
Clear Creek	HIS Clear Ck nr Igo	USGS 11372000
Cole Creek	HIS Cole Creek blw Diversion Dam	USGS 11315000
Colusa Basin Drain	HIS Colusa Basin Drain at Knights Landing	DWR A02945
Colusa Basin Drain	HIS Colusa Basin Drain nr Highway 20	DWR A02976
Colusa Weir	HIS Colusa Weir Spill to Butte Basin	DWR A02981
Contra Costa Canal	HIS Contra Costa Canal	CDEC INB
Cosumnes River	HIS Cosumnes at Michigan Bar	USGS 11335000
Cottonwood Creek	HIS Cottonwood Ck nr Cottonwood	USGS 11376000
Cottonwood Creek	HIS Cottonwood Ck nr Olinda	USGS 11375810
Cow Creek	HIS Cow Ck nr Millville	USGS 11374000
Cresta Tunnel	HIS Cresta Powerhouse	USGS 11404360
Deer Creek Yuba	HIS Deer Ck nr Smartville	USGS 11418500
Deer Creek	HIS Deer Ck nr Vina	USGS 11383500
Chalk Bluff Canal	HIS Deer Ck Powerhouse nr Washington	USGS 11414205
Drum Canal	HIS Drum Canal at Tunnel Outlet	USGS 11414170
Dry Creek Mok	HIS Dry Ck nr Ione	USGS 11328000
Duncan Creek	HIS Duncan Canyon Ck blw Diversion Dam	USGS 11427750
Dutch Flat Powerhouse No. 1	HIS Dutch Flat Powerhouse No. 1	USGS 11421750
Dutch Flat Powerhouse No. 2	HIS Dutch Flat Powerhouse No. 2	USGS 11421760
El Dorado Canal	HIS El Dorado Canal nr Kyburz	USGS 11439000
Elder Creek	HIS Elder Ck nr Paskenta	USGS 11379500
Feather River	HIS Feather at Oroville	USGS 11407000
Feather River	HIS Feather nr Nicolaus	USGS 11425000

River	Gauge	Gauge ID
Feather River	HIS Feather River nr Gridley	DWR A05165
Folsom South Canal	HIS Folsom South Canal	CDEC FSC
Fordyce Creek	HIS Fordyce Ck blw Fordyce Dam	USGS 11414100
Fremont Weir	HIS Freemont Weir Spill	DWR A02930
French Meadows Hell Hole Tunnel	HIS French Meadows Powerhouse	USGS 11427200
Georgiana Slough	HIS Georgiana Slough	USGS 11447903
Gerle Creek	HIS Gerle Ck blw Loon Lake	USGS 11429500
Loon Lake Powerplant	HIS Gerle Ck Powerplant	USGS 11429340
Glenn-Colusa Canal	HIS Glenn Colusa Canal	N/A
Grizzly Creek	HIS Grizzly Ck blw Diversion Dam	USGS 11404300
Buck Grizzly Tunnel	HIS Grizzly Creek Powerhouse	USGS 11404240
Bear River Canal	HIS Halsey Powerhouse	USGS 11425310
Joint Board Canal	HIS Joint Board Canal	USGS 11406910
Jones Fork Tunnel	HIS Jones Fork Powerhouse	USGS 11440900
Delta Mendota Canal	HIS Jones PP	CDEC TRP
Clear Creek Tunnel	HIS Judge Francis Carr Powerhouse	USGS 11525430
Kelly Ridge Powerhouse	HIS Kelly Ridge Powerhouse nr Oroville	USGS 11396329
Lake Valley Canal	HIS Lake Valley Canal	USGS 11426190
Little Rubicon River	HIS Little Rubicon River blw Buck Island	USGS 11428400
Lohman Ridge Tunnel	HIS Lohman Ridge Tunnel at Intake	USGS 11408870
Marsh Creek	HIS Marsh C nr Byron	USGS 11337500
McCloud River	HIS McCloud R abv Shasta Lk	USGS 11368000
Middle Fork American River	HIS MF American abv MF Powerhouse	USGS 11427760
Middle Fork American River	HIS MF American at French Meadows	USGS 11427500
Middle Fork American River	HIS MF American nr Foresthill	USGS 11433300
Middle Fork Feather River	HIS MF Feather nr Merrimac	USGS 11394500
Middle Fork Mokelumne River	HIS MF Mokelumne nr West Point	USGS 11317000
Middle Yuba River	HIS MF Yuba bl Milton Dam	USGS 11408550
Middle Yuba River	HIS MF Yuba blw Our House Dam	USGS 11408880
Hell Hole Tunnel	HIS Middle Fork Powerhouse	USGS 11428600
Mill Creek	HIS Mill Ck nr Los Molinos	USGS 11381500
Milton Bowman Tunnel	HIS Milton Bowman Tunnel at Outlet	USGS 11408000
Mokelumne Aqueduct	HIS Mokelumne Aqueduct	EBMUD
Mokelumne River	HIS Mokelumne at Mokelumne Hill	USGS 11319500
Mokelumne River	HIS Mokelumne at Woodbridge	USGS 11325500
Mokelumne River	HIS Mokelumne River blw Camanche Dam	USGS 11323500
Moulton Weir	HIS Moulton Weir Spill	DWR A02986
South Canal	HIS Newcastle PP nr Newcastle	USGS 11425416
North Fork American River	HIS NF American at NF Dam	USGS 11427000
North Fork American River	HIS NF American nr Colfax	USGS 11426500
North Fork Cache Creek	HIS NF Cache Ck nr Clear Lake Oaks	USGS 11451300
North Fork Feather River	HIS NF Feather at Pulga	USGS 11404500
North Fork Feather River	HIS NF Feather bw Rock Creek Dam	USGS 11403200
North Fork Feather River	HIS NF Feather blw Belden Dam	USGS 11401112
North Fork Feather River	HIS NF Feather nr Prattville	USGS 11399500
North Fork Mokelumne River	HIS NF Mokelumne blw Electra Dam	USGS 11316700
North Fork Mokelumne River	HIS NF Mokelumne bw Salt Springs	USGS 1131400; 11314500
Yuba River	HIS NF Yuba blw Goodyears Bar	USGS 11413000
Oregon Creek	HIS Oregon Ck blw Log Cabin Dam	USGS 11409400
Paynes Creek	HIS Paynes and Sevenmile Cks	USGS 11377500
Pilot Creek	HIS Pilot Ck blw Mutton Canyon	USGS 11433040
Pit and Upper Sacramento River	HIS Pit R near Montgomery Ck	USGS 11365000
Pit and Upper Sacramento River	HIS Pit R nr Bieber	USGS 11352000
Poe Tunnel	HIS Poe Powerhouse	USGS 11404900
Putah Creek	HIS Putah Ck blw Diversion Dam	USBR

River	Gauge	Gauge ID
Putah Creek	HIS Putah Ck nr Winters	USGS 11454000
Putah South Canal	HIS Putah South Canal	USGS 11454210
Ralston Tunnel	HIS Ralston Powerplant	USGS 11427765
Richvale Canal	HIS Richvale Canal	USGS 11406890
Robbs Peak Tunnel	HIS Robbs Peak PP	USGS 11429300
Rock Creek Tunnel	HIS Rock Creek Powerhouse	USGS 11403800
Rubicon River	HIS Rubicon blw Hell Hole Dam	USGS 11428800
Rubicon River	HIS Rubicon River blw Rubicon Lake	USGS 11427960
Honcut Creek	HIS S Honcut Ck nr Bangor	USGS 11407500
Sacramento River	HIS Sacramento abv Bend Bridge	USGS 11377100
Sacramento River	HIS Sacramento at Butte City	USGS 11389000
Sacramento River	HIS Sacramento at Colusa	USGS 11389500
Sacramento River	HIS Sacramento at Freeport	USGS 11447650
Sacramento River	HIS Sacramento at Hamilton City	DWR A02630
Sacramento River	HIS Sacramento at Keswick	USGS 11370500
Sacramento River	HIS Sacramento at Ord Ferry	DWR A02570
Sacramento River	HIS Sacramento at Verona	USGS 11425500
Sacramento River	HIS Sacramento at Vina	DWR A02700
Sacramento River	HIS Sacramento River abv Delta	USGS 11342000
Sacramento River	HIS Sacramento River at Rio Vista	USGS 11455420
Sacramento River	HIS Sacramento River blw Wilkins Slough	USGS 11390500
Salt Springs Powerhouse No. 2	HIS Salt Springs Powerhouse near WestPoint	USGS 11313510
Sutter Bypass	HIS Sacramento Slough nr Karnak	DWR A02925
Sacramento Weir	HIS Sacramento Weir	USGS 11426000
San Joaquin River	HIS San Joaquin nr Vernalis	USGS 11303500
South Fork American River	HIS SF American nr Kyburz	USGS 11439500
South Fork American River	HIS SF American nr Placerville	USGS 11444500
South Fork Cottonwood Creek	HIS SF Cottonwood Ck nr Olinda	USGS 11375870
South Fork Feather River	HIS SF Feather blw Diversion Dam	USGS 11395200
South Fork Feather River	HIS SF Feather blw Forbestown	USGS 11396200; 11396290
South Fork Feather River	HIS SF Feather blw Little Grass Valley	USGS 11395030
South Fork Mokelumne River	HIS SF Mokelumne nr West Point	USGS 11318500
South Fork Silver Creek	HIS SF Silver Ck nr Ice House	USGS 11441500
South Yuba River	HIS SF Yuba at Jones Bar	USGS 11417500
Silver Creek	HIS Silver Ck blw Camino Dam	USGS 11441900
Silver Creek	HIS Silver Ck blw Junction Dam	USGS 11441800
Silver Creek	HIS Silver Creek	USGS 11442000
Slate Creek Tunnel	HIS Slate Ck Diversion Tunnel	USGS 11413250
Slate Creek	HIS Slate Creek blw Diversion Dam	USGS 11413300
South Fork Tunnel	HIS South Fork Tunnel nr Strawberry	USGS 11395150
South Yuba Canal and Wasteway	HIS South Yuba Canal nr Emigrant Gap	USGS 11414200
Spring Creek Conduit	HIS Spring Creek Powerhouse at Keswick	USGS 11371600
Tehama Colusa Canal	HIS Tehama Colusa Canal	USBR
Power Canal	HIS Thermalito Afterbay Release	USGS 11406920
Power Canal	HIS Thermalito Power Plant	USGS 11406850
Thomes Creek	HIS Thomes Ck at Paskenta	USGS 11382000
Tiger Creek	HIS Tiger Creek below Regulator Reservoir	USGS
Tiger Creek Conduit	HIS Tiger Creek Conduit blw Salt Springs Dam	USGS 11314000
Tiger Creek Powerhouse	HIS Tiger Creek Powerhouse nr West Point	USGS 11316610
Tisdale Weir	HIS Tisdale Weir Spill to Sutter Bypass	DWR A02960
Toadtown Canal	HIS Toadtown Canal abv Butte Canal	USGS 11389800
Trinity River	HIS Trinity at Lewiston	USGS 11525500
Union Valley Powerhouse	HIS Union Valley Powerhouse	USGS 11441002
Western Canal	HIS Western Canal and PGE Lateral	USGS 11406880; 11406900
White Rock Tunnel	HIS White Rock Powerplant	USGS 11443460

River	Gauge	Gauge ID
Wise Canal	HIS Wise Powerhouse nr Auburn	USGS 11425415
Yolo Bypass	HIS Yolo Bypass nr Woodland	USGS 11453000
Yuba River	HIS Yuba blw Englebright nr Smartville	USGS 11418000
Yuba River	HIS Yuba River nr Marysville	USGS 11421000
Jaybird Conduit	HIS Jaybird Powerhouse	USGS 11441780
Long Canyon Creek	HIS Long Canyon nr French Meadows	USGS 11433100
Middle Fork American River	HIS MF American blw Interbay Dam	USGS 11427770
Rock Creek	HIS Rock Creek and Powerhouse	USGS 11444201; 11444280
South Fork American River	HIS SF American nr Camino	USGS 11443500
South Fork Rubicon River	HIS SF Rubicon River blw Gerle	USGS 11430000

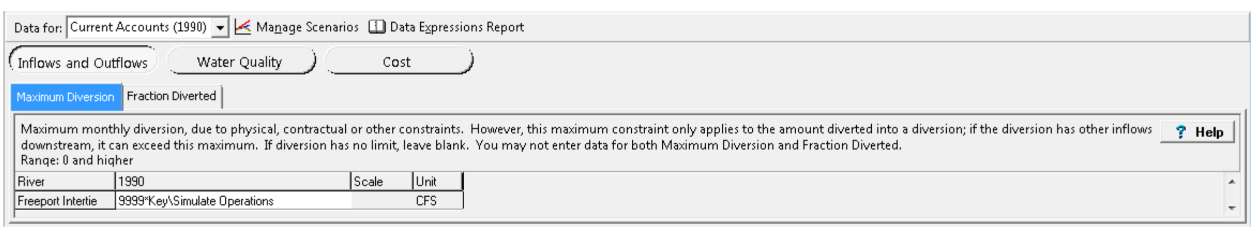
Key:
abv = above, blw = below, CDEC = California Data Exchange Center, Ck = creek, DWR = Department of Water Resources, EBMUD = East Bay Municipal Utility District, EST = estimated flows, FNF = full natural flow, HIS = historical observed monthly flows, nr = near, PP = pumping plant, Res = reservoir, USACE = U.S. Army Corps of Engineers, USBR = U.S. Bureau of Reclamation, USGS = U.S. Geological Survey.

6.2 Diversion

Diversion arcs typically represent conveyance facilities, including canals, pipelines, tunnels, and hydropower penstocks. They are represented by orange arcs in the SacWAM schematic. In the WEAP data tree, 'Diversions' are aggregated with 'Rivers.' However, some of the diversion object properties differ from those for rivers. The head of a diversion branch includes *Inflows and Outflow*, *Water Quality*, and *Cost* features. The WEAP *Water Quality* and *Cost* features for diversions are not used. The *Inflows and Outflows* feature is described below.

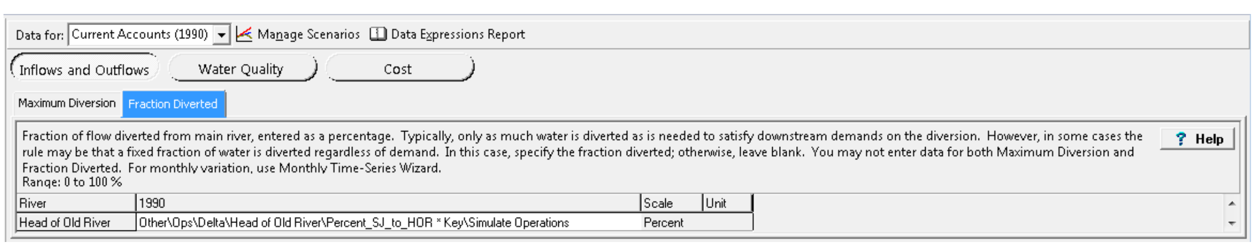
6.2.1 Inflows and Outflows

6.2.1.1 Maximum Diversion



The maximum diversion parameter is used to limit the flow through a diversion arc. In SacWAM, this parameter is used to restrict flow through a canal or pipeline to its physical limit. See **maximum diversions** for more information.

6.2.1.2 Fraction Diverted



The *Fraction Diverted* parameter is only occasional used in SacWAM. For the head of the Old River, the inflow is expressed as a fraction of the upstream flow in the San Joaquin River (*Other\Ops\Delta\Head of*

*Old River\Percent_SJ_to_HOR * Key\Simulate Operations*). Elsewhere this parameter is used to simulate canal seepage losses.

6.2.2 Reaches

6.2.2.1 Inflows and Outflows

6.2.2.1.1 Surface Water Inflow

The WEAP *Surface Water Inflow* feature for diversions is not used in SacWAM.

6.2.2.1.2 Groundwater Inflow and Groundwater Outflow

Some *Reaches* include expressions for groundwater inflow and outflow. These parameters are controlled through *Other Assumptions* and explained in Chapter 7.

6.2.2.1.3 Evaporation

The WEAP *River Evaporation* feature is not used in SacWAM.

6.2.2.1.4 River Flooding Threshold

The WEAP *River Flooding Threshold* feature for diversions is not used in SacWAM.

6.2.2.1.5 River Flooding Fraction

The WEAP *River Flooding Fraction* feature for diversions is not used in SacWAM.

6.2.2.1.6 Reach Length

The WEAP *River Length* feature for diversions is not used in SacWAM.

6.2.2.2 Physical

The WEAP *Physical* feature for diversions is not used in SacWAM.

6.2.2.3 Cost

The WEAP *Cost* feature for diversions is not used in SacWAM.

6.3 Groundwater

SacWAM includes ten groundwater basins, and each basin is represented using a groundwater object on the model schematic. Vertical recharge to the groundwater basins includes deep percolation from agricultural, urban, and refuge areas represented by the demand unit catchment objects, deep percolation from treated wastewater associated with urban demand sites, and conveyance losses on the surface water distribution systems represented by losses to groundwater on transmission links. Vertical stresses also include groundwater pumping to meet demands in the catchments and demand sites. The groundwater nodes also interact with the stream network through the *Groundwater Inflow* and *Groundwater Outflow* parameters on stream reaches. No subsurface lateral flows are simulated between the groundwater basins. Details of the groundwater schematic representation are presented in Section 3-4.

6.3.1 Deep Percolation

To simulate deep percolation from irrigation and rainfall, an analysis was conducted to determine which groundwater basin receives recharge from each DU. The aggregated **groundwater basins** were intersected with the SacWAM DUs to produce the **groundwater basin intersection** shapefile. This intersection determined the percentage of each DU within one or more groundwater basins. The post-intersection processing is documented in the **gw basins spreadsheet**.

The information in the **groundwater basin intersection** shapefile was used to specify the destination of infiltration links (dashed blue line) from catchments and return flow links (solid red line) from urban demand sites. If the DU overlaid multiple groundwater basins, the relative proportions determined by the spatial intersection described above were used to disaggregate the flows. A listing of each agricultural, urban, and refuge DU and their associated links to groundwater basins is provided in Table 6-13.

Where the percentage of a DU that lies within a groundwater basin is less than or equal to 10%, the infiltration or runoff link is not represented on the schematic and proportions were recalculated with the groundwater basin portions less than or equal to 10% omitted from the total area.

6.3.2 Groundwater Pumping

Similar to deep percolation, the information in the **groundwater basin intersection** shapefile was used to determine the sources of groundwater for agricultural, urban, and refuge demand DUs (Table 6-13). All agricultural and refuge DUs have at least one groundwater source in SacWAM. Urban DUs either are supplied entirely by groundwater, or conjunctively use surface water and groundwater. Minimum and maximum levels were of groundwater pumping were established for each DU.

Refuges and managed wetlands have limited access to groundwater. In SacWAM, only Gray Lodge WA and Upper Butte Wildlife Area are assumed to pump groundwater.[27]

6.3.2.1 Minimum Groundwater Pumping

The minimum amount of groundwater pumping for a DU is set by constraining the maximum percentage of the demand that can be met by surface water. This constraint was calculated based on an analysis of the areal extent of the surface water delivery infrastructure. For instance, if 60% of a DU’s cropped area overlaps a surface water delivery service area then the maximum percentage of the demand that can be met by surface water was set to 60%. – equivalent to a minimum groundwater pumping constraint of 40% of demand. This constraint was implemented using the *Maximum Flow Percent of Demand* parameter for transmission links connecting catchments or demand sites to a surface water source. In cases where a DU has more than one surface water supply, a UDC was created that restricted the total

[27] Historically, a total of 21 groundwater wells have been used to supplement surface water deliveries to Gray Lodge WA and to supply water to parts of the wildlife area that cannot be irrigated by gravity flow from surface supplies. In 2011, new groundwater wells were installed in the wildlife area. All three units of the Upper Butte Wildlife Area have access to groundwater. The Little Dry Creek Unit has six groundwater wells, the Howard Slough Unit has five wells, and the Llano Seco Unit has a single well.

surface water supply to a fraction of the total water requirement. The fraction is calculated as 1-*Minimum Groundwater Pumping Factor.* For more information, see Section 8.20.

6.3.2.2 Maximum Groundwater Pumping

The maximum amount of groundwater pumping is specified using the *Maximum Flow Percent of Demand* parameter on transmission links connecting catchments and demand sites to groundwater sources. These parameter values were derived from information contained in DWR county land use surveys (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a).

Table 6-13. Deep Percolation Destinations and Groundwater Sources

Demand Unit	Deep Percolation to Groundwater Basin(s)	Groundwater Source(s)
Agricultural Demand Units		
A_02_NA	Redding (100%)	Redding (100%)
A_02_PA	Redding (100%)	Redding (100%)
A_02_SA	Redding (100%)	Redding (100%)
A_03_NA	Redding (100%)	Redding (100%)
A_03_PA	Redding (100%)	Redding (100%)
A_03_SA	Redding (100%)	Redding (100%)
A_04_06_NA1	Red Bluff Corning (35%); Colusa (65%)	Red Bluff Corning (35%); Colusa (65%)
A_04_06_NA2	Red Bluff Corning (100%)	Red Bluff Corning (100%)
A_04_06_PA1	Red Bluff Corning (100%)	Red Bluff Corning (100%)
A_04_06_PA2	Red Bluff Corning (100%)	Red Bluff Corning (100%)
A_05_NA	Red Bluff Corning (100%)	Red Bluff Corning (100%)
A_07_NA	Colusa (100%)	Colusa (100%)
A_07_PA	Colusa (100%)	Colusa (100%)
A_08_NA	Red Bluff Corning (14%); Colusa (86%)	Red Bluff Corning (14%); Colusa (86%)
A_08_PA	Colusa (100%)	Colusa (100%)
A_08_SA1	Colusa (100%)	Colusa (100%)
A_08_SA2	Colusa (100%)	Colusa (100%)
A_08_SA3	Colusa (100%)	Colusa (100%)
A_09_NA	Butte (100%)	Butte (100%)
A_09_SA1	Butte (100%)	Butte (100%)
A_09_SA2	Butte (100%)	Butte (100%)
A_10_NA	Butte (100%)	Butte (100%)
A_11_NA	Sutter Yuba (15%); Butte (85%)	Sutter Yuba (15%); Butte (85%)
A_11_SA1	Butte (100%)	Butte (100%)
A_11_SA2	Butte (100%)	Butte (100%)
A_11_SA3	Butte (100%)	Butte (100%)
A_11_SA4	Sutter Yuba (100%)	Sutter Yuba (100%)
A_12_13_NA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_12_13_SA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_14_15N_NA1	Sutter Yuba (100%)	Sutter Yuba (100%)
A_14_15N_NA2	Sutter Yuba (100%)	Sutter Yuba (100%)
A_14_15N_NA3	Sutter Yuba (100%)	Sutter Yuba (100%)
A_14_15N_SA	Sutter Yuba (87%); Butte (13%)	Sutter Yuba (87%); Butte (13%)
A_15S_NA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_15S_SA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_16_NA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_16_PA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_16_SA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_17_NA	Sutter Yuba (50%); Butte (50%)	Sutter Yuba (50%); Butte (50%)
A_17_SA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_18_19_NA	Sutter Yuba (100%)	Sutter Yuba (100%)
A_18_19_SA	Sutter Yuba (100%)	Sutter Yuba (100%)

Demand Unit	Deep Percolation to Groundwater Basin(s)	Groundwater Source(s)
A_20_25_NA1	Yolo Solano (81%); Colusa (19%)	Yolo Solano (81%); Colusa (19%)
A_20_25_NA2	Yolo Solano (100%)	Yolo Solano (100%)
A_20_25_PA	Yolo Solano (100%)	Yolo Solano (100%)
A_21_NA	Yolo Solano (39%); Colusa (61%)	Yolo Solano (39%); Colusa (61%)
A_21_PA	Yolo Solano (38%); Colusa (62%)	Yolo Solano (38%); Colusa (62%)
A_21_SA	Yolo Solano (81%); Colusa (19%)	Yolo Solano (81%); Colusa (19%)
A_22_NA	American (100%)	American (100%)
A_22_SA1	American (100%)	American (100%)
A_22_SA2	American (100%)	American (100%)
A_23_NA	American (100%)	American (100%)
A_24_NA1	American (100%)	American (100%)
A_24_NA2	American (100%)	American (100%)
A_24_NA3	American (100%)	American (100%)
A_26_NA	American (100%)	American (100%)
A_50_NA1	Delta (100%)	Delta (100%)
A_50_NA2	Delta (100%)	Delta (100%)
A_50_NA3	Delta (100%)	Delta (100%)
A_50_NA4	Delta (100%)	Delta (100%)
A_50_NA5	Delta (100%)	Delta (100%)
A_50_NA6	Delta (100%)	Delta (100%)
A_50_NA7	Delta (100%)	Delta (100%)
A_60N_NA1	Cosumnes (100%)	Cosumnes (100%)
A_60N_NA2	Cosumnes (72%); American (28%)	Cosumnes (72%); American (28%)
A_60N_NA3	Eastern San Joaquin (56%); Cosumnes (44%)	Eastern San Joaquin (56%); Cosumnes (44%)
A_60N_NA4	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
A_60N_NA5	Eastern San Joaquin (24%); Cosumnes (76%)	Eastern San Joaquin (24%); Cosumnes (76%)
A_60S_NA	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
A_60S_PA	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
A_61N_PA	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
A_61N_NA1	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
A_61N_NA2	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
A_61N_NA3	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
Urban Demand Units		
U_02_NU	Redding (100%)	Redding (100%)
U_02_PU	Redding (100%)	None
U_02_SU	Redding (100%)	Redding (100%)
U_03_NU	Red Bluff Corning (100%)	Red Bluff Corning (100%)
U_03_PU	Redding (100%)	Redding (100%)
U_03_SU	Redding (100%)	Redding (100%)
U_04_06_NU	Red Bluff Corning (79%), Colusa (21%)	Red Bluff Corning (79%), Colusa (21%)
U_05_NU	Red Bluff Corning (100%)	Red Bluff Corning (100%)
U_07_NU	Colusa (100%)	Colusa (100%)
U_08_NU	Red Bluff Corning (12%), Colusa (88%)	Red Bluff Corning (12%), Colusa (88%)
U_09_NU	Butte (100%)	Butte (100%)
U_10_NU1	Butte (100%)	Red Bluff Corning (62%); Butte (38%)
U_10_NU2	Butte (100%)	Butte (100%)
U_11_NU1	Butte (100%)	None
U_11_NU2	Butte (100%)	Butte (100%)
U_12_13_NU1	Butte (100%)	Sutter Yuba (100%)
U_12_13_NU2	Sutter Yuba (100%)	Sutter Yuba (100%)
U_14_15N_NU	Sutter Yuba (100%)	Sutter Yuba (100%)
U_15S_NU	Sutter Yuba (100%)	Sutter Yuba (100%)
U_16_NU	Sutter Yuba (100%)	Sutter Yuba (100%)
U_16_PU	Sutter Yuba (100%)	Sutter Yuba (100%)
U_17_NU	Butte (100%)	Sutter Yuba (100%)

Demand Unit	Deep Percolation to Groundwater Basin(s)	Groundwater Source(s)
U_18_19_NU	Sutter Yuba (100%)	Sutter Yuba (100%)
U_20_25_NU	Yolo Solano (100%)	Yolo Solano (100%)
U_20_25_PU	None	Yolo Solano (100%)
U_21_NU	Sutter Yuba (13%); Colusa (87%)	Sutter Yuba (13%); Colusa (87%)
U_21_PU	Yolo Solano (100%)	None
U_22_NU	American (100%)	American (100%)
U_23_NU	American (100%)	American (100%)
U_24_NU1	American (100%)	American (100%)
U_24_NU2	American (100%)	American (100%)
U_26_NU1	American (100%)	American (100%)
U_26_NU2	American (100%)	American (100%)
U_26_NU3	American (100%)	American (100%)
U_26_NU4	American (100%)	American (100%)
U_26_NU5	American (100%)	American (100%)
U_26_NU6	American (100%)	None
U_26_PU1	American (100%)	American (100%)
U_26_PU2	American (100%)	American (100%)
U_26_PU3	American (100%)	American (100%)
U_26_PU4	American (100%)	American (100%)
U_26_PU5	American (100%)	American (100%)
U_60N_NU1	Eastern San Joaquin (61%); Cosumnes (39%)	Eastern San Joaquin (61%), Cosumnes (39%)
U_60N_NU2	Cosumnes (100%)	None
U_60N_PU	Cosumnes (100%)	None
U_60S_NU1	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
U_60S_NU2	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
U_61N_NU1	Eastern San Joaquin (100%)	Eastern San Joaquin (100%)
U_61N_NU2	Eastern San Joaquin (100%)	None
Refuge Demand Units		
R_08_PR	Colusa (100%)	Colusa (100%)
R_09_PR	Butte (100%)	Butte (100%)
R_11_PR	Butte (100%)	Butte (100%)
R_17_NR	Butte (100%)	Butte (100%)
R_17_PR1	Butte (100%)	Butte (100%)
R_17_PR2	Sutter Yuba (100%)	None

Note:

[1] Unlike agricultural and refuge lands that are represented by a single catchment object, urban areas are represented by both a catchment and demand site object. Consequently, an urban DU can have a return flow to a groundwater basin(s) from the demand site in addition to runoff from the catchment object.

6.3.2.3 Seepage Loss to Groundwater

$$Loss\ to\ Groundwater\ (\%) = f_{sp}\ *\ 100$$

The *Loss to Groundwater* parameter is specified on each transmission link (the *Supply and Resources\Transmission Link\Demand Unit\Loss to Groundwater* branch in the data tree) that connects a catchment or demand site to a surface water source. As indicated in the above equation, *Loss to Groundwater* is defined as the *Seepage Loss Factor* indicated on the DU level multiplied by 100 to obtain a percentage (see 4.4.2.1 - Seepage Loss Factor for more detail about how *Seepage Loss Factor* values were determined). As shown above, in addition to the percentage of transmission flow lost to groundwater, the receiving groundwater basin must also be specified. To determine which groundwater basin a surface transmission link loses water to, the following rules were implemented:

- If a DU overlies one groundwater basin as determined by the **groundwater basin intersection**, that groundwater basin is specified as the basin to which the transmission link loses water.
- If a DU overlies two or more groundwater basins as determined by the **groundwater basin intersection** and has one surface water transmission link, it was assumed the loss to groundwater infiltrates to the groundwater basin that underlies the larger proportion of the DU.
- If a DU overlies two or more groundwater basins as determined by the **groundwater basin intersection** and has multiple surface water transmission links, the loss to groundwater was split between the groundwater basins where the groundwater basin comprises 35% or more of the DU.

6.3.2.4 Stream – Aquifer Interaction

Interaction between streams and aquifers is simulated in the SacWAM using factors derived by State Water Board staff from the C2VSim groundwater model. These loss and gain factors were derived from a C2VSim model run in which the land use was kept constant at the level of development for water year 2009, the most recent year available in C2VSim. Historical groundwater storage has declined within the model domain, which results in long-term historical trends in stream-aquifer interaction. To simulate stream-aquifer interactions under existing conditions, the long-term trends were removed by estimating relationships between streamflow and stream gains/loss under current groundwater storage conditions. Details of the methods used to estimate the stream-aquifer interactions under existing conditions are explained below.

C2VSim is a monthly time step, finite element model that simulates linked groundwater and surface water flow throughout California's Central Valley (DWR, 2016). C2VSim requires initial conditions, land use, urban demands, inflows, and diversion information as model inputs. Each of these inputs was developed from previous C2VSim and CalSim II studies. Land use and urban water demands were set equal to those for water year 2005 from version R374 of the C2VSim coarse-grid (C2VSim-CG) historical simulation developed by DWR (DWR, 2016). Land use and urban demands were held constant throughout the simulation period. Major inflows and diversions used in the existing conditions C2VSim simulation were derived from the 2015 Delivery Capability Report studies, minor inflows and diversions were obtained from the C2VSim historical run (Table 6-14 and Table 6-15).

To remove long-term trends in groundwater elevation and better simulate current stream-groundwater interaction over the 82-year simulation period, an ensemble approach was taken. The ensemble runs were created by running multiple 3-year simulations, with an individual ensemble run beginning in each year of the 82-year C2VSim simulation period, and each with the initial condition equal to the October 2009 groundwater storages. The results for the first 2 years of each ensemble run were treated as a warm-up period to allow each ensemble run to stabilize and were discarded. The results for year 3 of each ensemble run were then combined to create a new 82-year time series that represents the stream gains and losses to groundwater with the variability in hydrology provided in the 82-year data set, while maintaining the current range of groundwater storages.

Table 6-14. C2VSim Inflow Information Sources for the Current Conditions Model Run

Inflow ID	Stream Node	C2VSim Stream Name	Source of Inflow to C2VSim[1,2,3]
1	205	Sacramento River	CalSim II (C5)
2	211	Cow Creek	CalSim II (C10801)
3	220	Battle Creek	CalSim II (C10803)
4	218	Cottonwood Creek	CalSim II (C10802)
5	225	Paynes and Sevenmile Creek	CalSim II (C11001)
6	233	Antelope Creek Group	CalSim II (C11307)
7	243	Mill Creek	CalSim II (C11308)
8	237	Elder Creek	C2VSim Historical
9	248	Thomes Creek	CalSim II (C11304)
10	256	Deer Creek Group	CalSim II (C11309)
11	263	Stony Creek	CalSim II (C42 + D42)
12	269	Big Chico Creek	CalSim II (C11501)
13	283	Butte and Chico Creek	CalSim II (I217)
14	341	Feather River	CalSim II (C203)
15	349	Yuba River	CalSim II (I230)
16	357	Bear River	CalSim II (I285)
17	390	Cache Creek	C2VSim 2000–2009 Matching
18	374	American River	CalSim II (C8)
19	400	Putah Creek	C2VSim 2000–2009 Matching
20	188	Cosumnes River	CalSim II (C501)
21	182	Dry Creek	C2VSim Historical
22	173	Mokelumne River	CalSim II (I504)+C2VSim Diversion 84
23	161	Calaveras River	CalSim II (C92)
24	146	Stanislaus River	CalSim II (C520)
25	135	Tuolumne River	CalSim II (C540)
26	128	Oristimba Creek	C2VSim Historical
27	116	Merced River	CalSim II (C20)
28	105	Bear Creek Group	C2VSim Historical
29	93	Deadman's Creek	C2VSim Historical
30	80	Chowchilla River	CalSim II (C53)
31	69	Fresno River	CalSim II (C52)
32	54	San Joaquin River	CalSim II (C18)
33	23	Kings River	C2VSim 2000–2009 Matching
34	420	Kaweah River	C2VSim 2000–2009 Matching
35	10	Tule River	C2VSim 2000–2009 Matching
36	1	Kern River	C2VSim 2000–2009 Matching
37	24	FKC Wasteway to Kings River	C2VSim 2000–2009 Matching
38	11	FKC Wasteway to Tule River	C2VSim 2000–2009 Matching
39	421	FKC Wasteway to Kaweah River	C2VSim 2000–2009 Matching
40	4	Cross-Valley Canal to Kern River	C2VSim 2000–2009 Matching
41	4	Friant-Kern Canal to Kern River	C2VSim 2000–2009 Matching

Notes:

[1] CalSim II data are from the 2015 Delivery Capability Report CalSim II study. Model node is listed in parentheses.

[2] C2VSim historical data are from version R374 of the C2VSim-CG model.

[3] "C2VSim 2000–2009 Matching" indicates that the values for 1992–1999 were chosen from the most similar year from 2000 to 2009 based on the Sacramento Valley index.

Table 6-15. C2VSim Diversion Information Sources for the Current Conditions Model Run

C2VSim ID	C2VSim Diversion	Assumed Existing Conditions Diversion
1	Whiskeytown and Shasta for Ag	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
2	Whiskeytown and Shasta for M&I	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
3	Sacramento River to Bella Vista conduit for Ag	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
4	Sacramento River to Bella Vista conduit for M&I	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
5	Sacramento River to Bella Vista conduit for export	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
6	Sacramento River, Keswick Dam to Red Bluff, for Ag	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
7	Sacramento River, Keswick Dam to Red Bluff, for M&I	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
8	Cow Creek riparian diversions	Average 2000–2009 C2VSim historical
9	Battle Creek riparian diversions	Average 2000–2009 C2VSim historical
10	Cottonwood Creek riparian diversions	Average 2000–2009 C2VSim historical
11	Clear Creek riparian diversions	Zero
12	Sacramento River diversions to the Corning Canal	CalSim II arc D171
13	Stony Creek to North Canal	CalSim II arc D17301
14	Stony Creek to South Canal	CalSim II arc D42
15	Stony Creek to the Tehama-Colusa Canal	Zero
16	Stony Creek to the Glenn-Colusa Canal	Zero
17	Sacramento River to Subregion 2	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
18	Antelope Creek riparian diversions	Average 2000–2009 C2VSim historical
19	Mill Creek riparian diversions	Average 2000–2009 C2VSim historical
20	Elder Creek riparian diversions	Average 2000–2009 C2VSim historical
21	Thomes Creek riparian diversions	Average 2000–2009 C2VSim historical
22	Deer Creek riparian diversions	Average 2000–2009 C2VSim historical
23	Sacramento River to the Tehama-Colusa Canal to Subregion 2	CalSim II arc D172
24	Sacramento River to the Tehama-Colusa Canal to Subregion 3	CalSim II arc C171 less D172
25	Sacramento River to the Glenn-Colusa Canal for Ag	CalSim II arc D114 less D143B, less 145B
26	Sacramento River to the Glenn-Colusa Canal for Refuges	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
27	Sacramento River to Subregion 3	Average 2000–2009 C2VSim historical * CalSim annual allocation
28	Sacramento River to Subregion 4	Average 2000–2009 C2VSim historical * CalSim annual allocation
29	Little Chico Creek	Average 2000–2009 C2VSim historical
30	Tarr Ditch	Average 2000–2009 C2VSim historical
31	Miocine and Wilenor Canals	Average 2000–2009 C2VSim historical
32	Palermo Canal	Average 2000–2009 C2VSim historical
33	Oroville-Wyandotte ID through Forbestown Ditch	Average 2000–2009 C2VSim historical
34	Little Dry Creek	Average 2000–2009 C2VSim historical
35	Bangor Canal	Average 2000–2009 C2VSim historical
36	Thermalito Afterbay	Average 2000–2009 C2VSim historical, except in 1924, 1931, 1934, 1977, 1988, and 1991 assume 525,000 AF/year (Jan-Dec)

C2VSim ID	C2VSim Diversion	Assumed Existing Conditions Diversion
37	Feather River to Subregion 5 for Ag	Zero
38	Feather River to Thermalito ID	Average 2000–2009 C2VSim historical, but not more than 8,200 AF/year
39	Feather River to Subregion 5 for Ag	Average 2000–2009 C2VSim historical, except in 1924, 1931, 1934, 1977, 1988, and 1991 assume 65,895 AF/year (Jan–Dec)
40	Feather River to Yuba City	Average 2000–2009 C2VSim historical
41	Feather River to Subregion 7 for Ag	Average 2000–2009 C2VSim historical
42	Yuba River for Ag	Average 2000–2009 C2VSim historical, except in 1977 assume cut by 50%.
43	Yuba River for M&I	Zero
44	Bear River to Camp Far West ID North Side	Average 2000–2009 C2VSim historical
45	Bear River to Camp Far West ID South Side	Average 2000–2009 C2VSim historical
46	Bear River to South Sutter WD	Average 2000–2009 C2VSim historical
47	Bear River Canal to South Sutter WD	Average 2000–2009 C2VSim historical
48	Boardman Canal	Average 2000–2009 C2VSim historical
49	Combie (Gold Hill) Canal	Average 2000–2009 C2VSim historical
50	Cross Canal	Average 2000–2009 C2VSim historical excluding Shasta critical years. In Shasta critical years, average data from 1991, 1992, 1994 C2VSim historical.
51	Butte Creek at Parrott-Phelan Dam	Average 2000–2009 C2VSim historical
52	Butte Creek at Durham Mutual Dam	Average 2000–2009 C2VSim historical
53	Butte Creek at Adams & Gorrill Dams	Average 2000–2009 C2VSim historical
54	Butte Creek to RD 1004	Average 2000–2009 C2VSim historical
55	Butte Creek to Sutter and Butte Duck Clubs	Average 2000–2009 C2VSim historical
56	Butte Slough	Average 2000–2009 C2VSim historical
57	Sutter Bypass East Borrow Pit to Sutter NWR	Average 2000–2009 C2VSim historical
58	Sutter Bypass West Borrow Pit North of Tisdale Bypass	Average 2000–2009 C2VSim historical
59	Sutter Bypass East Borrow Pit to lands within Sutter Bypass	Average 2000–2009 C2VSim historical
60	Sutter Bypass East Borrow Pit from North of Wadsworth Canal to Gilsizer Slough	Average 2000–2009 C2VSim historical
61	Sutter Bypass East Borrow Pit South of Gilsizer Slough	Average 2000–2009 C2VSim historical
62	Colusa Basin Drain to Subregion 3 for Ag	Average 2000–2009 C2VSim historical
63	Colusa Basin Drain to Subregion 3 for Refuges	Average 2000–2009 C2VSim historical
64	Knights Landing Ridge Cut	Average 2000–2009 C2VSim historical
65	Sacramento River between Knights Landing and Sacramento to Subregion 6 for Ag	Average 2000–2009 C2VSim historical excluding Shasta critical years. In Shasta critical years, average data from 1991, 1992, 1994 C2VSim historical.
66	Sacramento River to City of West Sacramento	Average 2000–2009 C2VSim historical
67	Sacramento River between Knights Landing and Sacramento to Subregion 7 for Ag	Average 2000–2009 C2VSim historical excluding Shasta critical years. In Shasta critical years, average data from 1991, 1992, 1994 C2VSim historical.
68	Sacramento River to City of Sacramento	Average 2000–2009 C2VSim historical
69	Cache Creek	Average 2000–2009 C2VSim historical
70	Yolo Bypass	Average 2000–2009 C2VSim historical

C2VSim ID	C2VSim Diversion	Assumed Existing Conditions Diversion
71	Putah South Canal for Ag	Average 2000–2009 C2VSim historical
72	Putah South Canal for M&I	Average 2000–2009 C2VSim historical
73	Putah South Canal exports	Average 2000–2009 C2VSim historical
74	Putah Creek riparian diversions	Average 2000–2009 C2VSim historical
75	Folsom Lake for Ag	Average 2000–2009 C2VSim historical
76	Folsom Lake for M&I	Average 2000–2009 C2VSim historical
77	Folsom South Canal for Ag	Zero
78	Folsom South Canal for M&I	Contract amount, CalSim annual allocation, 2000–2009 C2VSim historical monthly pattern
79	Folsom South Canal exports	Zero
80	American River to Carmichael WD	Average 2000–2009 C2VSim historical
81	American River to City of Sacramento	Average 2000–2009 C2VSim historical
82	Cosumnes River	Average 2000–2009 C2VSim historical
83	Mokelumne River from Camanche Reservoir	Average 2000–2009 C2VSim historical
84	Mokelumne River	Average 2000–2009 C2VSim historical
85	Calaveras River	CalSim II arc D506A + D506B + D506C +D507
86	Sacramento-San Joaquin Delta for Ag	Average 2000–2009 C2VSim historical
87	Sacramento-San Joaquin Delta for M&I	Average 2000–2009 C2VSim historical
88	Sacramento-San Joaquin Delta to North Bay Aqueduct for Ag	Zero
89	Sacramento-San Joaquin Delta to North Bay Aqueduct for M&I	CalSim II arc (1/3)*D403C
90	Sacramento-San Joaquin Delta to North Bay Aqueduct export	CalSim II arc D403A + D403B + (2/3)*D403C +D403D
91	Sacramento-San Joaquin Delta to Contra Costa Canal	CalSim II arc D408_OR + D408_RS +D408_VC
92	Sacramento-San Joaquin Delta to CVP	CalSim II arc D418 + D419_CVP
93	Sacramento-San Joaquin Delta to SWP	CalSim II arc D419_SWP

Note:
CalSim II data are from the 2015 Delivery Capability Report CalSim II study. C2VSim historical data are from version R374 of the C2VSim-CG model.

Key:
Ag = agriculture, CVP = Central Valley Project, ID = Irrigation District, M&I = municipal and industrial, NWR = National Wildlife Refuge, SWP = State Water Project, WD = Water District.

Table 6-16 presents a summary of the stream-groundwater interactions for the C2VSim reaches that are represented in SacWAM. These reaches include the valley floor portion of the Sacramento Valley watershed, and the lower sections of the Delta eastside tributaries (DWR 2016). On average, this region lost an estimated 802 TAF/year, with average annual gains or losses varying by subregion. The Delta eastside tributaries lost an average of 150 TAF/year, with the greatest loss (91 TAF/year) occurring along the Mokelumne River upstream of its confluence with the Cosumnes River. The Sacramento River valley floor watershed lost an average of 494 TAF/year, with the northern portion of the watershed (north of Thomes Creek) experiencing an average gain of 126 TAF/year and the southern ortion of the watershed experiencing an average loss of 620 TAF/year, with the largest losses occurring along the Sacramento River north and south of the American River (reaches 65 and 67).

Stream-aquifer interactions within the Delta region were assumed to be included in the pre-processed accretions and depletions estimates and were not used from C2VSim. Additional information regarding the magnitude of the stream-groundwater interaction in relation to total flow and variation in stream-groundwater interaction through the year is presented in Appendix A.

For each C2VSim reach upstream of the Delta and within the model domain, a linear regression was fit to stream gain as a function of outflow from the reach. Data were aggregated by calendar quarters to allow for seasonal variability in stream-aquifer interaction, while avoiding over-parameterization. If a positive intercept and negative slope were obtained, those values were used directly in the model, as described below. In several losing reaches within the model domain, regressions resulted in negative intercepts. Visual inspection of the data indicated that this occurs when the stream-aquifer interaction takes on a "hockey stick" shape, with a high rate of seepage loss at low flows, and a lower rate at higher flows. This relationship cannot be modeled in WEAP without introducing a nonlinearity, so in these cases a second linear regression model was used, which forced the intercept through zero. Finally, during dry seasons in some reaches, the modeled variability in flow was inadequate to estimate confidently the stream-aquifer interaction. In these cases, the relationship from an adjacent quarter was substituted in place of the estimated parameter values.

The parameters used to characterize the stream-aquifer interactions are provided in Table 6-17 and Table 6-18. The slope was entered into the Groundwater Outflow parameter to represent the percentage of streamflow that flows to the aquifer. The intercept was entered into the *Groundwater Inflow* parameter representing the flow from the aquifer to the stream reach. This information is provided in the **groundwater functions** spreadsheet. During calibration of the valley floor hydrology, these parameters were further adjusted to mimic the overall behavior of C2VSim (see Appendix A).

Based on comments on earlier drafts, an alternative C2VSim run was completed where instead of "resetting" the groundwater storage and compiling an ensemble of runs, the groundwater heads were held constant. This current conditions constant-head C2VSim simulation produced parameters that were nearly identical to those produced using the ensemble approach.

Figure 6-1 shows a comparison of parameters estimated using the ensemble approach and the constant head approach. The points circled in red on the slope and zero-intercept slope plots are the most divergent outliers in the comparisons of slopes. These values were not used in SacWAM. Both correspond to summer estimates for Reach 52, Butte Creek. The value on the slope graph corresponds to a regression with a negative intercept, and was not used, following the procedure described above. The zero-intercept slope for summer was replaced by the zero-intercept slope for fall, because the summer flow data from the C2VSim simulation were too limited to produce a reasonable estimate of seepage and produced an estimate of 45% seepage loss. Averaged over the whole model domain, the estimates of intercepts for the ensemble simulation are 2.7 cfs lower than for the constant head simulation. That difference does not translate directly to an average 2.7 cfs difference in the SacWAM model parameterization, but it shows that the two approaches to estimating parameters using C2VSim yield similar results.

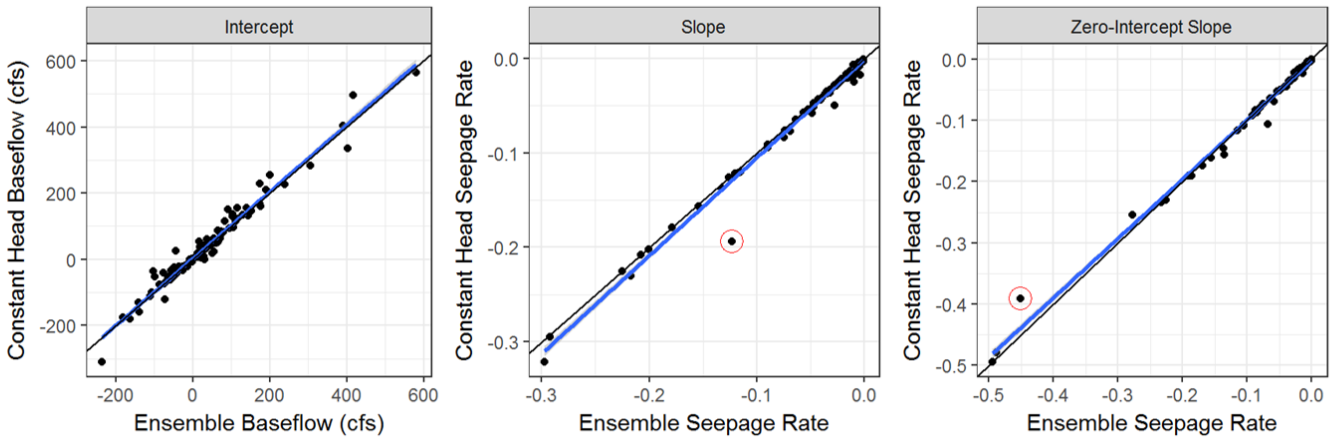


Figure 6-1. Comparison of Parameters from C2VSim Ensemble and Constant Head Simulations Used in SacWAM

Table 6-16. Average Annual Stream-Groundwater Interaction Simulated by the C2VSim Existing Conditions Run

C2VSim Reach Name	Average Annual Gain (+)/Loss (-) (TAF)
Reach 25 - Calaveras River	-53
Reach 27 - Mokelumne River	-91
Reach 28 - Dry Creek	-3
Reach 29 - Cosumnes River	-3
Reach 32 - Sacramento River	1
Reach 33 - Cow Creek	-11
Reach 34 - Sacramento River	18
Reach 35 - Cottonwood Creek	-7
Reach 36 - Battle Creek	10
Reach 37 - Sacramento River	25
Reach 38 - Paynes Creek	12
Reach 39 - Sacramento River	43
Reach 40 - Antelope Creek	14
Reach 41 - Sacramento River	9
Reach 42 - Elder Creek	2
Reach 43 - Mill Creek	2
Reach 44 - Sacramento River	8
Reach 45 - Thomes Creek	-18
Reach 46 - Sacramento River	4
Reach 47 - Deer Creek	-1
Reach 48 - Sacramento River	0
Reach 49 - Stony Creek	-69
Reach 50 - Big Chico Creek	0
Reach 51 - Sacramento River	-22
Reach 52 - Butte Creek	-122
Reach 53 - Sacramento River	-24
Reach 54 - Glenn Colusa Canal	0
Reach 55 - Colusa Basin Drainage Canal	80
Reach 56 - Colusa Basin Drainage Canal	63
Reach 57 - Sacramento River	-14
Reach 58 - Sutter Bypass	-44
Reach 59 - Feather River	6
Reach 60 - Yuba River	-22
Reach 61 - Feather River	-67
Reach 62 - Bear River	-40
Reach 63 - Feather River	31
Reach 64 - Feather River	-26
Reach 65 - Sacramento River	-175
Reach 66 - American River	-56
Reach 67 - Sacramento River	-104
Reach 68 - Cache Creek	-87
Reach 69 - Putah Creek	-54
Reach 71 - Sacramento River	-17
Total	-802

Table 6-17. Relationship Between C2VSim and SacWAM Reaches

C2VSim Reach No.	SacWAM Reach Name	Description	Basin
25	Below I_CLV026 Inflow	Calaveras River	Eastern San Joaquin
27	Below Mokelumne River RM 050	Mokelumne River	Cosumnes
27	Below Mokelumne River RM 035	Mokelumne River	Eastern San Joaquin
29	Below SR Cosumnes River	Cosumnes River	American
29	Below I_DEE023 Inflow	Cosumnes River	Cosumnes
32	Below SR Sacramento River above Bend Bridge Gauge	Sacramento River above Cow Creek	Redding
33	Below SR Cow Creek	Cow Creek	Redding
34	Below Bear Creek Inflow	Sacramento River below Cow Creek	Redding
35	Below SR Cottonwood Creek	Cottonwood Creek	Redding
36	Below Battle Creek RM 006	Battle Creek	Redding
37	Below SWRCB Sac AB Bend Bridge	Sacramento River below Battle Creek	Red Bluff Corning
37	Below Battle Creek Inflow to Sacramento RM 269	Sacramento River below Battle Creek	Redding
38	Below I_PYN001 Inflow	Paynes Creek	Red Bluff Corning
39	Below Sacramento River RM 240	Sacramento River below Paynes Creek	Red Bluff Corning
40	Below SR Antelope Creek	Antelope Creek	Red Bluff Corning
41	Below Catchment Inflow Node 94	Sacramento River below Antelope Creek	Red Bluff Corning
42	Below I_ELD027 Inflow	Elder Creek	Red Bluff Corning
43	Below Mill Creek RM 006	Mill Creek	Red Bluff Corning
44	Below McClure Creek Inflow to Sacramento River RM 225	Sacramento River below Mill Creek	Red Bluff Corning
45	Below SR Thomes Creek	Thomes Creek	Red Bluff Corning
46	Below Catchment Inflow Node 99	Sacramento River below Thomes Creek	Red Bluff Corning
47	Below Deer Creek RM 005	Deer Creek	Red Bluff Corning
48	Below Catchment Inflow Node 104	Sacramento River below Deer Creek	Red Bluff Corning
49	Below Constant Head Orifice Outflow	Stony Creek	Colusa
49	Below SR Stony Creek	Stony Creek	Red Bluff Corning
50	Below Catchment Inflow Node 106	Big Chico Creek	Butte
50	Below Catchment Inflow Node 105	Big Chico Creek	Red Bluff Corning
51	Below Sacramento River RM 159	Sacramento River below Big Chico Creek	Butte
51	Below SR Sacramento River above Butte City Gauge	Sacramento River below Big Chico Creek	Colusa
52	Below A_11_SA3 Runoff	Butte Creek	Butte
53	Below OPS Navigation Control Point	Sacramento River above CBD	Colusa
53	Below Sacramento River RM 109	Sacramento River above CBD	Sutter Yuba
55	Below Colusa Basin Drainage Canal CM 049	Upr Colusa Basin Drain	Colusa
56	Below SR Colusa Basin Drain Above Outfall Gates Gauge	Lwr Colusa Basin Drain	Colusa
57	Below Sutter Bypass Floodflow Inflow	Sacramento River below CBD	Colusa
57	Below Sutter Bypass Inflow to Sacramento RM 085	Sacramento River below CBD	Sutter Yuba
58	Below A_17_NA Runoff	Sutter Bypass	Sutter Yuba

C2VSim Reach No.	SacWAM Reach Name	Description	Basin
59	Below Feather River RM 039	Feather River above Yuba River	Butte
59	Below Feather River RM 045	Feather River above Yuba River	Sutter Yuba
60	Below Yuba River RM 003	Yuba River	Sutter Yuba
61	Below Feather River RM 014	Feather River above Bear River	Sutter Yuba
62	Below SR Bear River	Bear River	American
62	Below Dry and Hutchinson Creeks Inflow	Bear River	Sutter Yuba
64	Below REG Verona	Feather River below Sutter Bypass	American
64	Below Feather River RM 007	Feather River below Sutter Bypass	Sutter Yuba
65	Below Sacramento River RM 074	Sacramento River below Feather River	American
65	Below Natomas East Main Drain Inflow	Sacramento River below Feather River	Yolo Solano
66	Below REG American IFR	American River	American
67	Below Georgiana Slough fr Sacramento River RM 029 Outflow	Sacramento River below American River	Delta
68	Below Cache Creek RM 030	Cache Creek	Colusa
68	Below SR Cache Creek above Yolo Gauge	Cache Creek	Yolo Solano
69	Below REG Lower Putah Diversion Dam	Putah Creek	Yolo Solano
70	Below SR Yolo Bypass	Yolo Bypass	Yolo Solano

Table 6-18. C2VSim Stream-Aquifer Interaction Parameters

C2VSim Reach #	Description	Jan-Mar		Apr-Jun		Jul-Sep		Oct-Dec	
		Slope %	Intercept (cfs)	Slope %	Intercept (cfs)	Slope %	Intercept (cfs)	Slope %	Intercept (cfs)
25	Calaveras River	19.08	0.00	51.02	0.00	23.31	0.00	23.31	0.00
27	Mokelumne River	15.6	0.00	16.88	0.00	22.64	0.00	18.55	0.00
29	Cosumnes River	0.33	0.00	0.47	0.00	1.75	0.00	0.38	0.00
32	Sacramento River above Cow Creek	0.64	64.52	0.71	61.49	0.79	70.83	0.71	67.34
33	Cow Creek	2.66	0.00	3.22	22.90	3.96	13.37	3.96	0.00
34	Sacramento River below Cow Creek	0.22	50.61	0.2	46.15	0.26	47.17	0.24	46.55
35	Cottonwood Creek	1.13	0.00	1.52	0.57	3.18	13.41	1.67	2.71
36	Battle Creek	3.2	28.09	3.51	30.80	1.05	26.37	4.45	30.14
37	Sacramento River below Battle Creek	0.18	58.59	0.12	50.97	0.2	55.48	0.2	55.65
38	Paynes Creek	0.58	14.76	0.5	18.26	1	1.39	2.11	16.52
39	Sacramento River below Paynes Creek	0.16	80.23	0.12	75.82	0.13	72.89	0.16	76.83
40	Antelope Creek	1.17	20.78	0.84	22.44	1	18.92	1.57	21.28
41	Sacramento River below Antelope Creek	0.12	28.61	0.08	23.83	0.12	22.79	0.13	25.45
42	Elder Creek	7.49	0.00	7.47	14.99	12.58	5.89	12.58	12.90
43	Mill Creek	1.51	7.03	1.85	6.73	1.53	8.50	2.11	9.20
44	Sacramento River below Mill Creek	0.16	34.43	0.1	26.72	0.17	27.55	0.17	29.72
45	Thomes Creek	9.18	0.00	10.57	0.00	12.03	29.13	12.03	3.90
46	Sacramento River below Thomes Creek	0.15	26.56	0.09	19.91	0.15	21.42	0.16	23.16
47	Deer Creek	1.32	1.36	1.03	1.52	0.4	4.21	1.65	1.90
48	Sacramento River below Deer Creek	0.32	51.96	0.08	29.95	0.33	20.29	0.35	29.01
49	Stony Creek	4.85	0.00	13.62	0.00	8.48	0.00	8.48	0.00
50	Big Chico Creek	0.3	0.00	0.43	0.14	0.15	0.18	0.32	0.05
51	Sacramento River below Big Chico Creek	4.09	579.62	1	0.00	4.9	416.68	4.73	390.36
52	Butte Creek	2.33	0.00	4.18	0.00	4.94	0.00	4.94	0.00
53	Sacramento River above Colusa Basin Drain	1.64	144.46	0.51	36.35	1.19	91.49	1.78	140.69
55	Upper Colusa Basin Drain	6.37	151.69	6.37	103.08	6.92	103.45	6.92	130.54
56	Lower Colusa Basin Drain	29.21	402.27	29.71	304.99	21.72	173.76	21.72	176.27
57	Sacramento River below Colusa Basin Drain	0.28	12.94	0.23	10.74	0.38	13.01	0.37	12.85

C2VSim Reach #	Description	Jan-Mar		Apr-Jun		Jul-Sep		Oct-Dec	
		Slope %	Intercept (cfs)	Slope %	Intercept (cfs)	Slope %	Intercept (cfs)	Slope %	Intercept (cfs)
58	Sutter Bypass	3.49	24.43	2.54	53.22	1	32.85	3.66	15.00
59	Feather River above Yuba River	2.23	191.25	1	0.00	0.78	200.22	0.78	83.79
60	Yuba River	0.93	0.00	1.21	0.00	0.61	0.00	1.37	0.00
61	Feather River above Bear River	2.29	95.82	2.03	0.00	2.16	64.34	3.05	115.65
62	Bear River	5.3	0.00	7.98	0.00	6.39	0.00	6.39	0.00
64	Feather River below Sutter Bypass	2.24	238.20	0.37	55.17	0.38	73.29	2.76	173.35
65	Sacramento River below Feather River	1.51	106.45	0.79	0.00	2.43	115.97	2.39	111.19
66	American River	1.18	0.00	1.75	0.00	2.6	0.00	1.72	0.00
67	Sacramento River below American River	0.68	44.20	0.4	0.00	0.89	16.05	0.98	19.37
68	Cache Creek	1.28	0.00	1	22.24	1	0.00	3.3	0.00
69	Putah Creek	10.49	0.00	5.86	0.00	27.8	0.00	27.8	0.00
70	Yolo Bypass	1.06	0.00	1	54.81	1	43.46	2.74	0.00

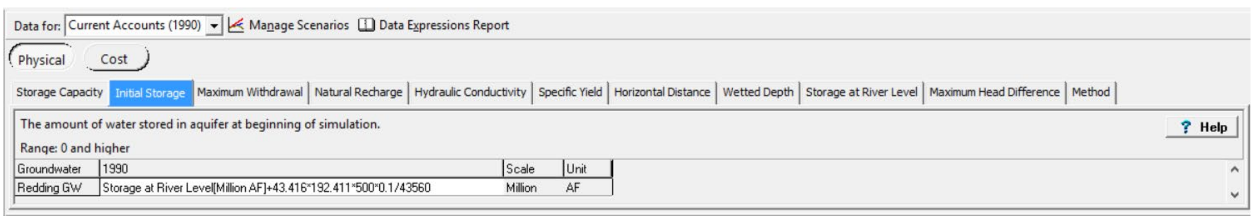
Key:
C2VSim = California Central Valley Groundwater-Surface Water Simulation Model, cfs = cubic feet per second.

6.3.3 Physical

6.3.3.1 Storage Capacity

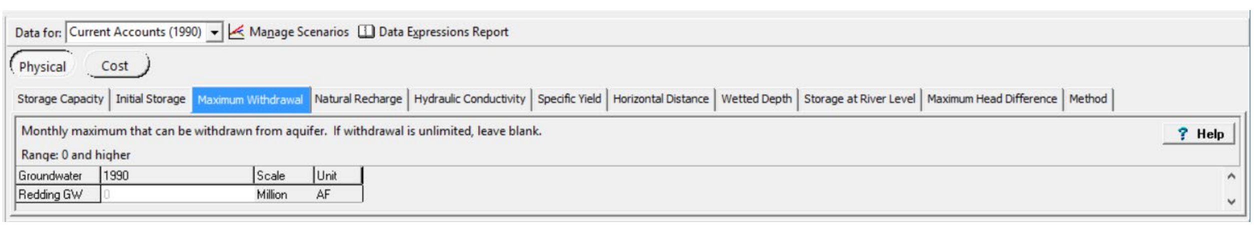
The *Storage Capacity* parameter is used to specify the total volume of available storage in a groundwater aquifer. In SacWAM, this parameter has been left blank, which means the capacity is unlimited.

6.3.3.2 Initial Storage



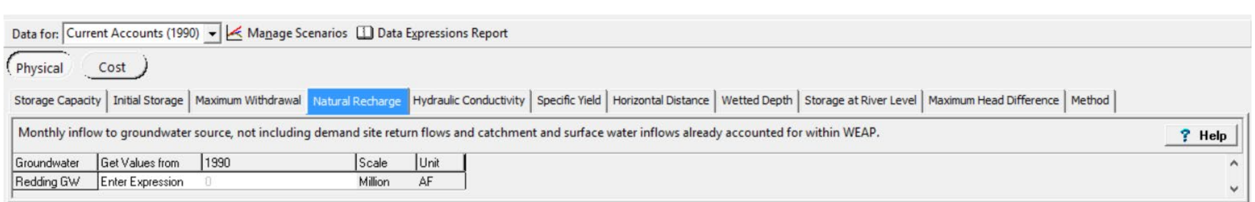
The *Initial Storage* parameter sets the initial storage for the groundwater basin. For all basins, this value was arbitrarily set to 30 million acre-feet.

6.3.3.3 Maximum Withdrawal



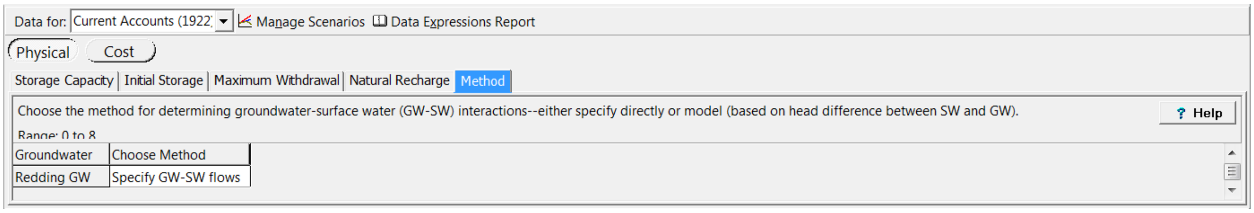
The *Maximum Withdrawal* parameter restricts the amount of water that can be withdrawn from the groundwater basin in a time step. In SacWAM this parameter was left blank making it unrestricted.

6.3.3.4 Natural Recharge



The *Natural Recharge* parameter is used to specify (pre-processed) recharge to the groundwater basin. In SacWAM this parameter was left blank, because aquifer recharge is simulated dynamically as deep percolation from catchments, return flows from demand sites, and seepage from transmission links.

6.3.3.5 Method



For each groundwater basin, the method for simulating stream-groundwater interaction is set to 'Specify GW-SW flows.'

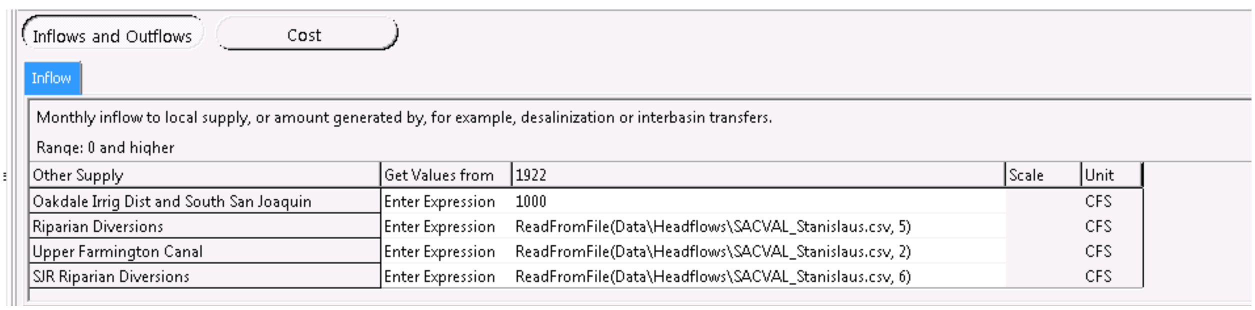
6.3.4 Cost

The WEAP *Cost* feature under *Groundwater* is not used in SacWAM.

6.4 Other Supply

Four Other Supply objects provide water to lands on the southern boundary of the model domain located between the Calaveras and Stanislaus rivers. They represent (1) CVP water that is diverted from the Stanislaus River into the Upper Farmington Canal for delivery to Central San Joaquin WCD and Stockton East WD; (2) water diverted into the South San Joaquin Main Canal for delivery to South San Joaquin ID, Oakdale ID, and the South San Joaquuin ID water treatment plant; (3) water diverted by riparian and appropriative water right holders on the right bank of the Stanislaus River; (4) riparian and appropriative water right holders on the right bank of the San Joaquin River between the Stanisaus River and Vernalis.

6.4.1 Inflows and Outflows



Monthly inflows for the other supply objects are read from the input file *data\headflows\SACVAL_Stanislaus.csv.* These data are based on simulation model results. The exception is supplies delivered to the South San Joaquin Canal. In this case, the Other Supply inflow was set to 1,000 cfs to ensure that there is sufficient water to meet district demands.

6.4.2 Cost

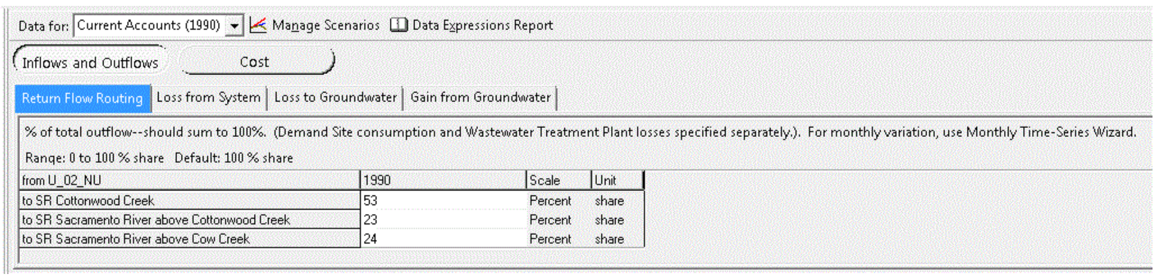
The WEAP *Cost* feature under *Other Supply* is not used in SacWAM.

6.5 Return Flows

6.5.1 Inflows and Outflows

6.5.1.1 Return Flow Routing

In addition to surface runoff fractions that are specified for urban catchments (dashed blue line in WEAP), return flow percentages from urban demand sites must be specified for return flow links (solid red line in WEAP). These are entered under the *Supply and Resources\Return Flows\Demand Site\Inflows and Outflows\Return Flow Routing* branch of SacWAM (below). Return flows were determined using the surface **returns intersection**, except where there are known WWTPs.



6.5.1.2 Loss from System

The WEAP *Loss from System* feature under Inflows and Outflows is not used in SacWAM.

6.5.1.3 Loss to Groundwater

The WEAP *Loss to Groundwater* feature under Inflows and Outflows is not used in SacWAM.

6.5.1.4 Gain from Groundwater

The WEAP *Gain from Groundwater* feature under Inflows and Outflows is not used in SacWAM.

6.5.2 Cost

The WEAP *Cost* feature under *Return Flows* is not used in SacWAM.

6.6 Transmission Links

Transmission links represent water deliveries to agricultural, urban, or refuge demands. They comprise surface water deliveries and groundwater pumping. Table 6-19, Table 6-20, Table 6-21 list the source of surface water for agricultural, urban, and refuge DUs, including the river mile, where applicable.

Table 6-19. Surface Water Diversions by Agricultural Demand Unit

Demand Unit	Surface Diversion(s)
CVP North of Delta Water Service Contracts	
A_02_PA	Clear Creek WTP (Whiskeytown Reservoir)
A_03_PA	Bella Vista Pipeline (Sacramento River RM 294)
A_04_06_PA1	Tehama-Colusa Canal CM 001
A_04_06_PA2	Tehama-Colusa Canal CM 022
A_07_PA	Tehama-Colusa Canal CM 081
A_08_PA	Colusa Basin Drain CM 028; Glenn-Colusa Canal CM 065
A_16_PA	Feather River RM 021
A_21_PA	Knights Landing Ridge Cut CM 005
CCWD	Mokelumne above Mokelumne Hill (Middle Fork Mokelumne River)
CVP Sacramento River Settlement Contracts	
A_02_SA	Sacramento River RM 296
A_03_SA	Sacramento River RM 289
A_08_SA1	Sacramento River RM 159 & RM 178; Colusa Basin Drainage Canal CM 049
A_08_SA2	Colusa Basin Drainage Canal CM 041; Glenn-Colusa Canal CM 027
A_08_SA3	Sacramento River RM 109 & RM 121; Colusa Basin Drain CM 028
A_09_SA1	Sacramento River RM 196; Butte Creek RM 045
A_09_SA2	Sacramento River RM 162; Butte Creek RM 012
A_21_SA	Sacramento River RM 074 & RM 083; Yolo Bypass CM 023
A_22_SA1	Sacramento River RM 078 & RM 082; Natomas Cross Canal
Other Federal Project Diverters	
A_SCKWD_NA	East Park Reservoir (Orland Project)
A_04_06_NA1	Stony Creek RM 021 & RM 026 (Orland Project)
A_20_25_PA	Putah South Canal CM 003 (Solano Project)
A_SIDSH_NA	Putah South Canal CM 027 (Solano Project)
SWP Feather River Service Area	
A_11_SA1	Western Canal (Thermalito Reservoir Afterbay)
A_11_SA2	Richvale Canal, Joint Board Canal (Thermalito Reservoir Afterbay)
A_11_SA3	Joint Board Canal
A_11_SA4	Feather River RM 039; Joint Board Canal
A_12_13_SA	Feather River RM 059
A_14_15N_SA	Feather River RM 045
A_15S_SA	Feather River RM 018 & RM 028
A_16_SA	Feather River RM 008, RM 014, RM 016 & RM 021
A_17_SA	Feather River RM 007
A_22_SA2	Feather River RM 007
In-Delta Diverters	
A_50_NA1	Sacramento River RM 041
A_50_NA2	Sacramento River RM 017
A_50_NA3	Sacramento River RM 000
A_50_NA4	Mokelumne River RM 004
A_50_NA5	San Joaquin River RM 026
A_50_NA6	San Joaquin River RM 013
A_50_NA7	Old River RM 027
Non-Project Diverters	
A_02_NA	Sacramento River RM 281; Cottonwood Creek RM 009
A_03_NA	Sacramento River RM 273; Battle Creek RM 006; Cow Creek RM 014
A_04_06_NA	Sacramento River RM 224; Thomes Creek RM 012
A_05_NA	Sacramento River RM 240; Antelope Creek RM 010; Mill Creek RM 006; Deer Creek RM 005 & RM 010
A_08_NA	Sacramento River RM 146
A_09_NA	Sacramento River RM 185 & RM 196; Butte Creek RM 045
A_10_NA	Butte Creek RM 036; West Branch Feather RM 015
A_11_NA	Sutter Bypass CM 028

Demand Unit	Surface Diversion(s)
A_12_13_NA	Oroville Wyandotte Canal CM 000; Miners Ranch Reservoir; Palermo Canal
A_14_15N_NA2	Yuba River RM 011
A_14_15N_NA3	French Dry Creek RM 006; Yuba River RM 013
A_15S_NA	Yuba River RM 011
A_16_NA	Sutter Bypass CM 028
A_17_NA	Sutter Bypass CM 014
A_18_19_NA	Sacramento River RM 136; Sutter Bypass CM 034
A_18_19_SA	Sacramento River RM 115, RM 121 & RM 136
A_20_25_NA1	Cache Creek RM 030
A_20_25_NA2	Cache Slough RM 005
A_21_NA	Sacramento River RM 081
A_22_NA	Sacramento River RM 075
A_21_PA	Knights Landing Ridge Cut CM 005
A_23_NA	Bear River RM 017; Auburn Ravine RM 006
A_24_NA1	Auburn Ravine RM 024; Rock Creek Reservoir; Bear River System (Lake Combie)
A_24_NA2	Auburn Ravine RM 010
A_24_NA3	Lower Boardman Canal CM 049; South Canal PCWA Zone 1
A_60N_NA1	Lake Amador
A_60N_NA2	Folsom South Canal CM 015
A_60N_NA3	Mokelumne River RM 050
A_60N_NA4	Mokelumne River RM 035
A_60N_NA5	Mokelumne River RM 050; Mokelumne River below Woodbridge
A_60S_PA	Calaveras River RM 026; Farmington Reservoir; Upper Farmington Canal
A_61N_NA2	Riparian Diversions (Stanislaus River RM 030)
A_61N_NA3	SJR Riparian Diversions (San Joaquin River RM 070)
A_61N_PA	Oakdale Irrigation District and South San Joaquin (Stanislaus River RM 059)
A_GDPUD_NA	Georgetown Divide Ditch
A_NIBR_NA	Bear River
A_NIDDC_NA	Deer Creek (Yuba River watershed)
A_SCKWD_NA	Little Stony Creek

Note:
[1] A_04_06_NA includes some minor CVP settlement contractors.

Key:
CM = Canal Mile, CVP = Central Valley Project, PCWA = Placer County Water Agency, RM = River Mile, SJR = San Joaquin River, SWP = State Water Project, WTP = Water Treatment Plant.

Table 6-20. Surface Water Diversions by Urban Demand Unit

Demand Unit	Surface Water Diversion(s)
CVP North of Delta Water Service Contracts	
U_02_PU	Whiskeytown Reservoir (Centerville CSD, Clear Creek CSD, Keswick CSA, Shasta CSD)
U_03_PU	Shasta Lake; Bella Vista Pipeline (Sacramento River RM 294); Whiskeytown Reservoir (City of Redding, Bella Vista WD, others)
U_21_PU	Sacramento River RM 065 (West Sacramento)
U_26_PU1	Roseville WTP CVP; Roseville WTP MFP (Folsom Lake) (City of Roseville)
U_26_PU2	Peterson WTP CVP; Peterson WTP MFP (Folsom Lake) (San Juan WD)
U_26_PU3	Folsom Prison; Folsom WTP (Folsom Lake) (City of Folsom/Folsom Prison)
U_26_PU4	Freeport Intertie CM 013; Freeport Intertie for Surplus DO; Sacramento River WTP (Sacramento River RM 054 & RM 062) (Sacramento County WA)
U_26_PU5	Folsom South Canal CM 003 (Golden State WC)
U_60N_PU	Folsom South Canal CM 025 (SMUD)
U_CCWD	Sacramento River RM 000; Contra Costa Canal CM 019 (Contra Costa WD)
U_EBMUD	Mokelumne Aqueduct CM 057 (EBMUD)
U_EIDLO	El Dorado Hills WTP WR; El Dorado Hills WTP CVP (Folsom Lake) (El Dorado ID)
U_EIDUP	El Dorado Hills WTP WR; Sly Park WTP (Folsom Lake) (El Dorado ID)
CVP Sacramento River Settlement Contracts	
U_02_SU	Foothill WTP (Sacramento River RM 296) (City of Redding)
U_03_SU	Foothill WTP (Sacramento River RM 296) (City of Redding)
Other Federal Projects	
U_20_25_PU	Putah South Canal CM 013 & CM 017 (Solano Project - City of Vacaville)
U_BNCIA_PU	Putah South Canal CM 033 (Solano Project – City of Benicia)
U_CSPS_NU	Putah South Canal CM 015 (Solano Project – California State Prison, Solano)
U_VLLJO_PU	Putah South Canal CM 033 (Solano Project – City of Vallejo)
U_FRFLD_PU	Putah South Canal CM 017 & CM 024 (Solano Project – City of Fairfield)
SWP Settlement and Long-Term Table A Contractors	
U_11_NU1	Thermalito Power Canal (Thermalito ID)
U_12_13_NU1	Miners Ranch Reservoir; West Branch Feather RM 015; Thermalito Power Canal (CalWater-Oroville)
U_16_PU	Feather River RM 031 (Yuba City)
U_20_25_PU	North Bay Aqueduct CM 011 (City of Vacaville)
U_20_25_SU	North Bay Aqueduct CM 011 (City of Vacaville)
U_BNCIA_PU	North Bay Aqueduct CM 021 (Solano County WA)
U_BNCIA_SU	North Bay Aqueduct CM 021 (Solano County WA)
U_FRFLD_PU	North Bay Aqueduct CM 011 (City of Fairfield)
U_FRFLD_SU	North Bay Aqueduct CM 011 (City of Fairfield)
U_NAPA_PU	North Bay Aqueduct CM 027 (Napa County FC&WCD)
U_NAPA_PU_A21	North Bay Aqueduct CM 027
U_SUISN_NU	Putah South Canal CM 020
U_TAFB_PU	North Bay Aqueduct CM 009
U_VLLJO_PU	North Bay Aqueduct CM 021 (Solano County WA)
Non-Project Diverters	
U_12_13_NU2	Miners Ranch Reservoir (South Feather Water and Power Agency)
U_14_15N_NU	Yuba River RM 003 (City of Marysville)
U_20_25_NU	Sacramento River RM 074 (Cities of Davis and Woodland)
U_24_NU1	Wise Canal CM 004; Lower Boardman Canal CM 038 (PCWA - Zone 1, Nevada ID)
U_24_NU2	South Canal CM 004; Auburn Tunnel CM 002 (PCWA - Zone 1)
U_26_NU1	American River RM 007 (City of Sacramento wholesale agreements)
U_26_NU2	American River RM 017 (Carmichael WD)
U_26_NU3	Sacramento River RM 062; American River RM 007 (City of Sacramento)
U_26_NU4	American River RM 007 (City of Sacramento)
U_26_NU5	Folsom Lake (Aerojet)
U_26_NU6	Folsom Lake (Parks and Recreation)
U_60N_NU2	Cosumnes River RM 033 (Rancho Murieta)

Demand Unit	Surface Water Diversion(s)
U_60S_NU1	Calaveras River RM 026; Mokelumne River RM 035; San Joaquin River RM 028; Farmington Reservoir (City of Stockton)
U_61N_NU1	South San Joaquin
U_AMADR_NU	North Fork Mokelumne River
U_ANTOC_NU	Contra Costa Canal CM 007; San Joaquin River RM 006 (City of Antioch)
A_CaCWD_NU	Mokelumne above Mokelumne Hill (Middle Fork Mokelumne River)
A_CaPUD_NU	Mokelumne above Mokelumne Hill (Middle Fork Mokelumne River)
U_CLLPT_NU	Clear Lake (lakeshore communities)
U_EBMUD_NU	Mokelumne Aqueduct CM 057 (EBMUD)
U_GDPUD_NU	Georgetown Divide Ditch
U_JLIND_NU	Calaveras River RM 043 (Jenny Lind)
U_PCWA3_NU	Lower Boardman Canal CM 010 (PCWA - Zone 3)

Key:
CM = Canal Mile, CSA = County Service Area, CSD = Community Service District, CVP = Central Valley Project, EBMUD = East Bay Municipal Utility District, FC&WCD = Flood Control and Water Conservation District, ID = Irrigation District, RM = River Mile, SMUD = Sacramento Municipal Utility District, SWP = State Water Project, WA = Water Agency, WC = Water Company, WD = Water District, WTP = Water Treatment Plant.

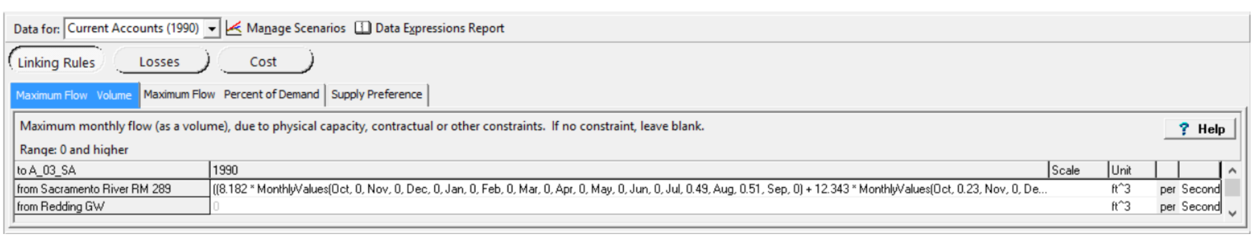
Table 6-21. Surface Water Diversions by Refuge Demand Unit

Demand Unit	Surface Diversion(s)
R_08_PR	Glenn-Colusa Canal CM 027, CM 039 & CM 056
R_09_PR	Sacramento River RM 196
R_11_PR	Richvale Canal; Western Canal (Thermalito Reservoir)
R_17_NR	Butte Creek RM 012
R_17_PR1	Joint Board Canal (Thermalito Reservoir)
R_17_PR2	Sutter Bypass CM 029; Joint Board Canal

Key:
CM = Canal Mile, RM = River Mile.

6.6.1 Linking Rules

6.6.1.1 Maximum Flow Volume



6.6.1.1.1 Central Valley Project Settlement Contractors

The **maximum flow volume** parameter is used to restrict the total volume of water that can flow through a transmission link. In SacWAM, this parameter is used to restrict flows according to water rights and contract limits. A sample expression is presented below for a CVP settlement contractor:

> ((8.182 * MonthlyValues(Oct, 0, Nov, 0, Dec, 0, Jan, 0, Feb, 0, Mar, 0, Apr, 0, May, 0, Jun, 0, Jul, 0.49, Aug, 0.51, Sep, 0)

+ 12.343 * MonthlyValues(Oct, 0.23, Nov, 0, Dec, 0, Jan, 0, Feb, 0, Mar, 0, Apr, 0.11, May, 0.14, Jun, 0.29, Jul, 0, Aug, 0, Sep, 0.23))

* Key\Units\TAFmonth2CFS * Other\Ops\CVP Allocations\Shasta_Crit

+ 9999 * MonthlyValues(Oct, 0, Nov, 1, Dec, 1, Jan, 1, Feb, 1, Mar, 1, Apr, 0, May, 0, Jun, 0, Jul, 0, Aug, 0, Sep, 0))

In this expression, the first block of information contains the contract amount (8.182 TAF) for the critical months (July and August) multiplied by the monthly portion of the contract that can be diverted during the peak months. The second block of information contains the full contract amount for the non-peak months (12.343 TAF) for the non-peak months multiplied by the monthly portion of the contract that can be diverted during the non-peak months. In the actual contract, only the total April – October (8.182+12.343) and July and August (8.182) volumes are specified. In SacWAM, the monthly proportions are based on average monthly water demands. The third block is a unit conversion from TAF to cfs. The fourth block implements an allocation based on Shasta critical years. The fifth block allows diversions (up to the full water demand) from November to March, as water rights outside of the irrigation season specified in the CVP contracts have not currently been quantified for SacWAM.

The CVP settlement contract amounts are presented in Table 6-22.

6.6.1.1.2 Central Valley Project Water Service Contractors

Deliveries to CVP water service contractors are constrained to the product of their full contract amount and the CVP allocation using the *Maximum Flow Volume* property of the transmission link. The CVP water service contract amounts are presented in Table 4-13 and Table 6-23.

6.6.1.1.3 Central Valley Project Level 2 Refuge Supplies

Deliveries of CVP water to refuges located in the Sacramento Valley are constrained to the product of the Level 2 amount and the CVP allocation using the *Maximum Flow Volume* property of the transmission link. The refuge level 2 amounts are presented in Table 6-24.

Table 6-22. North-of-Delta Central Valley Project Settlement Contractors

SacWAM Demand Unit	Central Valley Project Settlement Contractor	Contract Amount (acre-feet)
Water Budget Area 02: Sacramento River Right Bank, RM 254.1 – RM 309.5 [6]		
U_02_SU	Redding, City of [1]	10,500
	Subtotal	**10,500**
A_02_SA	Anderson-Cottonwood ID [3]	108,800
	Lake California Property Owners As. Inc.	780
	Leviathan, Inc.	700
	Subtotal	**110,280**
Water Budget Area 03: Sacramento River Left Bank, RM 250.1 – RM 309.5		
U_03_SU	Redding, City of [2]	10,500
	Subtotal	**10,500**
A_03_SA	Anderson-Cottonwood ID [4]	19,200
	Riverview Golf and Country Club	280
	Daniell, Harry W.	20
	Redding Rancheria Tribe	205
	Driscoll Strawberry Associates, Inc.	820
	Subtotal	**20,525**
Water Budget Area 04_06: Sacramento River Right Bank, RM 206.1 – RM 254.1		
A_04_06_NA [7]	Meyer Crest Limited	425
	Exchange Bank (Nature Conservancy)	780
	Rubio, Exequiel P. and Elsa A.	16
	Penner, Roger & Leona	180
	Alexander, Thomas and Karen	22
	Subtotal	**1,423**
Water Budget Area 05: Sacramento River Left Bank, RM 195.7 – RM 250.1		
A_05_NA [7]	J. B. Unlimited, Inc.	510
	Micke, Daniel H. and Nina J.	100
	Gjermann, Hal	12
	Subtotal	**622**
Water Budget Area 08: Sacramento River Right Bank, RM 92.8 – RM 206.1		
A_08_SA1	Princeton-Cordora-Glenn ID	67,810
	Provident ID	54,730
	Maxwell ID	899
	Green Valley Corporation	890
	Green Valley Corporation	880
	Tuttle, Charles, Jr. and Noack, Sue T., Trustees	390
	Cachil Dehe Band of Wintun Indians	180
	Seaver, Charles W. and B.J., Trustees	480
	Subtotal	**126,259**
A_08_SA2	Glenn-Colusa ID	825,000
	Subtotal	**825,000**
A_08_SA3	Roberts Ditch Irrigation Company, Inc.	4,440
	King, Benjamin and Laura	19
	King, Laura	26
	Wisler, John W., Jr.	35
A_08_SA3	Mehrhof Montgomery, S and J McPherson Montgomery	180

SacWAM Demand Unit	Central Valley Project Settlement Contractor	Contract Amount (acre-feet)
	Sycamore Family Trust	31,800
	Jansen, Peter and Sandy	190
	Gillaspy, William F., Trustee	210
	Beckley, Ralph and Ophelia	300
	Driver, Gary, et al.	30
	Reclamation District 108	232,000
	River Garden Farms Company	29,800
	Driver, John A. & Clare M., Trustees	230
	Driver, John A. & Clare M., Trustees	16
	Subtotal	**316,357**
Water Budget Area 09: Sacramento River Left Bank, RM 140.6 – RM 195.7		
A_09_SA1	Pacific Realty Associates, L.P. (M&T Chico Ranch)	17,956
	Subtotal	**17,956**
A_09_SA2	Reclamation District 1004	71,400
	Anderson, Arthur L. et al.	490
	Carter Mutual Water Company	7,122
	Forry, Laurie and Adams, Louise	2,285
	Otterson, Mike, Trustee	1,815
	Nene Ranch, LLC	1,560
	Griffin, Joseph and Prater, Sharon	2,760
	Baber, Jack W. et al.	6,260
	Eastside Mutual Water Company	2,804
	Zelmar Ranch, Inc.	164
	Gomes, Judith A., Trustee	246
	Butte Creek Farms, Inc.	36
	Butte Creek Farms, Inc.	95
	Butte Creek Farms, Inc.	204
	Butte Creek Farms, Inc.	640
	Howard, Theodore W. and Linda M.	76
	Ehrke, Allen A. and Bonnie E.	380
	Subtotal	**98,337**
Water Budget Area 18_19: Sacramento River Left Bank, RM 87.5 – RM 140.6		
A_18_19_SA	Fedora, Sibley G. and Margaret L., Trustees	210
	Reische, Laverne C. et al.	450
	Reische, Eric L.	90
	Tarke, Stephen E. and D.F., Trustees	2,700
	Meridian Farms Water Company	35,000
	Churkin, Michael Jr. et al.	130
	Eggleston, Ronald H. et ux.	65
	Hale, Judith A. and Marks, Alice K.	130
	Hale, Judith A. and Marks, Alice K.	75
A_18_19_SA (contd.)	Davis, Ina M.	85
	Chesney, Adona, Trustee	700
	Andreotti, Beverly F. et al.	3,620
	Lomo Cold Storage and Micheli, Justin J.	7,110
	Anderson R. and J., Properties, LP	237

SacWAM Demand Unit	Central Valley Project Settlement Contractor	Contract Amount (acre-feet)
	Lonon, Michael E.	1,155
	Tisdale Irrigation and Drainage Company	9,900
	Sutter MWC	226,000
	Oji Brothers Farm, Inc.	3,200
	Young, Russell L., et al.	10
	Butler, Dianne E., Trust	434
	Hatfield Robert and Bonnie	26
	Howald Farms, Inc.	2,760
	Kary, Carol Trustee	1,000
	Wilson, Dennis, Farms, Inc.	355
	Lockett, William P. and Jean B.	417
	O'Brien, Frank J., and Janice C.	839
	Dyer, Jeffrey E., and Wing-Dyer, Jan	520
	Pelger Mutual Water Company	8,860
	Bardis, Cristo D. et al.	10,070
	Wakida, Haruye, Trustee	325
	Wakida, Haruye, Trustee	160
	Nelson, Thomas L., Jr., and Hazel H.	136
	Rauf, Abdul and Tahmina	3,160
	Hiatt, Thomas, Trustee	1,485
	Hiatt, Thomas, and Illerich, Phillip, Trustees	584
	Oji, Mitsue, Family Partnership et al.	4,740
	Henle, Thomas N., Trustee	935
	Windswept Land and Livestock Company	4,040
	Schreiner (Sioux Creek Property LLC)	200
	Munson, James T. and Delmira	155
	KLSY LLC	170
	Quad-H Ranches, Inc.	500
	Giusti, Richard J. and Sandra A., Trustees	1,610
	Jaeger, William L. and Patricia A.	870
	Morehead, Joseph A. and Brenda	255
	Heidrick, Joe Jr., Trustee	560
	Leiser, Dorothy L.	60
	MCM Properties, Inc.	1,470
	Richter, Henry D. et al.	2,780
	Furlan, Emile and Simone, Family Trust	53
	Wallace, Kenneth L. Living Trust	867
	Byrd, Anna C., and Osborne, Jane [5]	1,265
	Subtotal	**342,528**
Water Budget Area 21: Sacramento River Right Bank, RM 62.1 – RM 92.8		
A_21_SA	Driver, William A., et al.	160
	Driver, Gregory E.	20
	Giovannetti, B.E.	520
	Heidrick, Mildred M., Trustee	120
	Knights Landing Investors, LLC	3,640
	Heidrick, Mildred M., Trustee	430

SacWAM Demand Unit	Central Valley Project Settlement Contractor	Contract Amount (acre-feet)
	Sacramento River Ranch LLC	4,000
	Knaggs Walnut Ranches Company, L.P.	630
	Conaway Preservation Group	50,862
	Wilson Ranch Partnership	370
	Reclamation District 900 and 1000	404
	Mesquite Investors, LLC (Riverby Limited)	500
	Subtotal	**61,656**
Water Budget Area 22: Sacramento River Left Bank, RM 64.9 – RM 82.7		
A_22_SA1	Pleasant Grove-Verona MWC	26,290
	Natomas Central MWC	120,200
	Odysseus Farms Partnership	630
	Cummings, William C.	300
	Lauppe, Burton H., and Kathryn L.	950
	Natomas Basin Conservancy	490
	E.L.H. Sutter Properties Inc.	20
	Lauppe, Burton H., and Kathryn L.	350
	Willey, Edwin E. and Marjorie E.	95
	Sacramento, County of	750
	Subtotal	**150,075**
Total		**2,092,018**

Notes:

[1] Contract for City of Redding estimated as 50% of 21,000 acre-feet based on Census 2000 population located within Foothill, Hill 900 and Cascade pressure zones.

[2] Contract for City of Redding estimated as 50% of 21,000 acre-feet based on Census 2000 population located within Enterprise Zone.

[3] Contract for Anderson-Cottonwood ID estimated as 85% of 125,000 acre-feet based on historical delivery data. Additional 85% of 3,000 acre-feet water rights.

[4] Contract for Anderson-Cottonwood ID estimated as 15% of 125,000 acre-feet based on historical delivery data. Additional 15% of 3,000 acre-feet water rights.

[5] Contractor located in WBA 17 and WBA 18_19. For modeling purposes, land assumed to be located in WBA 18_19.

[6] CalSim 3.0 river mile refers to most upstream diversion point. RM 61.7 corresponds to the I Street Bridge in the City of Sacramento. This is RM 0.0 for Reclamation Contract river miles.

[7] Given the small contract amount, these landowners were aggregated with non-CVP water demands.

Key:

ID = Irrigation District, LLC = Limited Liability Company, LP = Limited Partnership, MWC = Mutual Water Company.

Table 6-23. North-of-Delta Central Valley Project Water Service Contractors

SacWAM Demand Unit	CVP Water Service Contractor	Contract Amount (acre-feet)
Sacramento and Trinity River Divisions		
A_02_PA	Clear Creek CSD	13,150
U_02_PU	Centerville CSD	3,800[1]
	Clear Creek CSD	8,000
	Shasta CSD	1,000
	Shasta County WA	332
	Keswick CSA	400
	Total	**13,352**
A_03_PA	Bella Vista WD	18,000
U_03_PU	Bella Vista WD	6,578
	City of Shasta Lake	4,400
	Mountain Gate CSD	1,350
	Jones Valley CSA	290
	City of Redding (Buckeye WTP)	6,140
	Total	**29,420**
Corning Canal Unit		
A_04_PA1	Corning WD	23,000
	Proberta WD	3,500
	Thomes Creek WD	6,400
	Total	**32,900**
Tehama-Colusa Canal Unit		
A_04_PA2	Kirkwood WD	2,100
A_07N_PA	Glide WD	10,500
	Kanawha WD	45,000
	Orland-Artois WD	53,000
	Colusa, County of	20000
	Colusa County WD	62,200
	Davis WD	4,000
	Dunnigan WD	19,000
	La Grande WD	5,000
	Westside WD	65,000
	Total	**283,700**
Black Butte Unit		
A_SCKWD_NA	4-E WD	35
	Stony Creek WD	3,345
	U.S. Forest Service (Salt Creek)	45
	Whitney Construction, Inc.	25
	U.S. Forest Service	10
	Colusa, County of (Stonyford)	40
	Total	**3,500[2]**
Colusa Basin Drain		
A_08_PA	Colusa Drain MWC	54,600
A_21_PA	Colusa Drain MWC	15,400
American River Division		
U_26_PU1	City of Roseville	32,000

SacWAM Demand Unit	CVP Water Service Contractor	Contract Amount (acre-feet)
U_26_PU2	San Juan WD	24,200
U_26_PU3	City of Folsom	7,000[7]
U_26_PU4	Sacramento County WA	45,000[3]
U_26_PU5	Golden State WC	
U_60N_PU	SMUD	30,000[4]
EBMUD	East Bay MUD	133,000[5]
U_ELDLO_NU	El Dorado ID	7,550
Delta Division		
U_CCWD_NU	Contra Costa WD	195,000
Other		
A_16_PA	Feather WD	20,000
U_21_PU	City of West Sacramento	23,600[6]
Total		**564,085**

Notes:
[1] Centerville Community Services District as part of the liquidation of the Townsend Flat Water Ditch Company's pre-1914 water rights holdings on Clear Creek has secured 900 acre-feet of CVP supplies in addition to the 2,900 acre-feet. These quantities of supply are not subject to cutbacks, and the water may be transferred to any other purveyor in the Redding Basin.
[2] This value has been corrected – previously SacWAM used a value of 3,700 acre-feet.
[3] The CVP contract amount for Sacramento County WA includes a 30,000-acre-foot assignment from SMUD and 15,000 acre-feet of Fazio water. SacWAM assumes that the first 12,300 acre-feet of CVP water is wheeled through the City of Sacramento's water treatment plant and delivered to the county's service area through the Franklin Intertie. Based on the County's 2010 urban water management plan, the demand for CVP water is limited to 25,000 acre-feet.
[4] SMUD's original 1970 contract with Reclamation was for 60,000 acre-feet. In 2006, SMUD assigned 30,000 acre-feet of this CVP contract to Sacramento County WA. SMUD also holds a separate Warren Contract, executed in 2012, for the delivery of up to 15,000 acre-feet of water rights water. This value has been corrected – previously SacWAM used a value of 30,000 acre-feet.
[5] The CVP contract allows EBMUD to divert up to 133,000 acre-feet of American River water each year with a total not to exceed 165,000 acre-feet in 3 consecutive years. This diversion can only occur in drought years when EBMUD's total system storage is forecast to be less than 500,000 acre-feet.
[6] The CVP contract authorizes the City of West Sacramento to divert up to 23,600 acre-feet per year from the Sacramento River of combined appropriative right water and CVP water.
[7] In 1999, Reclamation signed a contract (6-07-20-W1372) with Sacramento County WA for the provision of CVP water as part of Section 206 of Public Law 101- 514. The contract dedicated 22,000 acre-feet of Fazio water to the agency. The City of Folsom was specifically named in the Reclamation contract as a subcontractor to gain benefit of a portion of the Fazio Water supply. In 2000, Sacramento County WA entered into a separate contract with the city to provide 7,000 acre-feet of the 22,000 acre-feet of Fazio Water.

Key:
CSA = County Service Area, CSD = Community Service District, CVP = Central Valley Project, ID = Irrigation District, M&I = municipal and industrial, MUD = Municipal Utility District, MWC = Mutual Water Company, SMUD = Sacramento Municipal Utility District, WA = Water Agency, WD = Water District, WTP = water treatment plant.

Table 6-24. North-of-Delta Central Valley Project Level 2 Refuge Supplies

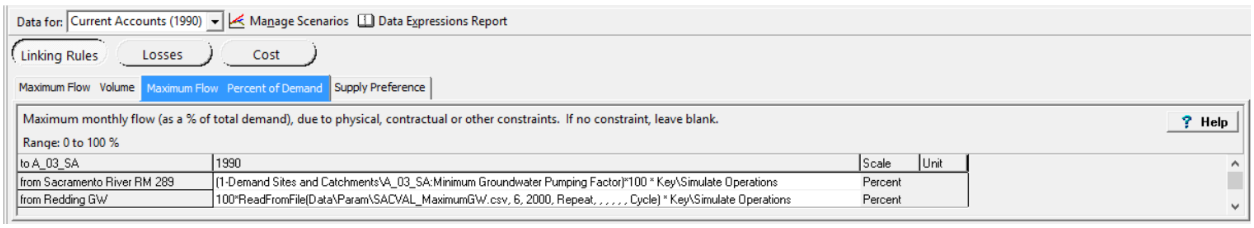
SacWAM Demand Unit	Refuge	Level 2 Contract Amount (acre-feet)
R_08_PR	Sacramento NWR	46,400
	Delevan NWR	20,950
	Colusa NWR	25,000
	Total	92,350
R_17N_PR	Sutter NWR	23,500
R_17S_PR	Gray Lodge WA	35,400
Total		**151,250**

Key:
NWR = National Wildlife Refuge, WA = Wildlife Area

6.6.1.1.4 State Water Project and the Feather River Sevice Area

Deliveries to the Feather River Service Area are constrained to the product of their full contract amount and the SWP allocation using the *Maximum Flow Volume* property of the transmission link. Only part of the settlement/contract amount may be subject to deficiencies in dry years. South of the Delta, water demands of the SWP long-term contractors are assumed equal to their full Table A amount. Deficiencies are imposed using the *Maximum Flow Percent of Demand* property of the transmission link, which is set equal to SWP allocation. SWP Table A amounts are presented in Table 4-14.

6.6.1.2 Maximum Flow Percent of Demand

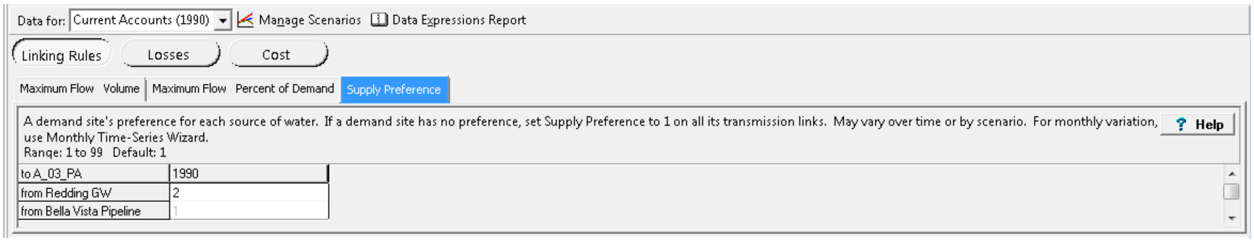


The **maximum flow percent of demand** is used to restrict the flow through a transmission link to a percent of the demand in the destination catchment or demand site. In SacWAM, this parameter is used to implement various restrictions:

- For transmission links that convey groundwater to agricultural catchments, the maximum groundwater pumping fraction is entered in this parameter. These values were determined from an analysis of DWR county land use surveys (DWR, 1994a-b, 1995a-b, 1996, 1997b, 1998a-c, 1999a-b, 2000a) and are the ratio of the total area in a DU that is reliant on groundwater to the total area served by both groundwater, surface water, or a mix of both sources.
- For transmission links that convey surface water to agricultural catchments, the maximum percent of demand that can be met by surface water is defined as one minus the minimum groundwater pumping factor (see Minimum Groundwater Pumping Factor in Section 4.4.2.6).
- For urban demand sites, this parameter is used to enforce conjunctive use of groundwater and surface water and is a surrogate for installed capacity, operational constraints, and other factors. However, many urban demands rely on groundwater, or only use surface water.
- For demand sites representing CVP and SWP contractors served by the Delta-Mendota Canal and California Aqueduct, this parameter is used to restrict total deliveries when water allocations are less than 100%.

All expressions in the 'Maximum Flow Percent of Demand' branch are multiplied by the factor *Key\Simulate Operations*. This factor has a value of zero when the model is run in the unimpaired mode resulting in no flow through transmission links. For further details, see Section 9.11.

6.6.1.3 Supply Preference

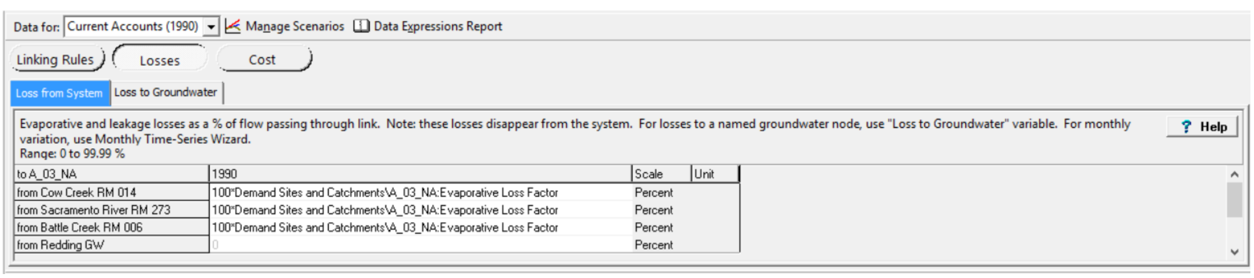


When demand sites or catchments are connected to more than one supply source, supply preferences determine the order of water withdrawal. Similar to demand priorities, supply preferences are assigned a value between 1 and 99, with lower numbers indicating preferred water sources. The assignment of these preferences usually reflects some combination of economic, environmental, historic, legal, and political realities. When the preferred water source is insufficient to satisfy all of an area's water demands, WEAP treats the additional sources as supplemental supplies and draws from these sources only after it encounters a capacity constraint (expressed as either a maximum flow volume or a maximum percent of demand) associated with the preferred water source. In general, SacWAM is set up such that surface water is given preference over pumping groundwater.

Supply preference is used to determine the order in which supplies are accessed in cases where a catchment or demand site has more than one supply source. Most commonly, this situation arises when a catchment or demand site is connected to a surface water supply and a groundwater supply. Typically, in SacWAM, surface water is used preferentially, and therefore given a preference value of '1', and groundwater is a supplemental supply with a preference value of '2'.

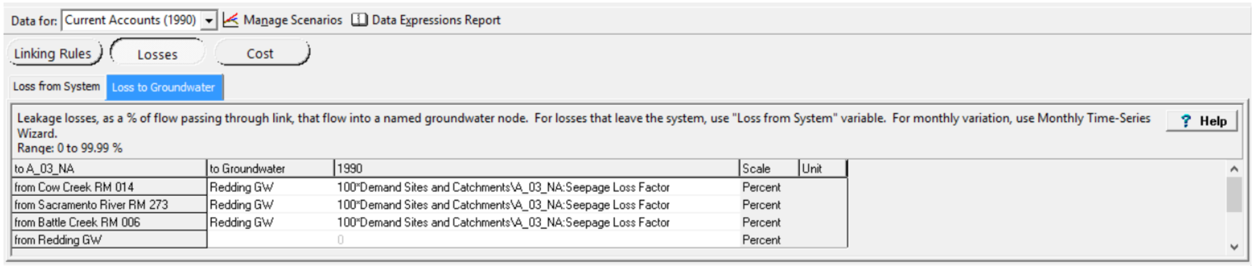
6.6.2 Losses

6.6.2.1 Loss from System



The *Loss from System* parameter specifies the fraction of water conveyed from the source to the demand that is lost through evaporation. This parameter is specified using the *Evaporative Loss Factor* described in Section 4.4.1.

6.6.2.2 Loss to Groundwater



The *Loss to Groundwater* parameter specifies the fraction of water lost from delivery canals or pipelines to the underlying groundwater through seepage. This parameter is specified using the *Seepage Loss Factor* described in Section 4.4.1.

6.6.3 Cost

The WEAP *Cost* feature is not used in SacWAM.

6.7 Runoff and Infiltration

A comprehensive, GIS-based approach was used to determine surface water runoff and return flow locations for SacWAM DUs. This approach ensured the accurate simulation of flows of tributary rivers at their confluences with the Sacramento River, the accurate simulation of flows at USGS gauges on the Sacramento River, and flows into the Delta (Figure 1-2, Figure 1-3).

The contributing watersheds for each of these return points of interest (**valley floor returns**) were delineated through a combination of GIS tools and the use of the Natural Resources Conservation Service (NRCS) **Hydrologic Unit Code (HUC)-12 watersheds** dataset (NRCS, 2013a). In the case where the point of interest fell on a boundary between two NRCS **HUC-12 watersheds**, the HUC-12 boundary was used. In all other cases, the watershed tool in ArcGIS was used to delineate the downstream extent of the watershed boundary using the National Hydrography Dataset (NHD) **flow accumulation** grid and the NRCS **HUC-12 watersheds** were used from the point that the GIS-generated watershed boundary intersected the HUC-12 boundary. There are two places where the approach was amended. These include the American River and Rodeo Creek, where relevant flow details are not captured in the NRCS **HUC-12 watersheds**. Rodeo Creek flows into McClure Creek, rather than directly into the Sacramento River as suggested by the HUC-12 boundaries. For this reason, the approximate area of the Rodeo Creek HUC-12 that drains to Rodeo Creek was added to the contributing area for McClure Creek. The American River watershed was divided along a boundary established in DWR models (**American boundaries**). The resulting file is called **watershed boundaries**.

Once SacWAM watershed boundaries were determined, an intersection was performed with the **demand units** and **watershed boundaries** shapefiles. The result of this intersection is the surface **returns intersection** shapefile. This intersection determined the proportion of each DU that lies within each SacWAM watershed. Where the percentage of a DU that lies within each SacWAM watershed is less than or equal to 10%, the return was not represented on the schematic and proportions were recalculated with the watersheds less than or equal to 10% omitted from the total area. The post-intersection processing is documented in the **surface returns** file. Table 6-25 presents surface runoff and return information for each DU, with the percentage of runoff/return flow that contributes to each return location. On the schematic, surface runoff and return locations are referred to with an 'SR' preceding location name. For instance, surface runoff to Cottonwood Creek from DU A_02_NA is referred to as 'SR Cottonwood Creek' in Table 6-25 and in SacWAM.

Surface runoff is represented in SacWAM with a runoff link to a surface water body (dashed blue line). If a catchment has multiple receiving surface water bodies, the runoff is distributed among the return locations using the surface returns intersection. The corresponding percentage of runoff that contributes to each return location (indicated in Table 6-25 and the **surface returns** file) was entered in the *Supply and Resources\Runoff and Infiltration\Demand Unit\Inflows and Outflows\Surface Runoff Fraction* branch of the data tree.

Some urban DUs represent both municipalities and scattered urban communities. For example, U_02_NU represents the City of Anderson, Cottonwood WD, Lake California (Rio Alto WD) and small communities (self-supplied). The municipalities hold permits to discharge wastewater to the Sacramento River at RM 281, but the small communities do not. In SacWAM, these DUs are represented with multiple return flows. One return flow link will flow to the wastewater treatment plant (WWTP) discharge location, and the other link(s) will flow to the groundwater basin(s), which the DU overlies. The rainfall-runoff from this DU type will flow to surface water locations as determined by the surface **returns intersection**.

The exceptions to the approach described above were the DUs that encompass the Delta, and one demand unit in the Putah Creek watershed, A_20_25_NA3. The DUs that encompass the Delta are: A_50_NA1, A_50_NA2, A_50_NA3, A_50_NA4, A_50_NA5, A_50_NA6, and A_50_NA7, which have runoff to specified RMs. Because the HUC-12 watersheds may be an imprecise indicator of flow in the Delta, surface returns from CalSim II were used instead (Reclamation, 2007). Demand unit A_20_25_NA3, which has runoff to Putah Creek, was added to SacWAM after the returns intersection file was created. Consequently, surface runoff locations and percent of runoff for this demand unit were taken from a previous CalSim 3.0 analysis. Demand unit A_20_25_NA3 has surface water runoff to Putah Creek at RM 21 and RM 24.

Runoff to surface water bodies from urban catchments was treated in the same way as runoff from agricultural catchments. Surface runoff locations and percentages were determined from the surface **returns intersection** for each DU. In cases where a DU only represents municipalities that hold a permit to discharge to a WWTP, it was assumed that 100% of the runoff from the urban DU's catchment flows to the WWTP discharge location. The parameter values are contained in the surface returns file.

Table 6-25. Runoff from Demand Units

Demand Unit	Return Flow Node	Percent of Runoff (%)
Agricultural Demand Units		
A_02_NA	SR Cottonwood Creek	84
	SR Sacramento River above Keswick Gauge	16
A_02_PA	SR Sacramento River above Bend Bridge Gauge	62
	SR Cottonwood Creek	23
	SR Clear Creek	15
A_02_SA	SR Sacramento River above Bend Bridge Gauge	54
	SR Cottonwood Creek	46
A_03_NA	SR Sacramento River above Bend Bridge Gauge	85
	SR Cow Creek	15
A_03_PA	SR Sacramento River above Bend Bridge Gauge	75
	SR Cow Creek	25
A_04_06_NA1	SR Sacramento River above Ord Ferry Gauge	28
	SR Stony Creek	28
	SR Colusa Basin Drain	21
	SR Sacramento River above Hamilton City Gauge	12
	SR Sacramento River above Butte City Gauge	11
A_04_06_NA2	SR Sacramento River above Hamilton City Gauge	59
	SR Thomes Creek	41
A_04_06_PA1	SR Sacramento River above Hamilton City Gauge	56
	SR Sacramento River above Vina Gauge	44
A_09_NA	SR Butte Creek	87
	SR Sacramento River above Butte City Gauge	13
A_09_SA1	SR Butte Creek	88
	SR Sacramento River above Ord Ferry Gauge	12
A_11_SA3	SR Butte Creek	52
	SR Sutter Bypass	48
A_12_13_SA	SR Feather River	80
	SR Feather River above Gridley Gauge	20
A_14_15N_NA3	SR Yuba River above Marysville Gauge	58
	SR Feather River	42
A_15S_NA	SR Bear River	74
	SR Feather River	26
A_20_25_NA1	SR Yolo Bypass	53
	SR Cache Creek	31
	SR Cache Creek above Yolo Gauge	16
A_20_25_NA2	SR Sacramento River above Rio Vista Gauge	87
	SR Sacramento River RM 003	13
A_20_25_NA3	SR Putah Creek RM 024	62
	SR Putah Creek RM 021	38

Demand Unit	Return Flow Node	Percent of Runoff (%)
A_22_SA1	SR Natomas East Main Drain	77
	SR Sacramento River above Verona Gauge	23
A_23_NA	SR Auburn Ravine RM 000	76
	SR Bear River	24
A_24_NA1	SR Auburn Ravine RM 000	84
	SR Auburn Ravine	16
A_24_NA2	SR Auburn Ravine RM 000	83
	SR Bear River	17
A_24_NA3	SR Auburn Ravine	29
	SR Dry Creek	27
	SR Secret Ravine	22
	SR Natomas Cross Canal	22
A_26_NA	SR Mokelumne River	70
	SR American River above Fair Oaks Gauge	17
	SR Natomas East Main Drain	13
A_50_NA1	Sacramento River RM 041	100
A_50_NA2	Sacramento River RM 017	100
A_50_NA3	Sacramento River RM 000	100
A_50_NA4	Sacramento River RM 004	100
A_50_NA5	Sacramento River RM 026	100
A_50_NA6	Sacramento River RM 013	100
A_50_NA7	Old River RM 027	100
A_60N_NA1	SR Jackson Creek	87
	SR Dry Creek	13
A_60N_NA3	SR San Joaquin River	57
	SR Mokelumne River	43
A_60N_NA4	SR Mokelumne River	73
	SR San Joaquin River	27
A_60N_NA5	SR Cosumnes River	56
	SR Dry Creek	24
	SR San Joaquin River	20
A_60S_PA	SR San Joaquin River	76
	SR Calaveras River	24
A_61N_NA1	SR Stanislaus River	47
	SR Littlejohns Creek	37
	SR San Joaquin River	16
Urban Demand Units		
U_02_NU_O	SR Cottonwood Creek	53
	SR Sacramento River above Bend Bridge Gauge	47
U_04_06_NU_O	SR Sacramento River above Vina Gauge	87
	SR Sacramento River above Hamilton City Gauge	13

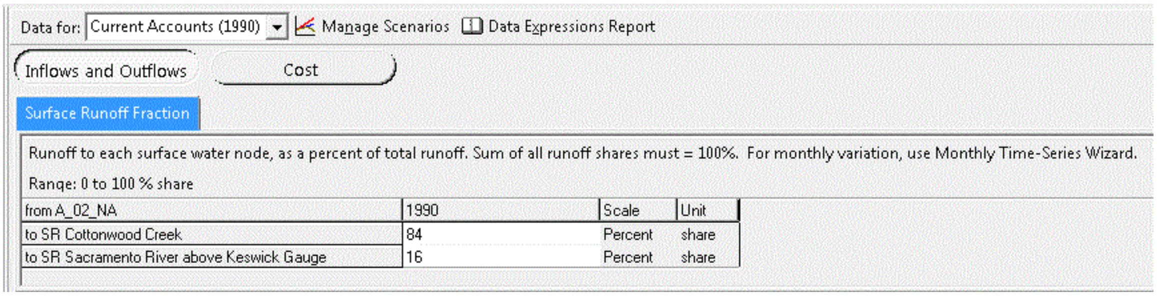
Demand Unit	Return Flow Node	Percent of Runoff (%)
U_05_NU_O	SR Antelope Creek	69
	SR Sacramento River above Vina Gauge	31
U_11_NU2_O	SR Sutter Bypass	50
	SR Butte Creek	50
U_24_NU2_O	Natomas Cross Canal CM 002 (Lincoln WWTP)	50
	Natomas East Main Drain CM 007 (Deer Creek WWTP)	50
U_26_NU1_O	SR Natomas East Main Drain	79
	American River RM 007	21
U_26_NU4_O	SR Mokelumne River	56
	Sacramento River RM 048 (Sacramento Regional WWTP)	32
	American River RM 007	12
U_26_PU2_O	SR Natomas East Main Drain	72
	SR American River above Fair Oaks Gauge	15
	American River RM 007	13
U_26_PU3_O	SR American River above Fair Oaks Gauge	73
	American River RM 007	27
U_26_PU5_O	American River RM 007	85
	Sacramento River RM 048 (Sacramento Regional WWTP)	15
U_61N_NU2_O	SR San Joaquin River	57
	SR Stanislaus River	43
Refuge Demand Units		
R_08_PR	SR Colusa Basin Drain above HWY 20 Gauge	80
	SR Colusa Basin Drain Above Outfall Gates Gauge	20

Key:
CM = canal mile, RM = river mile, SR = surface runoff, WWTP = wastewater treatment plant.

For some urban DUs, the surface **returns intersection** was not used to determine return flows and/or surface runoff locations. Treated wastewater from large urban centers, with dedicated or regional WWTPs, may be discharged to surface waters. However, in most rural and smaller towns, wastewater typically is discharged to private systems or evaporation ponds, which recharge the underlying groundwater aquifer. An example of a DU that holds a permit to discharge to a surface water body is U_26_NU4. Wastewater from the municipalities represented by this DU is treated at the Sacramento Regional WWTP and discharged to the Sacramento River at RM 048.

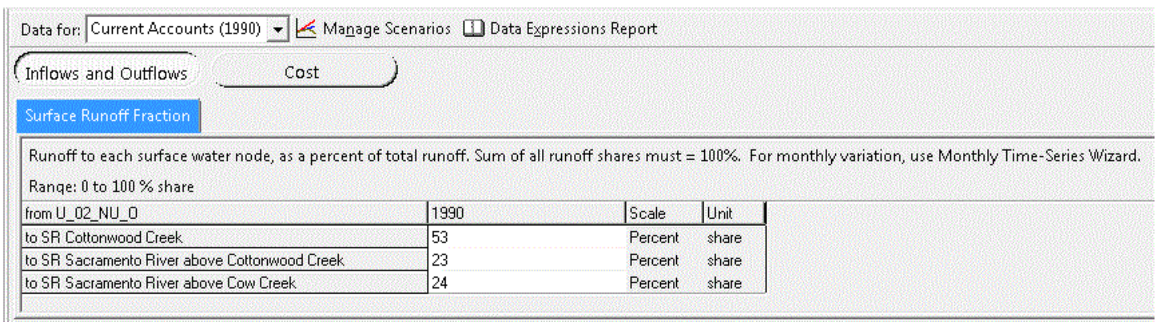
6.7.1 Inflows and Outflows

6.7.1.1 Surface Runoff Fraction for Agricultural Catchments



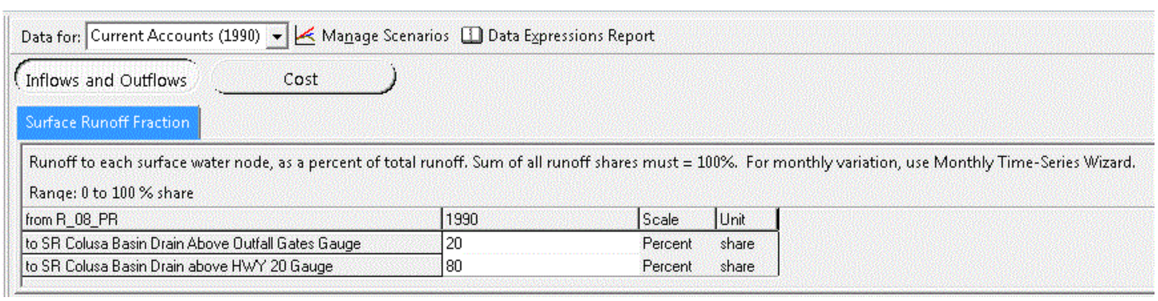
The surface runoff fraction is used to divide the runoff from a catchment object among different receiving surface water bodies. For agricultural catchments, these percentages can be found in Table 6-25 as described previously.

6.7.1.2 Surface Runoff Fraction for Urban Catchments



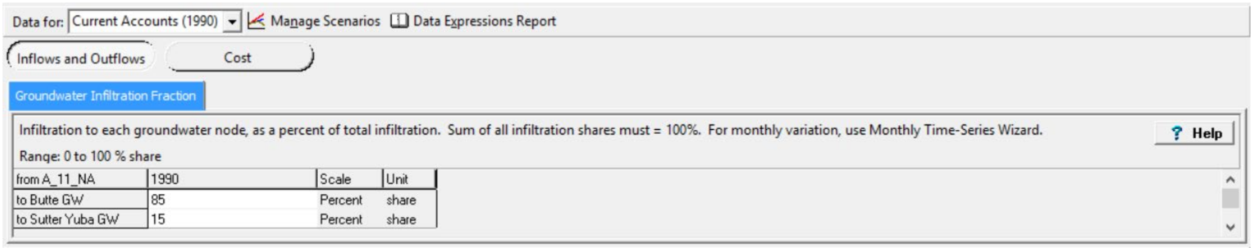
Surface runoff from urban catchments is divided using the values in Table 6-25 as described previously.

6.7.1.3 Surface Runoff from Refuge Catchments



Surface runoff from refuge catchments is treated in a similar manner to that from agricultural catchments. Their specified percentages are listed in Table 6-25.

6.7.1.4 *Groundwater Infiltration Fraction*



The groundwater infiltration fraction specifies the fraction of the total deep percolation that flows to a receiving groundwater basin. This is used when a DU overlies more than one groundwater basin. The fractions entered in this parameter for agricultural, urban, and refuge DUs are described in Section 3.4 and provided in Table 6-13.

6.7.2 Cost

The WEAP *Cost* features under *Runoff and Infiltration* are not used in SacWAM.

6.8 Data Directory

Table 6-26 provides location information in the SacWAM data directory for the datasets referenced in Chapter 6.

Table 6-26. File Location Information for Supply and Resources

Referenced Name	File Name	File Location[1]
Maximum diversions	maximum diversion.xlsx	Rivers\Diversions
Maximum flow percent of demand	maximum flow percent of demand.xlsx	Transmission_Links
Maximum flow volume	maximum flow volume.xlsx	Transmission_Links
Reservoir storage capacity	sacval_sr_riv_res_storage.xlsx	Rivers\Reservoirs
Returns intersection	sac_val_returns_intersection.shp	GIS\Hydrology
Streamflow gauges	sacval_sr_riv_streamflow_gauges.xlsx	Rivers\Streamflow_Gauges
Supply preference	supply preference.xlsx	Transmission_Links
Upper watershed diversion flows	sacval_upperwshed_diversionflows.xlsx	Rivers\Diversions
Valley floor inflows	sacval_sr_riv_inflows.xlsx	Rivers\Historical_Inflows
Volume elevation curve	sacval_sr_riv_res_vol_elev.xlsx	Rivers\Reservoirs

Note:
[1] Files located at Data\ Supply_and_Resources \... except for GIS files (GIS\...).

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7 Other Assumptions

This Chapter describes the 'Other Assumptions' branch of the SacWAM data tree. Other Assumptions allows for the development of model logic that is more complex than that directly supported by the interface screens related to the schematic objects. Other Assumptions contain: (a) model input parameters[28] that are evaluated at the beginning of each time and are used to formulate the LP water allocation problem; and (b) output variables that are calculated at the end of each time step following solution of the water allocation problem. Other Assumptions are often used in combination with 'User-

[28] This document uses the term 'parameter' when referring to model input and the term 'variable' or 'decision variables' to describe factors that are assigned a value by the MILP solver. Decision variables determined in a previous time step, e.g., previous end of month storage, are called 'state' variables.

Defined LP Constraints,’ which are discussed in Chapter 8.

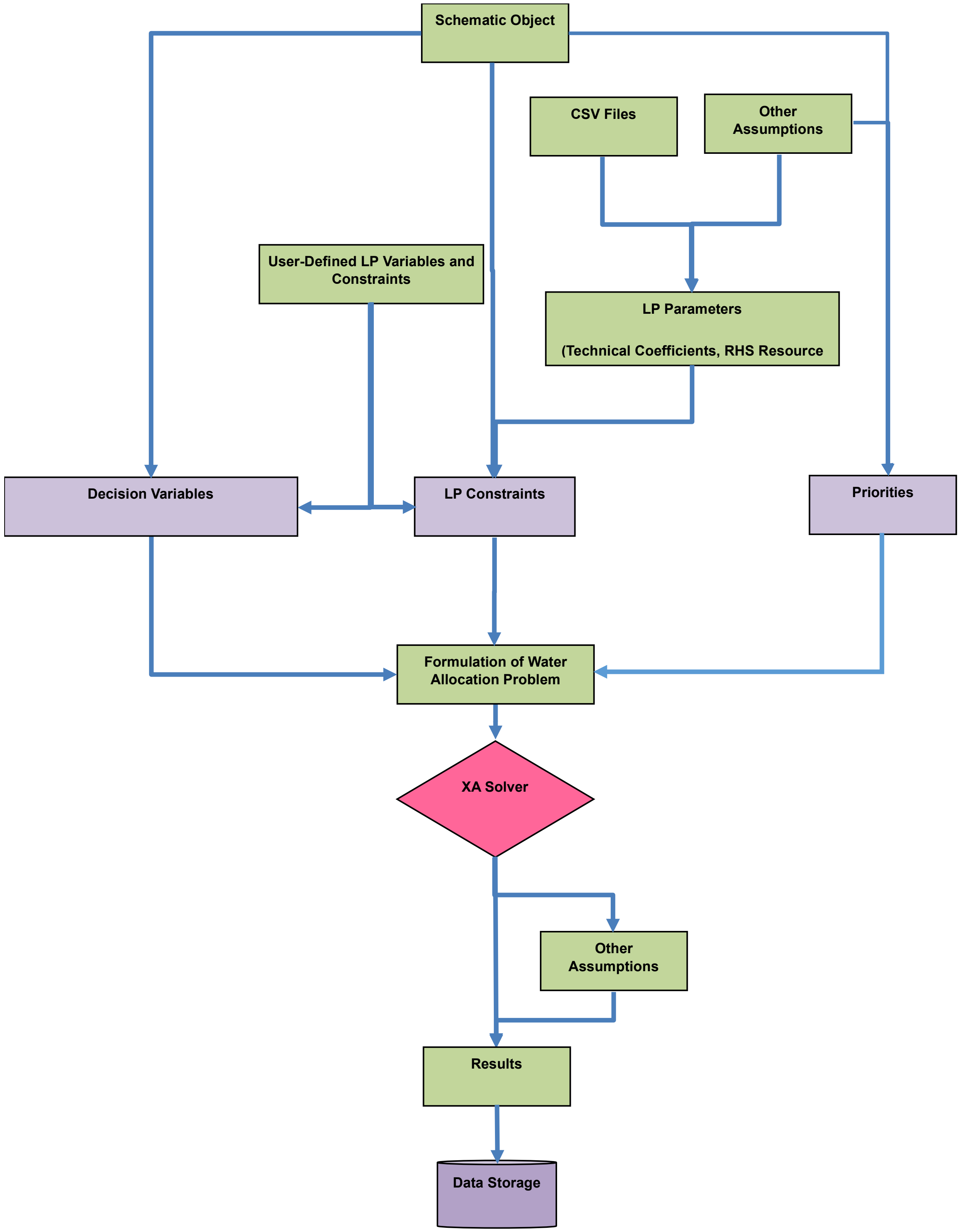


Figure 7-1 illustrates WEAP's calculation process of combining information from schematic objects, Other Assumptions, and User-Defined LP Constraints, formulating the LP problem, and storing results.

Other Assumptions in SacWAM are grouped into six sub-branches, as follows:

1. Simulation Options
2. Calibration Switches
3. Operations (Ops)
4. Upper Watershed Hydrology
5. Valley Floor Hydrology
6. Water Allocation Priorities

The sub-branches listed above are further divided into additional layers of sub-branches. In general, when a branch contains subbranches, the branch level is left empty although this may add some redundancy in branch and variable names.

In many cases, there is considerable overlap between *Other Assumptions* and *User-Defined LP Constraints*. For example, Delta outflow required for salinity control is determined using an Artificial Neural Network (ANN). Input parameters to the ANN are defined under *Other Assumptions*, e.g., water quality standards at compliance locations. Output from the ANN is used to formulate a linear constraint between Sacramento River inflow to the Delta and Delta exports. This linear constraint is defined under the *User-Defined LP Constraints* branch.

In cases where there is overlap between *Other Assumptions* and *User-Defined LP Constraints*, general background and information (e.g., description of the ANN) is included in this chapter (7) and referenced in Chapter 8. In general, the headings in this chapter correspond to 1 with 1 with the branches in the SacWAM data tree. However, the names of some data tree branches have been expanded for clarity. For example, the heading "Freeport Water Supply Project (Freeport)" in this report corresponds to the data tree branch "Freeport." For the purposes of model documentation, additional sections (i.e., additional to the SacWAM data tree structure) have been inserted in this chapter to provide background to local water agencies and local water project operations.

SacWAM has been developed by multiple people over multiple years. The data tree includes both legacy code that is no longer used but has been retained in the model for possible future use and further development. Elements of the data tree that are not in current use, but are described in this report, have been "grayed out," for example: "this branch of the data tree, although described, in not currently used in the model."

7.1 Simulation Options

SacWAM offers different approaches for determing outflow requirements for salinity control and X2 compliance.

7.1.1 Delta Salinity

Operation of CVP and SWP facilities is partially dictated by the need to meet D-1641 water quality standards for the Delta. SacWAM offers two methods for computing Delta outflow requirements for salinity control: the Artificial Neural Network (ANN), and the G-model. Both options compute Delta outflow requirements using external functions called from SacWAM. Only one option can be selected when the model is run. The default option selects ANN to compute Delta salinity. The G-model was used in early model building and development.

DWR has developed an ANN that mimics Delta flow-salinity relationships as simulated in the one-dimensional hydrodynamic and water quality model, DSM2 (Sandhu, 1995; Wilbur and Munévar, 2001; Jayasundara, 2020). Inputs to the ANN include Delta inflows, San Joaquin River salinity, Delta Cross Channel gate position, and Delta exports and diversions.[29] Values for each of these parameters for the previous five months are inputs to the ANN, representing an estimate of the length of memory of antecedent flow conditions in the Delta. Inputs also include the monthly averaged Delta salinity standard at four compliance locations (Collinsville, Emmaton, Jersey Point, and Rock Slough).[30] Section 8.8.2 presents additional information regarding user-defined variables relating to the ANN.

DWR's ANN is implemented in SacWAM to determine Delta outflow requirements for salinity control.[31] The ANN does not explicitly compute a flow requirement that SacWAM tries to meet. Rather, it specifies a set of linear relationships between Delta exports and Sacramento River inflows that must be maintained to meet D-1641 Delta water quality standards at the four compliance locations. A Delta flow balance is used to to determine the outflow requirement for a given export. Additionally, the ANN provides salinity estimates for Clifton Court Forebay and Contra Costa WD Los Vaqueros diversion locations (Old River and Victoria Canal). The ANN may also be used to calculate Delta salinity at the various compliance locations for the preceding time step once all Delta flows have been determined.

[29] The ANN also uses an indicator of tidal energy, but these data are combined into the ANN dynamic link library.

[30] In cases where standards are not year-round, 'guide' standards have been developed for the remains of the year so that antecedent salinity conditions at the on-set of salinity requirements do not prevent the standard from being met.

[31] DWR has also developed a set of ANNs that have been trained using four sea-level-rise scenarios (1-foot rise, 2- foot rise, 1-foot rise plus 4-inch amplitude increase, and 2-foot rise plus 4-inch amplitude increase).

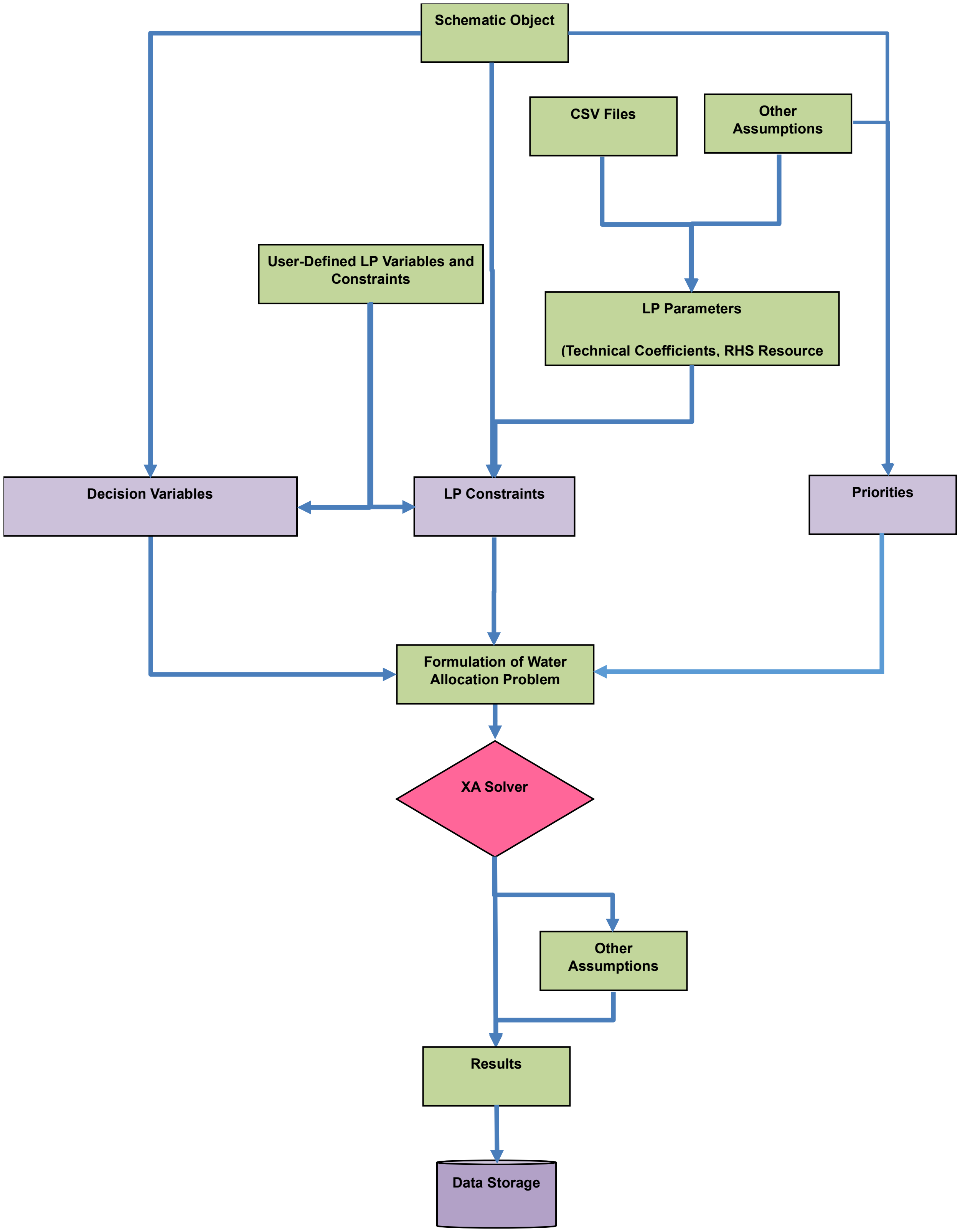


Figure 7-1. WEAP Calculation Process for Each Time Step

Outflow requirements to meet Delta salinity standards may be determined by linking SacWAM to Contra Costa WD's salinity-outflow model, commonly referred to as the 'G-model' (Denton and Sullivan, 1993). The G-model is based on a set of empirical equations, developed from the one-dimensional advection-dispersion equation. The G-model predicts salinity caused by seawater intrusion at key locations in Suisun Bay and the western Delta as a function of antecedent Delta outflow. The antecedent Delta outflow is a surrogate for directly modeling salinity distribution within the Delta and incorporates the combined effect of all previous Delta outflows. That is, the G-model assumes that salinity is a function of both current outflow and outflows from the previous 3 to 6 months. Because this salinity-outflow model was developed from the one-dimensional advection-dispersion equation, it accounts for the transport of salt by both mean flow (advection) and tidal mixing (dispersion). One limitation of the G-model is that its accuracy is limited to the western Delta. Additionally, the equations were developed under current sea level conditions.

The approach to determining outflow requirements for salinity control is controlled by the *ANN* parameter. An assigned value of '1' turns-on the ANN and disables the G-model; a value of '0' implements the G-model.

7.1.2 X2

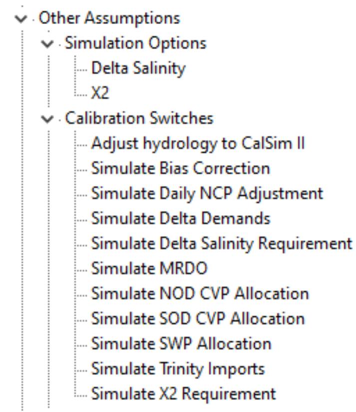
The X2 standard is expressed in terms of the location of the 2 parts per thousand (ppt) bottom isohaline as measured in kilometers upstream from the Golden Gate Bridge. SacWAM contains two methods to compute the net Delta outflow required to meet this standard. The model can call the ANN, described above and used to compute other salinity compliance requirements, alternatively the model can use the Kimmerer-Monismith equation (Jassby et al., 1995). Either approach can be selected by changing the value of *Other\Ops\Delta\X2\UseANN*. A value of '1' sets SacWAM to use the ANN and a value of '0' sets SacWAM to use the Kimmerer-Monismith equation. The SacWAM default approach is to use the ANN.

7.2 Calibration Switches

Other Assumptions contain calibration switches that allow the user to force portions of the model to operate using predefined values. These switches were used to calibrate or test SacWAM and will generally not be altered by future users of the model. In general, a switch value of '0' causes the model to use values derived from either historical data or CalSim II simulated data; a switch value of '1' causes the model to use simulated values generated by SacWAM. Switches are included for the following:

- Adjust hydrology to CalSim II
- Simulate Bias Correction
- Simulate Daily NCP Adjustment
- Simulate Delta Demands
- Simulate Delta Salinity Requirement
- Simulate MRDO

- Simulate NOD CVP Allocation
- Simulate SOD CVP Allocation
- Simulate SWP Allocation
- Simulate Trinity Imports
- Simulate X2 Requirement



CalSim II input values were obtained from the 'existing conditions' model version developed for the 2015 SWP Delivery Capability Report (DWR, 2015). In most cases, selecting a CalSim II option limits the SacWAM period of simulation to 82 years, water years 1922-2003.

7.2.1 Adjust Hydrology to CalSim II

The purpose of the CalSim II hydrology adjustment is to give the model user the option of aligning the SacWAM hydrology to that of CalSim II. This option was exercised during model development to test and validate SacWAM's CVP/SWP operational logic. No judgment is made regarding the relative accuracy of the SacWAM or CalSim II hydrologies, which are very different in nature. The hydrology correction is calculated as the difference between SacWAM and CalSim II combined simulated flows for the Sacramento River at Freeport and the Yolo Bypass at the Lisbon Weir, after removing the effects of upstream CVP and SWP storage regulation and Trinity River imports to the Sacramento Valley. Thus, this correction adjusts for differences in model hydrology *and* for differences in model simulation of non-project tributaries.

7.2.2 Simulate Bias Correction

The *Simulate Bias Correction* switch allows the model user to activate inflow bias corrections implemented on the Sacramento River at Bend Bridge and Butte City. The corrections, which are applied just upstream from the Bend Bridge gauge (RM 258) and Butte City gauge (RM 170), are based on a historical water balance of river inflows and outflows for the river reach Shasta to Bend Bridge and the reach Bend Bridge to Butte City. Components of the flow balance include observed streamflow data, historical storage regulation and evaporation, historical trans-watershed imports, unimpaired inflows as used in SacWAM, historical stream diversions, and estimates of historical rainfall-runoff, historical irrigation return flows, and historical groundwater inflows. In the winter and spring, the residual or closure term in the flow balance is attributed to errors in the SacWAM unimpaired inflows (stream headflows). In many cases, these inflows were derived from an extension of incomplete gauge data using statistical methods. Bias corrections are only applied in high flow months when unimpaired flows are considered the most likely source of error. High flow months are defined as months in which water historically spilled over the Fremont Weir into the Yolo Bypass. Without these bias corrections, SacWAM is unable to match the historical volume of water entering the Delta from the Yolo Bypass.

7.2.3 Simulate Daily NCP Adjustment

The *Simulate Daily NCP Adjustment* switch allows the user to activate an adjustment to the Navigation Control Point (NCP) flow requirement for the Sacramento River below Wilkins Slough. This adjustment is used in CalSim II to determine additional releases that are needed to meet the NCP requirement because of differences between monthly-averaged flows and daily flows. The switch is turned off by default in SacWAM but can be activated for making comparisons to CalSim II.

7.2.4 Simulate Delta Demands

The representation of in-Delta water use is discussed in Section 3.9.3.173.9.3.17. The *Simulate Delta Demands* switch allows the user to choose between simulating Delta agricultural demands using WEAP catchment objects or using a time series of Delta channel accretions and depletions obtained from CalSim. A value of '0' sets SacWAM to use the CalSim II data, a value of '1' enables the SacWAM Delta catchment objects and dynamic calculation of Delta diversions and return flows. For the Delta demands switch, the CalSim II Delta accretions and depletions were extended through water year 2015 using unpublished model data from CalSim 3.[32]

7.2.5 Simulate Delta Salinity Requirements

Various switches allow the model user to constrain SacWAM to Delta salinity requirements from the CalSim II 2015 SWP Delivery Capability Report simulation. For a *Simulate Delta Salinity Requirement* value of '0', the model uses CalSim II data to determine the net Delta outflow required for salinity control. A value of '1' enables dynamic calculation of the requirement using the ANN embedded in SacWAM.

7.2.6 Simulate MRDO

In SacWAM, the minimum required Delta outflow (MRDO) refers to regulatory requirements specified in D-1641 in terms of flow in cfs. For the purposes of SacWAM, it does not include outflow required to meet the X2 standard. The *MRDO* switch allows the user to choose between two options in setting MRDO. When *MRDO* is assigned a value of '0', SacWAM uses CalSim II-based values; a value of '1' enables dynamic calculation of this outflow requirement using SacWAM's internal process (ANN implementation or Kimmerer-Monismith Equation). The purpose of the *MRDO* switch is to facilitate model debugging.

7.2.7 Simulate NOD CVP Allocation

CVP allocations to its contractors are initially determined in March (the start of the CVP contract year) and subsequently updated in April and May as water supply conditions become more apparent. SacWAM includes a switch that allows the model user to fix CVP allocations north of the Delta to those

[32] CalSim 3 has sinced been revised by DWR to simulate Delta accretions and depletions using DWR's Delta Channel Depletion (DCD) model.

simulated by CalSim II. A *Simulate NOD CVP Allocation* value of ‘0’ indicates SacWAM will use simulated values from CalSim II; a value of ‘1’ indicates that SacWAM will use its own internal allocation logic.

7.2.8 Simulate SOD CVP Allocation

SacWAM includes a switch that allows the model user to fix CVP allocations south of the Delta to those simulated by CalSim II. A *Simulate SOD CVP Allocation* value of ‘0’ indicates SacWAM will use values from CalSim II; a value of ‘1’ indicates that SacWAM will use its internal CVP allocation logic.

7.2.9 Simulate SWP Allocation

Similar to the CVP, SacWAM includes a switch that allows the model user to constrain SacWAM SWP allocations to values derived from CalSim II. A *Simulate SWP Allocation* value of ‘0’ sets the model allocations equal to CalSim II data; a value of ‘1’ enables dynamic calculation of SWP allocations within SacWAM.

7.2.10 Simulate Trinity Imports

As part of the CVP, Trinity River water is imported into the Sacramento Valley through Clear Creek Tunnel in to Whiskeytown Reservoir. The *Simulate Trinity Imports* switch offers two methods for determining Trinity River imports: the first sets these imports equal to a time series of historical Clear Creek Tunnel flows; the second uses import logic that assesses simulated storage levels in Trinity and Shasta reservoirs to dynamically determine Trinity River imports. A *Simulate Trinity Imports* value of ‘1’ indicates the decision to use SacWAM’s internal simulation logic, otherwise SacWAM will use predefined time series of import values.

Subsequent to the addition of this switch, an additional switch for Trinity River imports was added to allow the user to base imports on a previous SacWAM model run. This option is listed under the Key Assumptions.

7.2.11 Simulate X2 Requirement

The X2 standard, established by the State Water Board in the 1995 Water Quality Control Plan and included in D-1641, is expressed in terms of the location of the 2 parts per thousand bottom isohaline as measured in kilometers upstream from the Golden Gate Bridge. SacWAM includes an IFR object on net Delta outflow to simulate both the D-1641 and USFWS BiOp requirements for the X2 location. The *Simulate X2 Requirement* switch allows the model user to set this instream flow requirement to preprocessed values determined by CalSim II for the purposes of model testing and debugging. A *Simulate X2 Requirement* value of ‘0’ sets SacWAM to use the CalSim II data; a value of ‘1’ enables dynamic calculation of the required flow within SacWAM using the ANN.

7.3 Water Management Operations (Ops)

Water management within the Sacramento Valley is subject to many regulatory requirements. These requirements are most commonly enacted using WEAP IFR objects. Both water supply and regulations influence the way that water managers (including, but not limited to, the CVP and SWP) allocate and distribute water throughout the valley. Allocation logic has been developed for the CVP and SWP and most of the major local water projects. Operational logic and parameters appear in the SacWAM data tree under *Other Assumptions\Ops* and are grouped into sub-branches as follows:

- *CVPSWP*: contains operational logic for the CVP and SWP, including contractor allocation logic, coordinated operations agreement, export constraints, and reservoir balancing.
- *Delta Channels*: contains parameters and requirements relating to operation of the Delta Cross Channel and the Old and Middle rivers.
- *Delta Salinity*: determines flow requirements for meeting X2 and flow-based equivalents of D-1641 water quality standards determined using the ANN.
- *Flow Requirement*s: determines regulatory instream flow requirements.
- *Hydrologic Indices*: defines indices that are in-turn used to determine stream flow requirements and reservoir storage levels.
- *Local Projects*: contains operational logic for projects owned and operated by local water agencies, utility districts, and power companies.

The following sections describe each of these sub-branches.

7.4 Ops\CVPSWP

The following sections describe SacWAM's simulation of the CVP and SWP including reservoir operational logic, allocation and delivery logic, sharing of water and responsibilities between the two projects, and regulatory requirements and constraints that affect Delta operations. CVP and SWP contractors within and south of the Delta are described in Section 4.8.1. CVP contractors located north of the Delta and their contract entitlement are listed in Table 7-1.

Table 7-1. CVP Water Service Contracts for Service Areas North of Delta

Central Valley Project Water Service Contractor	Contract Number	CalSim 3.0 Representation		Contract (acre-feet per year)	
		Demand Unit	Diversion Node	Irrigation	M&I
Sacramento and Trinity River Divisions[4]					
Clear Creek CSD	489-A	02_PA	WKYTN	7,300[1]	-
Centerville CSD	14-06-200-3367X	02_PU	WKYTN	-	3,800[3]
Clear Creek CSD	14-06-200-489-A	02_PU	WKYTN	-	8,000[1]
Shasta CSD	14-06-200-862A	02_PU	WKYTN	-	1,000
Shasta County WA	14-06-200-3367A	02_PU	WKYTN	-	332[2]
Keswick CSA	N/A	02_PU	WKYTN	-	400[2]
Bella Vista WD	14-06-200-851A	03_PA	SAC294	18,000[8]	-
Bella Vista WD	14-06-200-851A	03_PU2	SAC294	-	6,578[8]
City of Shasta Lake	4-07-20-W1134	03_PU1	SHSTA	-	4,400
Mountain Gate CSD	14-06-200-6998	03_PU1	SHSTA	-	1,350
Jones Valley CSA	N/A	03_PU1	SHSTA	-	290[2]
Redding, City of (Buckeye WTP)	14-06-200-5272A	03_PU3	WKYTN	-	6,140
Subtotal				**29,420**	**28,170**
Corning Canal Unit					
Corning WD	14-06-200-6575	04_PA1	CCL005	23,000	-
Proberta WD	14-06-200-7311	04_PA1	CCL005	3,500	-
Thomes Creek WD	14-06-200-5271A	04_PA1	CCL005	6,400	-
Subtotal				**32,900**	**0**
Tehama-Colusa Canal Unit					
Kirkwood WD	7-07-20-W0056	04_PA2	TCC022	2,100	-
Glide WD	W0040	07N_PA	TCC036	10,500	-
Kanawha WD	466-A	07N_PA	TCC036	45,000	-
Orland-Artois WD	14-06-200-8382A	07N_PA	TCC036	53,000	-
Colusa, County of		07N_PA	TCC036		
Holthouse WD (65%) (assigned)	1-07-20-W0224	07N_PA	TCC036	1,593	-
Colusa, County of	14-06-200-8310A	07S_PA	TCC081 TCC111	[10]	-
4-M WD (assigned)	0-07-20-W0183	07S_PA	TCC081 TCC111	5,700	-
Colusa County WD (assigned)	1-07-20-W0220	07S_PA	TCC081 TCC111	5,964	-
Cortina WD (assigned)	0-07-20-W0206	07S_PA	TCC081 TCC111	1,700	-
Glenn Valley WD (assigned)	1-07-20-W0219	07S_PA	TCC081 TCC111	1,730	-
Holthouse WD (35%) (assigned)	1-07-20-W0224	07S_PA	TCC081 TCC111	857	-
La Grande WD (assigned)	0-07-20-W0190	07S_PA	TCC081 TCC111	2,200	-
Myers-Marsh MWC (assigned)	1-07-20-W0225	07S_PA	TCC081 TCC111	255	-
Colusa County WD	14-06-200-304-A	07S_PA	TCC081 TCC111	62,200	-
Colusa, County of	14-06-200-8310A	07S_PA	TCC081 TCC111	1	
Davis WD	14-06-200-6001A	07S_PA	TCC081 TCC111	4,000	-
Dunnigan WD	14-06-200-399-A	07S_PA	TCC081 TCC111	19,000	-
La Grande WD	7-07-20-W0022	07S_PA	TCC081 TCC111	5,000	-
Westside WD	14-06-200-8222	07S_PA	TCC081 TCC111	65,000	-
Subtotal				**285,800**	**0**
Black Butte Unit					
4-E WD	3-07-20-W0312	N/A	N/A	35	-
Elk Creek CSD	3-07-20-W0312				100

Central Valley Project Water Service Contractor	Contract Number	CalSim 3.0 Representation		Contract (acre-feet per year)	
		Demand Unit	Diversion Node	Irrigation	M&I
Stony Creek WD	2-07-20-W0261	SCKWD	EPARK		3,345
U.S. Forest Service (Salt Creek)	14-06-200-3621A	N/A	N/A		45
Whitney Construction, Inc.	14-06-200-5749A	N/A	N/A		25
U.S. Forest Service	14-06-200-3464A	N/A	N/A		10
Colusa, County of (Stonyford)	4-07-20-W0348	N/A	N/A		40
Subtotal				**35**	**3,565**
Colusa Basin Drain					
Colusa Drain MWC[5]	8-07-20-W0693	08N_PA	CBD049	5,600	-
Colusa Drain MWC[5]	8-07-20-W0693	08S_PA	CBD028	49,000	-
Colusa Drain MWC[5]	8-07-20-W0693	21_PA	KLR005	15,400	-
Subtotal				**70,000**	**0**
American River Division					
El Dorado ID	14-06-200-1357A	ELDID	FOLSM	-	7,550
City of Roseville	14-06-200-3474A	26N_PU1	FOLSM	-	32,000
Sacramento County WA	6-07-20-W1372	26S_PU4, 26S_PU6	SAC052, SAC062	-	22,000
San Juan WD	6-07-20-W1373	26N_PU2, 26N_PU3	FOLSM	-	24,200
East Bay MUD	14-06-200-5183A	EBMUD	FOLSM	-	133,000
SMUD	14-06-200-5198A	60N_PU	FOLSM	-	30,000
Sacramento County WA (SMUD assignment)	N/A	26S_PU4, 26S_PU6	SAC052, SAC062	-	30,000
Placer County WA	14-06-200-5082A	[6]	FOLSM	-	35,000
Subtotal				**0**	**313,750**
Delta Division					
Contra Costa WD	I75r-3401A	CCWD	RSL004, OMR021, VCT002	-	195,000
Subtotal				**0**	**195,000**
Other					
Feather WD	14-06-200-171-A	16_PA	FTR020	20,000	
City of West Sacramento[7,9]	0-07-20-W0187	21_PU	SAC066		23,600
Subtotal				**20,00**	**23,600**
Total				**458,155**	**564,085**

Notes:

[1] Split between irrigation and M&I use based on an urban demand of 8,000 acre-feet per year.

[2] Shasta County WA provides water to water purveyors in Shasta County, including 500 acre-feet to Keswick CSA, 190 acre-feet to Jones Valley CSA, and 332 acre-feet elsewhere. For modeling purposes, it is assumed that 332 acre-feet are made available to contractors in 02_PU. Under a 2008 transfer agreement, 100 acre-feet of Shasta County WA water were transferred from Keswick CSA to Jones Valley CSA.

[3] Centerville Community Services District as part of the liquidation of the Townsend Flat Water Ditch Company's pre-1914 water rights holdings on Clear Creek have secured 900 acre-feet of CVP supplies in addition to the 2,900 acre-feet. These quantities of supply are not subject to cutbacks, and the water may be transferred to any other purveyor in the Redding Basin.

[4] The McConnell Foundation as part of the liquidation of the Townsend Flat Water Ditch Company's pre-1914 water rights holdings on Clear Creek, has secured 5,100 acre-feet of CVP supplies. These quantities of supply are not subject to cutbacks, and the water may be transferred to any other purveyor in the Redding Basin. For modeling purposes, it is assumed that this water is available to urban municipalities.

[5] Division of the 70,000 acre-feet per year contract for the Colusa Drain MWC is based on GIS land use (irrigated area) and split 8%, 70%, and 22% among the 3 demand units 08N_PA, 08S_PA, and 21_PA.

[6] Placer County WA currently has no facilities to take delivery of CVP water from Folsom Lake.

[7] Contract amount for West Sacramento includes water right water and CVP project water.

[8] Split between irrigation and M&I use for Bella Vista WD based on Reclamation delivery data for water years 2000 – 2009.

[9] The City of West Sacramento also could be categorized as a CVP settlement contractor.

Central Valley Project Water Service Contractor	Contract Number	CalSim 3.0 Representation		Contract (acre-feet per year)	
		Demand Unit	Diversion Node	Irrigation	M&I

[10] Seven districts have assigned a total of 20,000 acre-feet to Colusa County Water District.

Key:
CSA = County Service Area, CSD = Community Service District, ID = Irrigation District, M&I = municipal and industrial, MUD = Municipal Utility District, MWC = Mutual Water Company, N/A = not applicable, SMUD = Sacramento Municipal Utility District, WA = Water Agency WD = Water District, WTP = water treatment plant.

7.4.1 Contracts

The logic provided under the Contracts branch allows CVP Settlement Contractors to 'move' unused water from non-critical to non-critical months and from critical months to non-critical months. Typically, contracts provide for two separate volumes of water. The first is to be used during April, May, June, September, and October. The second volume is to be used during July and August. Water that is unused in April-June can be used during September and October. Unused water from July and August can be used in September and October. The logic described below applies to the settlement contractor demand units: A_02_SA, A_03_SA, A_08_SA1, A_08_SA2, A_08_SA3, A_09_SA1, A_08_SA2, A_18_19_SA, A_21_SA, and A_22_SA1. For demand units with multiple points of diversion a suffix "_RMXXX" is added to specifiy the location of the point of diversion in river miles.

7.4.1.1 Contract

The expression in Contract provides the monthly maximum volume of water that can be diverted under the settlement contract. The expression typically includes the annual total volume and a monthly distribution based on typical water use patterns. Some expressions represent more than one contract.

7.4.1.2 Delivery

The Delivery variable is the simulated flow in the transmission link.

7.4.1.3 PrevTSCumContractVol1

This represents the cumulative contract volume up to the end of the previous month for the non-critical months (April, May, June, September, and October).

7.4.1.4 PrevTSCumContractVol2

This represents the cumulative contract volume, at the end of the previous month, for the critical period, July and August.

7.4.1.5 PrevTSCumDeliveries1

This represents the cumulative deliveries up to the end of the previous month for the non-critical months (April, May, June, September, and October).

7.4.1.6 PrevTSCumDeliveries2

This represents the cumulative deliveries, at the end of the previous month, for the critical period, July and August.

7.4.1.7 UnusedVol1

This represents the difference between the PrevTSCumContractVol1 and PrevTSCumDeliveries1 and represents the volume of unused water from previous non-critical months.

7.4.1.8 UnusedVol2

This represents the difference between the PrevTSCumContractVol2 and PrevTSCumDeliveries2 and represents the volume of unused water from previous critical months.

7.4.2 Controls

The *Controls* branch implements a series of operational control indicators that show which regulations, permits, and physical capacities are controlling various aspects of CVP and SWP operations. Controls are defined when pumping, flow, or storage are equal to specified maximum limits. Most of the control indicators are binary (0,1), with a few exceptions.

7.4.2.1 CVP San Luis vs Rule

The *CVP San Luis vs Rule* control is the amount by which CVP San Luis Reservoir is above (+) or below (-) the rule curve.

7.4.2.2 Delta MRDO

The *Delta MRDO* control identifies whether Delta outflow is controlled by (i.e., just meeting) the D-1641 MRDO requirement (1=at MRDO, 0=above MRDO).

7.4.2.3 Delta Salinity_CO

The *Delta Salinity_CO* control identifies whether Delta flows are controlled by the salinity requirements at Collinsville (1 = controlled, 0 = not controlled).

7.4.2.4 Delta Salinity_EM

The *Delta Salinity_EM* control identifies whether Delta flows are controlled by the salinity requirements at Emmaton (1 = controlled, 0 = not controlled)

7.4.2.5 Delta Salinity_JP

The *Delta Salinity_JP* control identifies whether Delta flows are controlled by the salinity requirements at Jersey Point (1 = controlled, 0 = not controlled)

7.4.2.6 Delta Salinity_RS

The *Delta Salinity_RS* control identifies whether Delta flows are controlled by the salinity requirements at Rock Slough (1 = controlled, 0 = not controlled)

7.4.2.7 Delta Surplus

The *Delta Surplus* control identifies whether there is Delta Surplus under COA for the CVP and SWP combined (1=Delta Surplus, 0=No Delta Surplus).

7.4.2.8 Delta Surplus CVP

The *Delta Surplus CVP* control identifies whether there is Delta Surplus under COA for the CVP (1=Delta Surplus, 0=No Delta Surplus).

7.4.2.9 Delta Surplus SWP

The *Delta Surplus SWP* control identifies whether there is Delta Surplus under COA for the SWP (1=Delta Surplus, 0=No Delta Surplus).

7.4.2.10 Delta SWRCB

The *Delta SWRCB* control identifies whether Delta flows are controlled by the proposed flow requirements by State Water Control Board (1 = controlled, 0 = not controlled)

7.4.2.11 Delta UWFE IBU

The *Delta UWFE IBU* control identifies whether Delta flows include Unstored Water for Export (UWFE) or water for In Basin Use (1 = UWFE, 0 = IBU)

7.4.2.12 Delta X2

The *Delta X2* control identifies whether Delta outflow is controlled by (i.e., just meeting) the X2 requirement (1=at requirement, 0=above requirement).

7.4.2.13 Exports AprMay D1641 cap

The *Exports AprMay D1641 cap* control identifies whether combined CVP and SWP exports are controlled by the D-1641 Pulse Period export cap (1=controlled, 0=not controlled).

7.4.2.14 Exports AprMayD1641 CVP split

The *Exports AprMayD1641 CVP split* control identifies whether combined CVP exports are controlled by half of the D-1641 Pulse Period export cap (1=controlled, 0=not controlled).

7.4.2.15 Exports AprMayD1641 SWP split

The *Exports AprMayD1641 SWP split* control identifies whether combined SWP exports are controlled by half of the D-1641 Pulse Period export cap (1=controlled, 0=not controlled).

7.4.2.16 Exports Banks HandS

The *Exports Banks HandS* control identifies whether Banks Pumping Plant diversions are at minimum level of 300 cfs (1=at or below, 0=above).

7.4.2.17 Exports Banks max capacity

The *Exports Banks max capacity* control identifies whether Banks Pumping Plant diversions are at maximum permit capacity (1=at capacity, 0=below capacity).

7.4.2.18 Exports EI ratio

The *Exports EI ratio* control identifies whether combined CVP and SWP exports are controlled by the D-1641 E/I ratio export cap (1=controlled, 0=not controlled).

7.4.2.19 Exports EI split CVP

The *Exports EI split CVP* control identifies whether CVP exports are controlled by half of the D-1641 E/I ratio export cap (not currently implemented).

7.4.2.20 Exports EI split SWP

The *Exports EI split SWP* control identifies whether SWP exports are controlled by half of the D-1641 E/I ratio export cap (not currently implemented).

7.4.2.21 Exports Jones HandS

The *Exports Jones HandS* control identifies whether Jones Pumping Plant diversions are at minimum level of 800 cfs or 600 cfs when storage in Shasta Lake is below 1.5 MAF (1=at, 0=above).

7.4.2.22 Exports Jones max capacity

The *Exports Jones max capacity* control identifies whether Jones Pumping Plant diversions are at maximum permit capacity (1=at capacity, 0=below capacity).

7.4.2.23 Exports OMR control

The *Exports OMR control* control identifies whether OMR reverse flow is controlled by the OMR RPA maximum reverse flow limit (1=at limit, 0=above limit).

7.4.2.24 Exports RPA HandS

The *Exports RPA HandS* control identifies whether combined CVP and SWP exports are at minimum H&S under the BiOp RPAs controlled by the D-1641 EI ratio export cap (1=at H&S, 0=above H&S).

7.4.2.25 Exports SJR IE ratio

The *Exports SJR IE ratio* control identifies whether combined CVP and SWP exports are controlled by the April to May *SJR_EIRatio* export cap (1= controlled, 0=not controlled).

7.4.2.26 Exports SJR IE split CVP

The *Exports SJR IE split CVP* control identifies whether combined CVP exports are controlled by half of the April to May *SJR_EIRatio* export cap (not currently implemented).

7.4.2.27 Exports SJR IE split SWP

The *Exports SJR IE split SWP* control identifies whether combined SWP exports are controlled by half of the April to May *SJR_EIRatio* export cap (not currently implemented).

7.4.2.28 Folsom Flood Pool

The *Folsom Flood Pool* control identifies whether Folsom Lake is at its flood pool (i.e., the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.4.2.29 Folsom Ops MIFs

The *Folsom Ops MIFs* control identifies whether releases from Folsom Lake are controlled by (i.e., just meeting) either of the two downstream MFRs (1=at MFR, 0=above MFR). Requirements are D-893 and FMS.

7.4.2.30 Folsom Ops SWRCB

The *Folsom Ops SWRCB* control identifies whether releases from Folsom Lake are controlled by (i.e., just meeting) either of the two downstream MFRs proposed by SWRCB (1=at MFR, 0=above MFR).

7.4.2.31 MIF American River D893

The *MIF American River D893* control identifies whether releases from Folsom Lake are controlled by (i.e., just meeting) the D-893 MFR (1=at MFR, 0=above MFR).

7.4.2.32 MIF American River FMS

The *MIF American River FMS* control identifies whether releases from Folsom Lake are controlled by (i.e., just meeting) the FMS MFR (1=at MFR, 0=above MFR).

7.4.2.33 MIF Feather River at Verona

The *MIF Feather River at Verona* control identifies whether releases from Lake Oroville are controlled by (i.e., just meeting) the Verona MFR (1=at MFR, 0=above MFR).

7.4.2.34 MIF Feather River HFC

The *MIF Feather River HFC* control identifies whether releases from Lake Oroville are controlled by (i.e., just meeting) the High-Flow Channel MFR (1=at MFR, 0=above MFR).

7.4.2.35 MIF Feather River LFC

The *MIF Feather River LFC* control identifies whether releases from Lake Oroville are controlled by (i.e., just meeting) the Low-Flow Channel MFR (1=at MFR, 0=above MFR).

7.4.2.36 MIF Sacramento River at Keswick

The *MIF Sacramento River at Keswick* control identifies whether releases from Shasta Lake are controlled by (i.e., just meeting) the Keswick MFR (1=at MFR, 0=above MFR).

7.4.2.37 MIF Sacramento River at Red Bluff

The *MIF Sacramento River at Red Bluff* control identifies whether releases from Shasta Lake are controlled by (i.e., just meeting) the Red Bluff MFR (not currently implemented, Red Bluff MIF is not in the model).

7.4.2.38 MIF Sacramento River at Rio Vista

The *MIF Sacramento River at Rio Vista* control identifies whether Sacramento River flows are controlled by (i.e., just meeting) the Rio Vista D-1641 flow requirement (1=at requirement, 0=above requirement).

7.4.2.39 MIF Sacramento River at Wilkins Slough

The *MIF Sacramento River at Wilkins Slough* control identifies whether releases from Shasta Lake are controlled by (i.e., just meeting) the Wilkins Slough MFR (1=at MFR, 0=above MFR).

7.4.2.40 MIF Trinity River at Lewiston

The *MIF Trinity River at Lewiston* control identifies whether Triity River flows are controlled by (i.e., just meeting) the Leviston (1=at requirement, 0=above requirement).

7.4.2.41 Oroville Flood Pool

The *Oroville Flood Pool* control identifies whether Lake Oroville is at its flood pool (i.e., the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.4.2.42 Oroville Ops MIF

The *Oroville Ops MIF* control identifies whether releases from Lake Oroville are controlled by (i.e., just meeting) one of the three downstream MFRs (1=at MFR, 0=above MFR). MFRs are the High-Flow Channel, Low-Flow Channel, and Verona.

7.4.2.43 Oroville Ops SWRCB

The *Oroville Ops SWRCB* control identifies whether releases from Lake Oroville are controlled by (i.e., just meeting) SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.44 Shasta Flood Pool

The *Shasta Flood Pool* control identifies whether Shasta Lake is at its flood pool (i.e., the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.4.2.45 Shasta Flood Pool_P91

The *Shasta Flood Pool_P91* control identifies whether Shasta Lake is at its flood pool (i.e., the reservoir is spilling) before Joint Point of Diversions (1=at flood pool, 0=below flood pool).

7.4.2.46 Shasta Ops MIF
The *Shasta Ops MIF* control identifies whether releases from Shasta Lake are controlled by (i.e., just meeting) either of the two downstream MFRs (1=at MFR, 0=above MFR). MFRs are at Keswick and Wilkins Slough.

7.4.2.47 Shasta Ops SWRCB
The *Shasta Ops SWRCB* control identifies whether releases from Shasta Lake are controlled by (i.e., just meeting) either of the SWRCB proposed MFRs (1=at MFR, 0=above MFR).

7.4.2.48 SWP San Luis vs Rule
The *SWP San Luis vs Rule* control defines the amount by which SWP San Luis Reservoir is above (+) or below (-) the rule curve.

7.4.2.49 SWRCB American River MIF
The *SWRCB American River MIF* control identifies whether flow in American River is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.50 SWRCB Delta MIF
The *SWRCB Delta MIF* control identifies whether flow in Delta is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.51 SWRCB Feather River
The *SWRCB Feather River* control identifies whether flow in Feather River is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.52 SWRCB Folsom MIF
The *SWRCB Folsom MIF* control identifies whether release from Folsom Lake is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.53 SWRCB Oroville MIF
The *SWRCB Oroville MIF* control identifies whether release from Lake Oroville is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.54 SWRCB Sac abv Bend Bridge MIF
The *SWRCB Sac abv Bend Bridge MIF* control identifies whether flow in Sacramento River at Bend Bridge is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.55 SWRCB Sac at Butte City MIF
The *SWRCB Sac at Butte City MIF* control identifies whether flow in Sacramento River at Butte City is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.56 SWRCB Sac at Colusa MIF
The *SWRCB Sac at Colusa MIF* control identifies whether flow in Sacramento River at Colusa is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.57 SWRCB Sac at Freeport MIF
The *SWRCB Sac at Freeport MIF* control identifies whether flow in Sacramento River at Freeport is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.58 SWRCB Sac at Hamilton MIF

The *SWRCB Sac at Hamilton MIF* control identifies whether flow in Sacramento River at Hamilton is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.59 SWRCB Sac at Knights Landing MIF

The *SWRCB Sac at Knights Landing MIF* control identifies whether flow in Sacramento River at Knights Landing is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.60 SWRCB Sac at Old Ferry MIF

The *SWRCB Sac at Old Ferry MIF* control identifies whether flow in Sacramento River at Old Ferry is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.61 SWRCB Sac at Rio Vista MIF

The *SWRCB Sac at Rio Vista MIF* control identifies whether flow in Sacramento River at Rio Vista is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.62 SWRCB Sac at Verona MIF

The *SWRCB Sac at Verona MIF* control identifies whether flow in Sacramento River at Verona is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.63 SWRCB Sac at Vina MIF

The *SWRCB Sac at Vina MIF* control identifies whether flow in Sacramento River at Vina is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.64 SWRCB Sac at Wilkins Slough MIF

The *SWRCB Sac at Wilkins Slough MIF* control identifies whether flow in Sacramento River at Wilkins Slough is controlled by (i.e., just meeting) the SWRCB proposed MFR (1=at MFR, 0=above MFR).

7.4.2.65 Tolerance_Flow

The *Tolerance_Flow* parameter defines the tolerance for determing whether a channel flow is at its upper bound and any associated MFR is constraining operations.

7.4.2.66 Tolerance_Storage

The *Tolerance_Storage* parameter defines the tolerance for determing whether reservoir storage is at its upper bound.

7.4.2.67 Trinity ExtraImports

The *Trinity ExtraImports* variable represents additional Trinity River imports for the purposes of balancing Trinity – Shasta reservoirs for meeting COA obligations. It is equal to *Other\Ops\CVPSWP\TrinityShasta_balancing\Extraimports*.

7.4.2.68 Trinity Flood Pool

The *Trinity Flood Pool* control identifies whether Trinity Lake is at its flood pool (i.e., the reservoir is spilling) (1=at flood pool, 0=below flood pool).

7.4.2.69 Trinity Import Ops

The *Trinity Import Ops* control identifies whether releases from Trinity Lake are controlled by (i.e., just meeting) the Trinity Record of Decision MFR (1=at MFR, 0=above MFR).

7.4.3 CVP Allocations

SacWAM uses an approach similar to CalSim II (2015 SWP Final Delivery Capability Report: DWR, 2014e) to set contract allocation levels to CVP (and SWP) contractors in the Sacramento Valley. For calibration purposes, SacWAM also includes switches that allow the user to fix CVP allocations north and/or south of the Delta to those simulated by CalSim II. These switches are located in *Other\Calibration Switches\Simulate NOD CVP Allocation* and *Other\Calibration Switches\Simulate SOD CVP Allocation.*

The procedure for setting the annual allocation to CVP contractors is found in WEAP's data tree structure under *Other Assumptions\Ops\CVP Allocations*. The allocation that is the result of this procedure is referenced from each of the transmission links that divert surface water to CVP contractors. This allocation is applied to a monthly distribution of contract amounts to set an upper limit on diversions. These monthly values are based on Exhibit A of each contract, which specifies the distribution of the contractors' base supply and project water[33] over the irrigation season, April-October.

The approach for allocating water to CVP contractors relies on using a series of curves to manage uncertainty in promising water to contractors. These curves are generally used as a way of mitigating the risk of promising water given an assessment of water supplies for the water year. That is, they are conditioned such that within the model the full allocations that are promised during the allocation period (February to May) are typically satisfied without drawing upstream storage below acceptable levels.

The process occurs in the late winter and early spring as the water supply forecast becomes clearer. It begins by estimating the available water supplies by summing the existing water in storage and the forecasted inflows—WSI. SacWAM then estimates the level of demand that can be met with this supply (i.e., the *DemandIndex*, or DI) using a WSI-DI curve. This is shown in Table 7-2 and the accompanying graph.

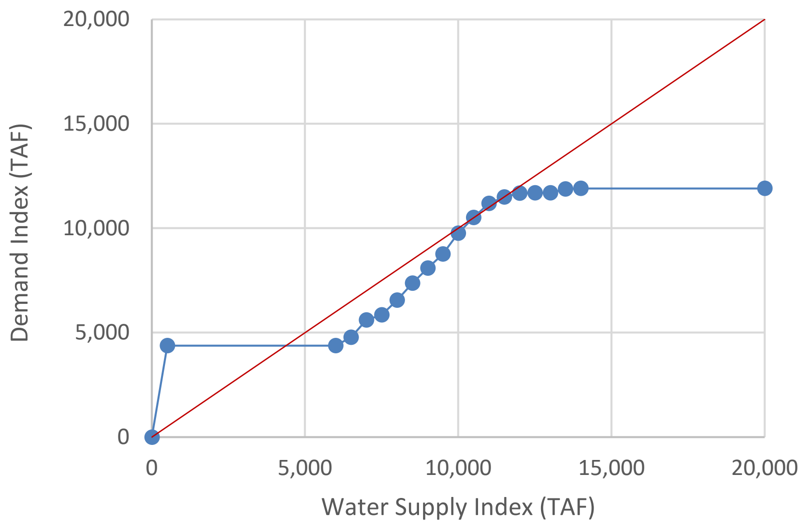
As the curve shows, under particularly low water supply conditions, the demand index (DI) is flat, which indicates that there exists some level of hard water demands that exist even in the driest conditions. DI is also flat at high levels of water supply because the system demand is limited, and above a certain water supply threshold, all water demand can be satisfied. Under intermediate water supply conditions, an increase in water supply translates into an increase in the water demand that can be satisfied. However, the curve often falls below the 1:1 line, suggesting that a smaller percentage of the available supply is made available to meet demand. This acknowledges that water is released from storage may not always reach demands due to regulatory and/or physical constraints, so the model is conditioned to reduce the risk of this occurring by promising to deliver less water.

[33] Base supply is the quantity of water that Reclamation agrees may be diverted, without charge, each month from April through October. Project water refers to additional quantities of water that may be diverted from April to October but are subject to pricing and other federal requirements.

Table 7-2. CVP Water Supply Index – Demand Index Curve

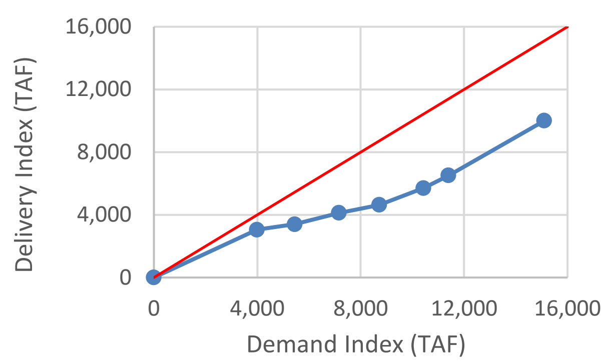
Water Supply Index (TAF)	Demand Index (TAF)
0	0
500	4,381
6,000	4,327
6,500	5,230
7,000	5,774
7,500	6,267
8,000	6,845
8,500	7,666
9,000	8,315
9,500	8,805
10,000	9,722
10,500	10,443
11,000	11,181
11,500	11,525
12,000	11,787
12,500	11,916
13,000	11,6946
13,500	12,173
14,000	12,173
20,000	12,173

Key:
TAF = thousand acre-feet



Demand Index (TAF)	Delivery Index (TAF)
0	0
3,990	3,055
5,442	3,402
7,162	4,122
8,717	4,637
10,434	5,704
11,395	6,515
15,100	9,999

Key:
TAF = thousand acre-feet



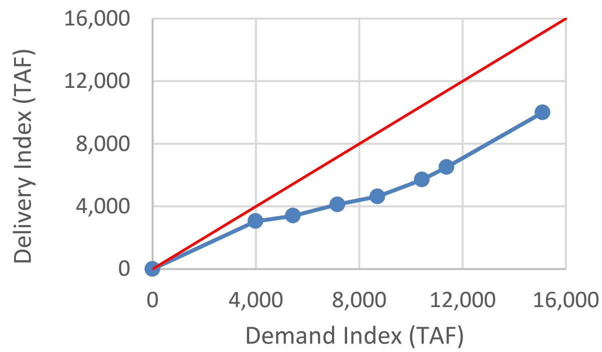
DI is the sum of both delivery and carryover storage demands. Thus, once the DI has been established, the model then references another lookup table to determine how this water should be partitioned between water left in storage (i.e., carryover) and water delivered. This is shown in and the paired graph. As DI decreases, a smaller percentage of the available supply is committed to carryover storage relative to the amount that is delivered to meet current water demands. This is the second component of risk management in the allocation process. Once this delivery target has been established using the Delivery-Carryover curve, the total volume of water is evaluated relative to the total annual project demands. If the delivery target is less than the sum of these demands, then a series of cuts is applied to different water users to determine the allocations as a percentage of contracts. The sequence of these cuts is outlined in the following flowchart, Figure 7-2 (where all values are expressed as volumes of water).

Sacramento Valley Settlement contractors and San Joaquin Valley Exchange contractors possess water rights that were secured before the construction of CVP, which under the prior appropriation doctrine, assures them a higher level of reliability for their supplies. Per their agreement with Reclamation, Settlement and Exchange contractors receive 100 percent of their contract amount in all years except 'critically dry' water years, as defined by the Shasta Hydrological Index. In Shasta critical years (i.e., when the total inflow to Shasta Lake is below 3.2 million acre-feet [MAF]), Settlement and Exchange contractors receive 75 percent of their contract amounts.

Table 7-3. CVP Demand Index — Delivery Index

Demand Index (TAF)	Delivery Index (TAF)
0	0
3,990	3,055
5,442	3,402
7,162	4,122
8,717	4,637
10,434	5,704
11,395	6,515
15,100	9,999

Key:
TAF = thousand acre-feet



When making annual allocations for Settlement and Exchange contractors, SacWAM must account for the cumulative inflows into Shasta to designate the Shasta Hydrological Index. To approximate the allocation process as it occurs in reality, WEAP does not use perfect foresight to estimate inflows to Shasta for the remainder of the water year after allocations are set (i.e., April-September). Instead, the model relies on a heuristic technique to estimate this quantity of water. This heuristic is explained in greater detail in Section 7.8.6.

7.4.3.1 Contracts Amounts

Parameters defined under the branch *Contract Amounts* are the full contract amounts by contractor type, split geographically into two regions – north of Delta and south of Delta. Table 7-4 lists these parameters and their values.

Table 7-4. Contract Amount Parameters

Parameter	Description	Contract Amount (acre-feet)
Contracts_AG_north	Agriculture north of Delta	458,155
Contracts_AG_south	Agriculture south of Delta	1,183,192
Contracts_EX	Exchange contractors and Fresno Slough Schedule 2	878,533
Contracts_MI_north	Municipal and industrial north of Delta	383,920
Contracts_MI_south	Municipal and industrial south of Delta	162,056
Contracts_RF_north	Refuges north of Delta	151,250
Congtracts_RF_south	Refuge south of Delta	248,638
Contracts_SC	Settlement contractors	2,092,020
Contracts_Losses	Canal losses	183,700
Contracts_Total_South	Total south of Delta excluding canal losses	3,102,419
Contracts_Total	Total north contract amount, excluding canal losses	6,187,764

Notes:
1. Settlement Contract amount should be 2,091,558 acre-feet.
1. North-of-Delta M&I should be 558,705 acre-feet.
2. North-of-Delta Ag should be 431,035 acre-feet.
3. South-of-Delta M&I should be 155,010 acre-feet.
4. South-of-Delta Ag should be 1,829,838 acre-feet. Excludes Cross Valley Canal.
5. Exchange Contractors and Fresno Slough Schedule 2 should be 875,623 acre-feet.
6. Amounts for refuges south of the Delta do not include amounts for Merced NWR and East Bear Creek Unit of San Luis NWR.

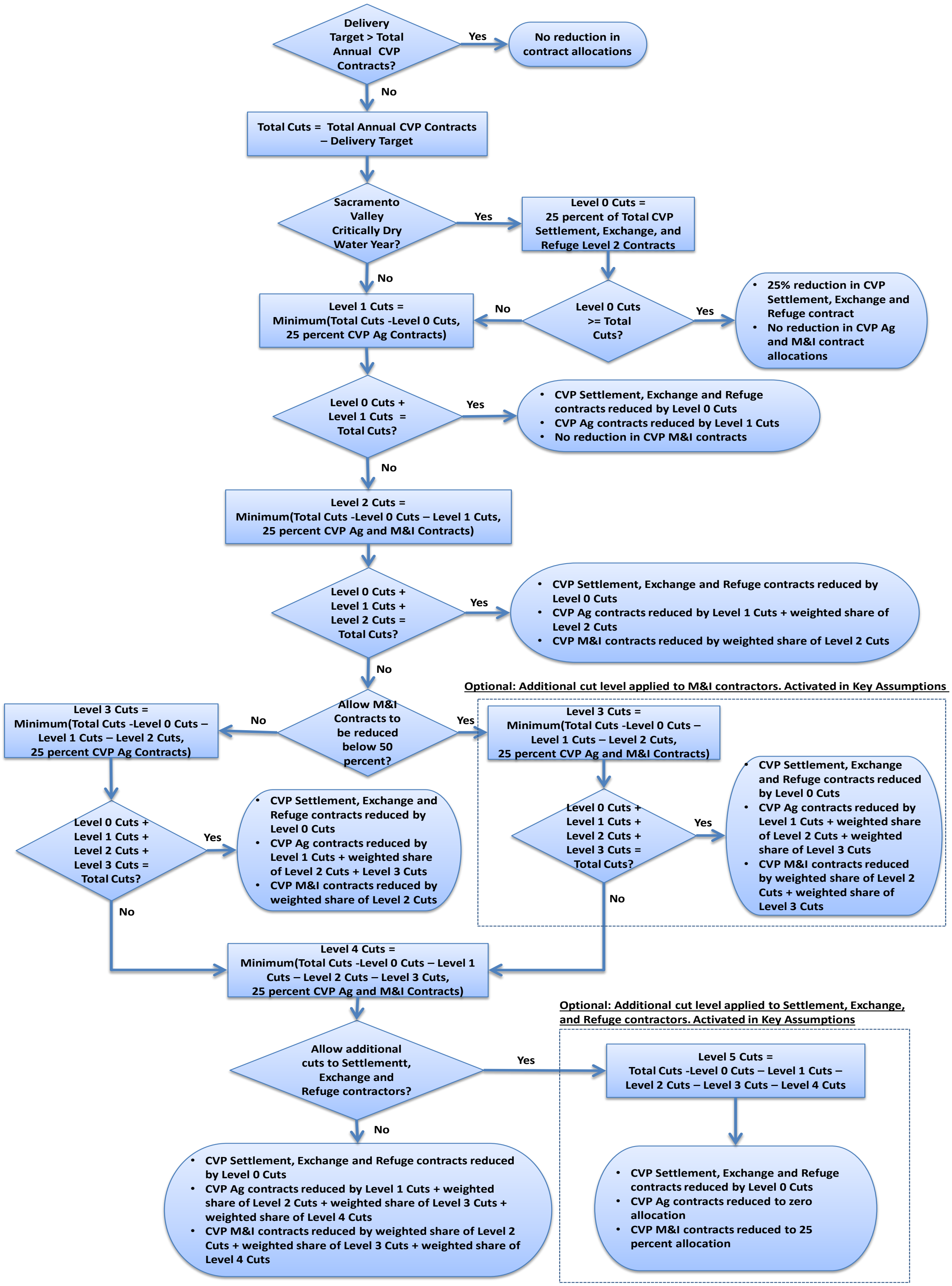


Figure 7-2. Central Valley Project Contract Allocation Logic

7.4.3.2 Contracts_AG_north

Contracts_AG_north is the total contract amount for agricultural water service contractors north of the Delta.

7.4.3.3 Contracts_AG_south

Contracts_AG_south is the total contract amount for agricultural water service contractor south of the Delta.

7.4.3.4 Contracts_EX

Contracts_EX is the total contract amount for San Joaquin River Exchange contractors and Fresno Slough Schdule 2 diverters.

7.4.3.5 Contracts_Losses

Contracts_Losses is the total losses in conveying contracted water.

7.4.3.6 Contracts_MI_north

Contracts_MI_north is the total contract amount for M&I water service contractors north of the Delta.

7.4.3.7 Contracts_MI_south

Contracts_MI_south is the total contract amount for M&I water service contractors south of the Delta.

7.4.3.8 Contracts_RF_north

Contracts_RF_north is the total contract amount for wildlife refuges north of the Delta.

7.4.3.9 Contracts_RF_south

Contracts_RF_south is the total contract amount for wildlife refuges south of the Delta.

7.4.3.10 Contracts_SC

Contracts_SC is the total contract amount for Sacramento River Settlement contractors

7.4.3.11 CVP_Ag

CVP _Ag represents the final allocation, expressed as a fraction, for CVP agricultural contractors located north of the Delta. This parameter is referenced throughout the model to constrain surface water diversions through transmission links to agricultural services contractors.

7.4.3.12 CVP_Rf

CVP _Rf represents the final allocation, expressed as a fraction, for CVP refuge contractors located north of the Delta. This parameter is referenced throughout the model to constrain surface water diversions through the transmission links.

7.4.3.13 CVP_SC

CVP _SC represents the final allocation, expressed as a fraction, for CVP settlement contractors in the Sacramento Valley. This parameter is referenced throughout the model to constrain surface water diversions through transmission links from the Sacramento River to settlement contractors.

7.4.3.14 CVP_Urb

CVP _Urb represents the final allocation, expressed as a fraction, for CVP M&I contractors located north of the Delta. This parameter is referenced throughout the model to constrain surface water diversions through transmission links to M&I contractors.

7.4.3.1 South

This subbranch contains parameters similar to those described in in the previous section to set allocations for CVP contractors located south of the Delta. In this case, however, SacWAM does not use the same set of WSI-DI curves to estimate available water supplies. Instead, it uses: (1) an estimate of Delta export capacity, (2) an estimate of water supply. These are described in the following sections.

7.4.3.1.1 Alloc_AG_Calsim

Alloc_AG_CalSim represents the south-of-Delta CVP allocation to agricultural water service contractors as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.2 Alloc_EX_Calsim

Alloc_EX_CalSim represents the south-of-Delta CVP allocation to the Exchange Contractors as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.3 Alloc_MI_Calsim

Alloc_MI_CalSim represents the south-of-Delta CVP allocation to M&I water service contractors as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.4 Alloc_RF_Calsim

Alloc_RF_CalSim represents the south-of-Delta CVP allocation to wildlife refuges as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.5 Cuts

As part of the allocation process, a series of cuts are made to CVP contractors until the total south-of-Delta allocations are equal to the available water supply. South of Delta allocations are calculated by first determining a demand deficit, which is equal to the difference between South of Delta contract demands and the *DeliveryIndex*, and then proceeding through a series of cuts (similar to those implemented for the Sacramento Valley) that systematically reduce the volume of water available to the different demand categories until the total volume of cuts is equal to the demand deficit.

Cut_level0

cut_EX0 is the cut to CVP San Joaquin River Exchange Contractors based on the Shasta Criteria.

cut_RF0 is the cut to south-of-Delta wildlife refuges based on the Shasta Criteria.

Cut_level1

cut_AG1 is the initial cut to south-of-Delta agricultural water service contractors, including Cross Valley Canal contractors, expressed as a volume.

percentcut1 is the initial cut of up to 25% to south-of-Delta agricultural water service contractors, including Cross Valley Canal contractors.

Cut_level2

cut_AG2 is the second cut to south-of-Delta agricultural water service contractors, including Cross Valley Canal contractors, expressed as a volume.

cut_MI2 is the initial cut to south-of-Delta M&I water service contractors expressed as a volume.

percentcut2 is the second cut of up to an additional 25% to agricultural water service contractors, including Cross Valley Canal contractors.

Cut_level3
cut_AG3 is the third cut to agricultural water service contractors, including Cross Valley Canal contractors, expressed as a volume.

percentcut3 is the third cut of up to 25% to agricultural water service contractors, including Cross Valley Canal contractors.

Cut_level4
cut_AG4 is the fourth cut to agricultural water service contractors, including Cross Valley Canal contractors, expressed as a volume.

cut_MI4 is the second cut to M&I water service contractors of up to an additional 25%, expressed as a volume.

percentcut4 is the fourth cut of up to agricultural water service contractors and the second cut to M&I contractors.

Cut_level5
cut_MI5 is the third cut to M&I water service contractors of up to an additional 25%, expressed as a volume.

percentcut5 is the third cut to M&I contractors.

Cut_level6
percentcut6 is not used.

Tier0cut
Tier0cut is set to 0.25 in Shasta critical years, otherwise it has a value of zero.

Tier0cut_EX
Tier0cut_EX is set to 0.23 in Shasta critical years, otherwise it has a value of zero.

Tier1cut
Tier1cut is set to 0.25.

Tier2cut

Tier2cut is set to 0.25.

Tier3cut
Tier3cut is set to 0.25.

Tier4cut
Tier4cut is set to 0.25.

Tier5cut
Tier5cut is set to 0.25.

Tier6cut
Tier6cut is not used.

Total_Cut_AG
Tier_Cut_AG is the total cut to CVP agricultural water service contractors, expressed as a volume.

Total_Cut_EX
Tier_Cut_EX is the total cut to San Joaquin River Exchange contractors, expressed as a volume.

Total_Cut_MI
Tier_Cut_MI is the total cut to CVP M&I water service contractors, expressed as a volume.

Total_Cut_RF
Tier_Cut_RF is the total cut to wildlife refuges, expressed as a volume.

Total_Cuts_South
Total_Cuts_South is the total cut to all CVP contractors south of the Delta, expressed as a volume. It is calculated as the positive difference between *Total Contracts_South* and *DeliveryIndex*.

7.4.3.1.6 *DeliveryIndex*

The *DeliveryIndex* represents the amount of water that is available to south-of-Delta CVP contractors. It is used to determine the totals cuts to a full allocation, i.e., *Total_Cuts_South*. The *DeliveryIndex* is calculated as the minimum of three variables: *Total Contracts_South*, *DeliveryIndex_first*, and *ExportCapacity_Adjust*.

Occasionally, CVP south of Delta water supply estimate leads to higher allocations for CVP contractors south of the Delta than those calculated for north of Delta contractors. In these cases, south of Delta allocations are subsequently limited to be no greater than allocations calculated under the CVP system logic.

7.4.3.1.7 *DeliveryIndex_first*

The parameter *DeliveryIndex* is first calculated in March and subsequently updated in April and May. It is calculated as *the Export_Index_CVP_adj* divided by *South\ExportCapacity_Adjust\fact_CVP*.

7.4.3.1.8 *DeltaIndex*

The parameter *DeltaIndex* is a measure of annual runoff entering the Delta.

7.4.3.1.9 *Export_Index_CVP*

The parameter *Export_Index_CVP* is an estimate of how much water may be exported as part of the CVP. It is a linear function of the *DeltaIndex*.

7.4.3.1.10 *Export_Index_CVP_adj*

The parameter *Export_Index_CVP_adj* is the sum of *Export_Index_CVP*, previous month storage in CVP San Luis Reservoir, and seasonal inflow to the Mendota Pool from the James Bypass.

7.4.3.1.11 *ExportCapacity_Adjust*

ExportCapacity_Adjust is assigned the value of *deltar_cvp_s* described below.

<u>AnnDelCapEst</u>
The parameter *AnnDelCapEst* is an estimate of the total water available for delivery to CVP contractors. It is calculated by dividing *CVPDelCapEst* by a factor (*fact_CVP*).

<u>Buff_CVP</u>
The parameter *Buff_CVP* is equal to 90 TAF for the months of March through May, otherwise it is equal to zero.

<u>CVPDelCapEst</u>
The parameter *CVPDelCapEst* is an estimate of the available water supply through the end of August. It is the sum of export capacity (*estCVPExp*), previous month storage in CVP San Luis Reservoir (*SL_CVP\BOM*), and the San Luis Reservoir carryover storage target (*buff_CVP*).

<u>Deltar_cvp_s</u>
The parameter *Deltar_cvp_s* is the basis for imposing deficiencies on CVP contractors south of the Delta and the departure point for the 'cut' logic. It is calculated as the minimum of the total south of Delta contract amount (*Contracts_Total_South*) and the estimate of water availability (*AnnDelCapEst).*

<u>EstCVPExp</u>
The parameter *EstCVPExp* is an estimate of the ability to export CVP water at Jones Pumping Plant from the current month through to the end of August, which typically corresponds to the low point in San Luis Reservoir. This ability is influenced by regulatory exports constraint under D-1641 and USFWS and NMFS BiOps. EstCVPExp is calculated for the month sof March through May

<u>Fact_CVP</u>
The parameter *FactCVP* has values for March, April, and May, only. These values are derived from model calibration and are used to adjust the estimate of CVP export capability.

<u>HighCVPSL</u>
The parameter *HighCVPSL* is assigned a value of 90 TAF in the month of May when storage in the CVP share of San Luis Reservoir at the end of April is greater than 700 TAF. It increases *CVPDelCapEst* by this amount and so increases the May allocation to water service contractors.

7.4.3.1.12 Percent_Alloc_AG

Percent_Alloc_Ag represents the final allocation, expressed as a fraction, for CVP agricultural contractors located south of the Delta. This parameter is referenced throughout the model to constrain surface water diversions through transmission links to agricultural services contractors.

7.4.3.1.13 Percent_Alloc_ EX

Percent_Alloc_Ex represents the final allocation, expressed as a fraction, for CVP exchange and water right contractors in the San Joaquin Valley. This parameter is referenced throughout the model to constrain surface water diversions through transmission links.

7.4.3.1.14 Percent_Alloc_MI

Percent_Alloc_MI represents the final allocation, expressed as a fraction, for CVP M&I contractors located south of the Delta. This parameter is referenced throughout the model to constrain surface water diversions through transmission links to M&I contractors.

7.4.3.1.15 Percent_Alloc_RFS

Percent_Alloc_Rf represents the final allocation, expressed as a fraction, for CVP refuge contractors located south of the Delta. This parameter is referenced throughout the model to constrain surface water diversions through transmission links.

7.4.3.1.16 SL_CVP\BoM

SL_CVP\BOM is the CVP share of San Luis Reservoir storage at the end of the previous month.

7.4.3.1.17 Total Contracts_South

Total Contracts_South is the combined CVP total contract amount for contractors located south of the Delta and canal losses along the Delta-Mendota Canal and the Joint Reach of the California Aqueduct. It is calculated as the sum of *Contracts_AG_south, Contracts_MI_south, Contracts_RF_south, Contracts_EX, Contracts_Losses* and *Contracts_CVC.*

7.4.3.1.18 SummerSOD

SeasonalDemand

The *SeasonalDemand* is the remaining CVP contract delivery, assuming a 100% allocation, from the current month through the end of August.

AG is the seasonal demand for the CVP agricultural water service contractors.

MI is the seasonal demand for the CVP M&I water service contractors.

RF is the seasonal demand for the CVP supplied wildlife refuges.

EX is the seasonal demand for the San Joaquin River Exchange Contractors.

LS is the seasonal canal loss.

WaterSupply Increase

WaterSupply Increase represents the difference between full contract amount and current allocation for the remaining summer months through end of August.

Summer_SOD_WS is an estimate of the available water supply based on San Luis Reservoir storage and the export capacity of the CVP.

Summer_SOD_WSag is an estimate of the remaining contract allocation obligation to agricultural water users.

Summer_SOD_WSmi is an estimate of the remaining contract allocation obligation to M&I water users.

Summer_SOD_WSrf is an estimate of the remaining contract allocation obligation to wildlife refuges.

Summer_SOD_WSex is an estimate of the remaining contract allocation obligation to San Joaquin River Exchange contractors and Fresno Slough Schedule 2 diverters.

Perdel Increase

Gap_AG is an estimate of the remaining seasonal agricultural ‘demand’ for water over above the current allocation as measured from the full contract amount.

Gap_MI is an estimate of the remaining seasonal M&I ‘demand’ for water over above the current allocation as measured from the full contract amount.

Gap_Total is the sum of *Gap_AG* and *Gap_MI.*

WS_Inc_AG is the volume of water available for increased allocations to agricultural contractors.

WS_Inc_MI is the volume of water available for increased allocations to M&I contractors.

Trigger_AG requires that any late summer increase in allocations be either zero or above 5%.

Trigger_MI requires that any late summer increase in allocations be either zero or above 5%.

AG is the late summer increase in agricultural allocations.

MI is the late summer increase in M&I allocations.

7.4.3.1 System

The *System* branch contains parameters that are used to set the WSI, DI (*DemandIndex*), Delivery Index, and to make subsequent adjustments to CVP water allocations in the Sacramento Valley. Table 7-5 lists these parameters. These include the corresponding CalSim II allocations that were applied during model calibration and testing (*Alloc_AG_CalSim, Alloc_MI_CalSim,* and *Alloc_SC*_CalSim). The parameters also include total contract amounts (*Contracts_Total*) as well as expressions for WSI, DI, and the Delivery Index. Final allocation levels for each demand category—agriculture (*Percent_Alloc_AG*), refuge (*Percent_Alloc_RF*), settlement (*Percent_Alloc_SC*), exchange (*Percent_Alloc_EX*), and M&I contractors (*Percent_Alloc_MI*)—are also located under this branch.

Table 7-5. CVP Allocations\System Sub-Branches

System\	Description
Alloc_AG_CalSim	Time series (1922-2003) of CalSim II allocation values for CVP NOD Agricultural Services contractors
Alloc_MI_CalSim	Time series (1922-2003) of CalSim II allocation values for CVP NOD Urban contractors
Alloc_SC_CalSim	Time series (1922-2003) of CalSim II allocation values for CVP NOD Settlement contractors
Contracts_Total	Total CVP contract amounts (TAF) north and south of the Delta
Cuts	*See following paragraph.*
DeliveryIndex	The lesser of *Contracts_Total* and *DeliveryIndex_first*
DeliveryIndex_first	The amount of DemandIndex that can be used for delivery
DemandIndex	The amount of the current water supply that can be allocated to delivery and carryover storage
DivReq	Diversion requirement
Percent_Alloc_AG	Final percentage allocation for CVP NOD Agricultural Services contractors
Percent_Alloc_EX	Final percentage allocation for CVP Exchange contractors
Percent_Alloc_MI	Final percentage allocation for CVP NOD Urban contractors
Percent_Alloc_RF	Final percentage allocation for CVP NOD Refuge contractors
Percent_Alloc_SC	Final percentage allocation for CVP Settlement contractors
WaterSupplyEst	Estimated water supply for the current water year

7.4.3.1.1 Alloc_AG_Calsim

Alloc_AG_CalSim represents the north-of-Delta CVP allocation to agricultural water service contractors as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.2 Alloc_MI_Calsim

Alloc_MI_CalSim represents the north-of-Delta CVP allocation to M&I water service contractors as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.3 Alloc_SC_Calsim

Alloc_SC_CalSim represents the north-of-Delta CVP allocation to the Sacramento River Settlement Contractors as determined by the CalSim II model. Values are read from the file *Data\Param\CalSimII_Allocations.csv*.

7.4.3.1.4 Contracts_Total

Contracts_Total is the total CVP full contract amount for contractors both north and south of the Delta. It is the sum of Contracts_AG_north, Contracts_AG_south, Contracts_MI_north, Contracts_MI_south, Contracts_SC, Contracts_EX, Contracts_RF_north, Contracts_RF_south, and Contracts_CVC.

7.4.3.1.5 Cuts

The *Cuts* subbranch contains all parameters involved in applying the logic outlined in Figure 7-2. 'Cuts' in this sense refers to the difference between the full contract amount and the annual allocation.

Cut_level0

Cut_level0 is the total cut, expressed as a volume, based on the Shasta Criteria. It is the sum of *cut_EX0, cut_RF0,* and *cut_SC0.*

cut_EX0 is the cut to CVP San Joaquin River Exchange Contractors based on the Shasta Criteria.

cut_RF0 is the cut to wildlife refuges based on the Shasta Criteria.

cut_SC0 is the cut to CVP Sacramento River Settlement Contractors based on the Shasta Criteria.

Cut_level1

Cut_level1 is calculated as the total system-wide cut less *Cut_level0.*

cut_AG1 is the initial cut to agricultural water service contractors, including Cross Valley Canal contractors, expressed as a volume.

percentcut1 is the initial cut of up to 25% to agricultural water service contractors.

Cut_level2

Cut_level2 is calculated as the total system-wide cut less *Cut_level0* less *cut_AG1.*

cut_AG2 is the second cut to agricultural water service contractors, including Cross Valley Canal contractors.

cut_AG2_initial is the second cut to agricultural water service contractors based on *percentcut2_initial.*

cut_MI2 is the initial cut to M&I water service contractors expressed as a volume.

*cut_MI2_initia*l is the first cut to M&I water service contractors based on *percentcut2_initial.*

MI2_adjust is an adjustment to the available water supply in cases where the urban water demand is less than the CVP contract allocation.

percentcut2 is an adjustment to the percent cut in cases where the urban water demand is less than the CVP contract volume.

percentcut2_initial is the second cut of up to an additional 25% to agricultural water service contractors and the initial cut of up to 25% to M&I contractors.

Cut_level3

Cut_level3 is calculated as the total system-wide cut less *Cut_level0,* less *cut_AG1,* less *cut_AG2,* less *cut_MI2.*

cut_AG3 is the third cut to agricultural water service contractors, including Cross Valley Canal contractors based on *percentcut3_AG.*

cut_AG3_initial is the second cut to agricultural water service contractors based on *percentcut3_AG_initial.*

cut_MI3 is the second cut to M&I water service contractors expressed as a volume based on *percentcut3_MI.*

*cut_MI3_initia*l is the initial second cut to M&I water service contractors based on *percentcut3_MI_initial.*

MI3_adjust is an adjustment to the available water supply in cases where the urban water demand is less than the CVP contract allocation.

percentcut3_AG is an adjustment to the percent cut in cases where the urban water demand is less than

percentcut3_AG_initial is the second cut of up to an additional to 25% to agricultural contractors.

percentcut3_MI is an adjustment to the percent cut in cases where the urban water demand is less than the CVP contract allocation.

percentcut3_MI_initial is the second cut of up to an additional to 25% to M&I contractors. This cut is set to zero if *Key\Allocation Reduction\Allow MI Reduction to 25percent* is equal to zero.

Cut_level4

Cut_level4 is calculated as the total system-wide cut less *Cut_level0,* less *cut_AG1,* less *cut_AG2,* less *cut_MI2,* less *cut_AG3,* less *cut_MI3.*

cut_AG4 is the last cut to agricultural water service contractors, including Cross Valley Canal contractors based on *percentcut4_AG.*

cut_AG4_initial is the last cut to agricultural water service contractors based on *percentcut4_AG_initial.*

cut_MI4 is the last cut to M&I water service contractors expressed as a volume based on *percentcut4_MI.*

*cut_MI4_initia*l is the initial last cut to M&I water service contractors based on *percentcut4_MI_initial.*

MI4_adjust is an adjustment to the available water supply in cases where the urban water demand is less than the CVP contract allocation.

Percentcut4_AG is an adjustment to the percent cut in cases where the urban water demand is less than the CVP contract allocation.

Percentcut4_AG_initial is the second cut of up to an additional to 25% to agricultural contractors.

Percentcut4_MI is an adjustment to the percent cut in cases where the urban water demand is less than the CVP contract allocation.

Percentcut4_MI_initial is the third cut of up to an additional 25% to M&I contractors. This cut is set to zero if *Key\Allocation Reduction\Allow MI Reduction to 25percent* is equal to zero.

Cut_level5

Cut_level5 is additional cuts to Sacramento River Settlement Contractors, San Joaquin River Exchange Contractors, and wildlife refuges. It is non-zero when *Key\Allocation Reduction\Allow Further SC EX Reductions* is set equal to '1'.

cut_EX5 is the second cut to CVP San Joaquin River Exchange Contractors.

*cut_level5_MI*_adjust is no longer used in SacWAM.

cut_RFN5 is the second cut to north-of-Delta wildlife refuges.

cut_RFS5 is the second cut to north-of-Delta wildlife refuges.

cut_SC5 is the second cut to CVP Sacramento River Settlement Contractors.

percentcut5_EX is the percent cut to San Joaquin River Exchange Contractors over and above the 23% imposed in Shasta critical years.

percentcut5_RFN is the percent cut to wildlife refuges north of the Delta over and above the 25% imposed in Shasta critical years.

percentcut5_RFS is the percent cut to wildlife refuges north of the Delta over and above the 25% imposed in Shasta critical years.

percentcut5_SC is the percent cut to Sacramento River Settlement Contractors over and above the 25% imposed in Shasta critical years.

Tier0cut_SC

Tier0cut is set to 0.25 in Shasta critical years, otherwise it has a value of zero.

Tier1cut

Tier1cut is set to 0.25.

Tier2cut

Tier2cut is set to 0.25.

Tier3cut
Tier3cut is set to 0.25.

Tier4cut
Tier4cut is set to 0.25.

Tier5cut_EX_RFS
Tier5cut_EX_SC is set to 0.60.

Tier5cut_SC_RFN
Tier5cut_RFN is set to 0.60.

Total_Cut_AG
Tier_Cut_AG is the total cut to CVP agricultural water service contractors, expressed as a volume. It is the sum of *Cut_Ag1*, *Cut_Ag2*, *Cut_Ag3*, and *Cut_Ag4*.

Total_Cut_EX
Tier_Cut_EX is the total cut to San Joaquin River Exchange contractors, expressed as a volume. It is the sum of *Cut_EX0* and *Cut_EX5*.

Total_Cut_MI
Tier_Cut_MI is the total cut to CVP M&I water service contractors, expressed as a volume. It is the sum of *Cut_MI2*, *Cut_MI3*, and *Cut_MI4*.

Total_Cut_RF
Tier_Cut_RF is the total cut to wildlife refuges, expressed as a volume. It is the sum of *Cut_RF0* and *Cut_RF5*.

Total_Cut_SC
Tier_Cut_SC is the total cut to Sacramento River Settlement contractors, expressed as a volume. It is the sum of *Cut_SC0* and *Cut_SC5*.

Total_System_Cuts
Total_System_Cuts is the total cut to all CVP contractors both north and south of the Delta, expressed as a volume. It is calculated as:

- minimum of the north-of-Delta contract amounts, and the associated land-use based irrigation demands,
- plus the south-of-Delta contract amounts,
- plus canal losses along the Delta-Mendota Canal and joint reach of the California Aqueduct
- less the available water supply (DeliveryIndex)

7.4.3.1.6 DeliveryIndex

First calculated in March, DeliveryIndex is equal to DeliveryIndex_first, but capped at the total CVP full contract amount. DeliveryIndex is recalculated in April and May but is prevented from being lower than the previous month’s value.

7.4.3.1.7 DeliveryIndex_first

DeliveryIndex_first is a function of the *DemandIndex*.

7.4.3.1.8 DemandIndex

DemandIndex_first is a function of the *WaterSupplyEstimate*.

7.4.3.1.9 DivReq

DivReq is the maximum water demand of the CVP contractors. It combines land-use-based water demands and diversions in the Sacramento Valley with full contract amounts for demands in the San Joaquin Valley and south-of-Delta service areas.

DivReq_North_AG

DivReq_North_AG is the land-use-based water demand for agricultural water service contractors.

DivReq_North_MI

DiveReq_North_MI is the average surface water delivery to CVP M&I waterservice cntractors in years of full allocation.

DivReq_North_RF

DivReq_North_RF is the land-use-based water demand for wildlife refuges north of the Delta.

DivReq_North_SC

DivReq_North_SC is the land-use-based water demand for Sacramento River Settlement Contractors.

DivReq_NorthSouth

DiveReq_NorthSouth combines *DivReq_North_AG, DivReq_North_MI, DivReq_North_RF, DivReq_North_SC* with south-of-Delta full contract amounts.

7.4.3.1.10 Percent_Alloc_AG

Percent_Alloc_Ag is the north-of-Delta CVP allocation to agricultural water service contractors north of the Delta. It is calculated as 1 – *percentCut1* – *percentCut2* – *percentCut3_Ag* – *percentCut4*.

7.4.3.1.11 Percent_Alloc_EX

Percent_Alloc_EX is the allocation to the San Joaquin River Exchange Contractors. It is calculated as 1 – *Tier0cut_EX* – *percentCut5_EX*.

7.4.3.1.12 Percent_Alloc_MI

Percent_Alloc_MI is the north-of-Delta CVP allocation to M&I water service contractors north of the Delta. It is calculated as 1 – *percentCut2* – *percentCut3_MI* – *percentCut4*.

7.4.3.1.13 Percent_Alloc_RFN

Percent_Alloc_RFN is the allocation to the north-of-Delta wildlife refuges. It is calculated as 1 – *Tier0cut_SC* – *percentCut5_RFN*.

7.4.3.1.14 Percent_Alloc_RFS

Percent_Alloc_RFS is the allocation to the north-of-Delta wildlife refuges. It is calculated as 1 – *Tier0cut_SC – percentCut5_RFS*.

7.4.3.1.15 Percent_Alloc_SC

Percent_Alloc_SC is the allocation to the Sacramento River Settlement Contractors. It is calculated as 1 – *Tier0cut_SC – percentCut5_SC*.

7.4.3.1.16 WaterSupplyEst

WaterSupplyEst represents the water available to the CVP for delivery to its contractors. It is first calculated in March and updated in April and May. *WaterSupplyEst* is the sum of pervious month storage in Trinity, Shasta, Folsom, and San Luis reservoirs, plus the forecasted inflow to Shasta Lake, plus the forecasted inflow to Folsom Lake, plus the inflow to the Mendota Pool from the James Bypass. The forecasted inflows are read from the file *Data\WYT\CVPShastaInflowForecast.csv*.

CVPSto_SL

CVPStor_SL is short-hand for referring to the previous end-of-month storage in the CVP share of San Luis Reservoir.

CVPStor_Fol

CVPStor_Fol is short-hand for referring to the previous end-of-month storage in Folsom Lake.

CVPStor_Sha

CVPStor_Sha is short-hand for referring to the previous end-of-month storage in Like Shasta.

CVPStor_Tri

CVPStor_Tri is short-hand for referring to the previous end-of-month storage in Trinity Lake.

7.4.3.1.17 WSI_Calsim

is associated with allocation reductions for certain demand categories. Under normal operations (i.e. ‘Existing’ scenario in SacWAM) there are five possible levels of cuts, beginning with cuts to settlement, refuge, and exchange contractors in Shasta Critical years (level 0) and progressing through to final reductions for agriculture and M&I contractors (level 4). At each level, the maximum possible allocation reduction is 25 percent of contract demands. Thus, agriculture, which is involved in each step 1 through 4 may be reduced to zero percent allocation by the end of the cuts procedure. Whereas, M&I may only be reduced to 50 percent of their contract demand, because they are implicated in only level 2 and level 4 cuts. At each level, a percentage less than 25 percent may be selected if it is sufficient to meet the remaining deficit between contract demands and the target delivery volume (or delivery index).

SacWAM includes two additional cut options that may be used in scenarios: one that subjects M&I to an additional cut level, which allows their allocations to be reduced to as low as 25 percent, and another that subjects settlement, exchange, and refuge contracts to a sixth (and final) cut level if additional cuts are needed after reducing agriculture to zero percent and M&I to 50 percent (or 25 percent if the first option is also used). These two options are activated in the Key Assumptions under Key\Allocation Reduction (see Section 9.1).

7.4.4 ExportOps

Exports and diversions from the Delta into the North Bay Aqueduct, Contra Costa Canal, Delta-Mendota Canal, and the California Aqueduct are limited by the physical and permitted capacities of the pumping plants[34] and by regulatory standards within the Delta. These regulations include export limits based on Delta inflows and interior Delta channel flows, and export limits based on the San Joaquin River flow at Vernalis during the spring pulse period. The following sections describe how these regulations are applied in SacWAM. See also the section on Delta Reverse Flows (Section 8.9).

7.4.4.1 Banks

Both physical and permit capacities limit the amount of water pumped at Banks Pumping Plant. The physical capacity to pump water into the California Aqueduct at the Banks Pumping Plant is approximately 10,300 cfs. However, DWR operates Banks Pumping Plant under the constraints of USACE Public Notice 5820-A dated October 13, 1981, as amended. The notice states:

> *Diversions or re-diversions of water by the Permitte at Banks Pumping Plant shall not result in daily diversions into Clifton Court Forebay in excess of 13,870 acre-feet or three-day average diversion of 13,250 acre-feet/day, except during the period from mid-December to mid-March when San Joaquin River flow at Vernalis exceeds 1,000 cubic feet per second (cfs), during which time diversions into Clifton Court Forebay may be increased by one-third of the San Joaquin River flow at Vernalis.*

Exports at Banks Pumping Plant cannot be sustained at high flow rates because of operational constraints along the California Aqueduct. For a monthly time step model, it is usually assumed that the maximum sustained capacity of Banks Pumping Plant is 8,500 cfs (A. Miller, 2016).

SacWAM assumes a maximum permitted capacity for Banks Pumping Plant of 6,800 cfs with adjustments to increase the permitted capacity by one-third of the San Joaquin River flow at Vernalis during the period from mid-December through mid-March when Vernalis flows exceed 1,000 cfs up to a maximum of 8,500 cfs.

7.4.4.1.1 DaysIncrease

The parameter *DaysIncrease* is the number of days in the month when pumping can exceed the lower level permit capacity (*Permit Cap1*). It is equal to 17 (days) in December 31 in January, 28 in February, and 15 in April. In all other months, the parameter is zero.

7.4.4.1.2 EWAReservedCap

As part of the Environmental Water Account, the USACE permit for water diversions from the Old River to Clifton Court Forebay was increased by 500 cfs, from 6,680 cfs to 8,500 cfs, for the months of July, August, and September to recover water supply costs associated with previous reductions in SWP diversions undertaken to benefit Bay-Delta fishery resources. This additional permitted capacity currently is used to convey lower Yuba River Accord water. The parameter *EWAReservedCap* represents this incremental permitted capacity.

[34] For the SWP, this includes permitted inflows to Clifton Court Forebay.

7.4.4.1.3 MaxAllow

The parameter *MaxAllow* is the maximum pumping level that may occur at Banks Pumping Plant. It accounts for the physical capacities, permit capacities, and San Joaquin River flows at Vernalis.

7.4.4.1.4 MaxDiversion

The parameter *MaxDiversion* is an intermediate step in the calculation of the maximum allowable pumping at Banks Pumping Plant.

7.4.4.1.5 MinPump

The parameter *MinPump* is the minimum level of export at Banks Pumping Plant given the size of individual pump units and demands along the upper reaches of the California Aqueduct. *MinPump* is set equal to a constant 300 cfs.

7.4.4.1.6 Permit Cap1

The parameter *Permit Cap1* is the the maximum amount of water that is permitted to be pumped at the Banks Pumping Plant outside of the winter period December 15th to March 15th. *Permit Cap 1* is set equal to a constant 6,680 cfs.

7.4.4.1.7 Permit Cap2

The parameter *Permit Cap2* is the maximum amount of water that is permitted to be pumped at the Banks Pumping Plant during the winter period December 15th to March 15th. *Permit Cap 2* is set equal to a constant 8,500 cfs. During this period, permitted pumping varies depending on the San Joaquin River flow at Vernalis.

7.4.4.1.8 Physical Capacity

The maximum amount of water that can physically be pumped at the Banks Pumping Plant is approximately 10,300 cfs. However, flow rates at Banks Pumping Plant cannot be sustained at this rate because of operational constraints along the California Aqueduct. The parameter *Physical Capacity* is set equal to 8,500 cfs.

7.4.4.2 D1641_PulsePeriod

D-1641 is a State Water Board Decision outlining flow and water quality requirements in the Delta watershed. It includes a 31-day pulse flow period from April 15 to May 15 that is intended to facilitate fish migration. During this period, exports are limited to the greater of 1,500 cfs or the San Joaquin River flow at Vernalis. The pumping limits defined here are applied using UDCs (see *AprMayPulse_CVP* and *AprMayPulse_SWP* under *UDC\Pumping Constraints*).

7.4.4.2.1 MaxExp

Variable with a value of maximum of 1,500 cfs or the SJR flow at Vernalis

7.4.4.2.2 PulseDays

Monthly values of Pulse Days (16 days in April, 15 days in May)

7.4.4.3 ExportInflow

In each month, total Delta exports are limited by a fraction of Delta inflows. This is referred to as the Export/Inflow (or E/I) ratio (*ExpRatio*). The E/I ratio limits Delta exports to 65 percent of inflow February through June and to 35 percent July through January (*EI_base*). However, in February, the E/I ration may be increased to 70 percent if the Eight Rivers Index is less than 1.5 MAF or increased to 75 percent if the Eight Rivers Index is less than 1 MAF (*Feb_adjust*). Delta inflows are estimated as the sum of Sacramento River flows at Freeport, San Joaquin River flows at Vernalis, and Delta inflows from the Yolo Bypass, Mokelumne River, and Calaveras River.

Delta exports are also adjusted during the spring pulse period (April 16 – May 15) according the 2009 NMFS BiOp (NMFS, 2009), which limits export levels based on the 60-20-20 San Joaquin Valley Water Year Classification. According to this schedule, the projects are always allowed to export a minimum of 1,500 cfs. If San Joaquin River flows at Vernalis exceed 1,500 cfs, then exports during the pulse period are limited to a defined ratio of Vernalis flow to exports depending on the water-year type (WYT) (Table 7-6).

Table 7-6. Delta Export Limits During Spring Pulse Period

San Joaquin Valley Water-Year Type	Pulse Period Vernalis Flow: Export Ratio
Critical	1 to 1
Dry	2 to 1
Below Normal	3 to 1
Above Normal	4 to 1
Wet	4 to 1

7.4.4.3.1 EI_base

Variable for limiting Delta exports to 35 percent February through June and 65 percent from July through January

7.4.4.3.2 EIRatio_Requirement

EI_base variable is adjusted for increased exports in February depending on value of Eight Rivers Index

7.4.4.3.3 EIRationActual_CVP_Last

Set to zero

7.4.4.3.4 EIRatioActual_Last

Set to zero

7.4.4.3.5 EIRatioActual_SWP_Last

Set to zero

7.4.4.3.6 Feb_adjust

Variable to increase February export by 10 percent if Eight Rivers Index is less than 1 TAF or by a lesser value depending on the value of Eight River Index is between 1 TAF and 1.5 TAF. No adjustment is made if the Eight River Index is more than 1.5 TAF.

7.4.4.4 Jones

Both physical and permit capacities limit the amount of water pumped at the Jones Pumping Plant. The installed and permitted capacity for Jones Pumping Plant is 4,600 cfs.

7.4.4.4.1 *DaysIncrease,*

Similar to Banks Pumping Plant, three parameters (*DaysIncrease*, *MaxDiversion*, *Permit Capacity*) establish the maximum flow through the Jones Pumping Plant (*MaxAllow*), which is the minimum of the permit capacity and physical capacity, which are described above.

7.4.4.4.2 *MaxAllow*

The parameter *MaxAllow* is the maximum pumping level that may occur at Jones Pumping Plant. It accounts for both physical capacity and authorized diversions under permits.

7.4.4.4.3 *MaxDiversion*

The parameter *MaxDiversion* is an intermediate step in the calculation of the maximum allowable pumping at Jones Pumping Plant.

7.4.4.4.4 *MinPump*

The parameter *MinPump* is the minimum level of export at Jones Pumping Plant given the size of individual pump units and demands along the upper reaches of the Delta_mendota Canal. *MinPump* is set equal to a constant 300 cfs. For modeling purposes, SacWAM uses a value of 800 cfs, which is reduced to 600 cfs if storage in Shasta Lake falls below 1.5 MAF.

7.4.4.4.5 *Permit Capacity*

The permitted capacity of Jones Pumping Plant, as represented by the parameter *Permit Capacity*, is set to 4,600 cfs.

7.4.4.4.6 *Physical Capacity*

The Jones Pumping Plant houses six pump units with capacities between 850 cfs and 1,050 cfs. The total installed capacity is approximately 5,200 cfs. The capacity of the downstream reach of the Delta-Mendota Canal is 4,600 cfs. For modeling purposes, the capacity of Jones Pumping Plant, as represented by the parameter *Physical Capacity*, is set to 4,600 cfs.

7.4.4.5 OMR Actions

The 2008 USFWS BiOp determined that the continued operation of the CVP and SWP would likely result in adverse modification to critical habitat of the delta smelt that would jeopardize the species' existence within the Delta. This jeopardy determination led to the development of a Reasonable and Prudent Alternative (RPA) that was designed to avoid the likelihood of these threats. RPA includes Components 1 and 2 that are intended to reduce Delta exports, as indexed by the combined Old and Middle River (OMR) flows, when the entrainment risk of delta smelt increases. The implementation of these actions in SacWAM is described in the sections below.

7.4.4.5.1 *(USFWS) Action 1*

Action1 provides adult delta smelt entrainment protection during the initial winter flow pulse that may occur from December through March and limits Delta exports so that OMR flows (*A1_OMR_Target*) are no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average of -2,500 cfs. In SacWAM, Action 1 may be triggered beginning December 21 when the three-day average turbidity at Prisoner's Point, Holland Cut, and Victoria Canal exceeds 12 nephelometric turbidity units

(NTU). SacWAM uses the unimpaired Sacramento Valley Four Rivers Index[35] (*SAC_RI*) as a surrogate for the turbidity trigger for this action, assuming 20,000 cfs (*Turbidity_Threshold*) is a conservative indicator of the 12 NTU threshold.[36] For modeling purposes, if turbidity-trigger conditions first occur in December, then the action starts on December 21; if turbidity-trigger conditions first occur in January, then the action starts on January 1; if turbidity-trigger conditions first occur in February, then the action starts on February 1; and if turbidity-trigger conditions first occur in March, then the action starts on March 1. It is assumed that once the action is triggered, it continues for 14 days. In SacWAM, there are six water years in which Action 1 is not triggered: 1924, 1930, 1931, 1976, 1977, and 1994.

A1_OMR_Target

The parameter *A1_OMR_Target* represents the lower bound on OMR flow when Action 1 is triggered. It has a constant value of -2,000 cfs.

A1_TurbT

The parameter *A1_TurbT* indicates when Action 1 is triggered. It is calculated as a function of the month, Sacramento Valley Four Rivers Index, turbidity threshold, and whether action has been previously triggered. A value of 1 indicates Action 1 is triggered in December, 2 indicates action triggered in January, 3 for February, and 4 for March. A value of 99 indicates that Action 1 is not triggered in the current month.

A1_TurbTC

The parameter *A1_TurbTC* indicates whether Action 1 is or has been triggered (value of 1) or not (value of 0). It is calculated from the parameter *A1_TurbT*. The parameter is not referenced elsewhere in the model and is for output purposes only.

SAC_RI

The parameter *SAC_RI* represents the Sacramento Valley Four Rivers Index.[37]

Turbidity_Threshold

The parameter *Turbidity_Threshold* is an indicator of 12 NTU Turbidity at three turbidity stations (Holland Cut, Prisoner's Point and Victoria Canal) defined in the FWS BO.

NoTurbBrid

The parameter *NoTurbBrid* represents to avoid turbidity bridge to protect adult Delta Smelt that may present in the main stem of the San Joaquin River from moving southwards to the export facilities. It has a constant value of -2000 cfs.

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[35] Sacramento River at Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River at Folsom.

[36] This procedure is a modification of that implemented by DWR and Reclamation in CalSim II. Instead of the Sacramento River Index, CalSim II uses the sum of: inflows to Shasta, Oroville, and Folsom, and the Yuba River flow above Daguerre Point Dam. The unimpaired Sacramento Valley Four Rivers Index is approximately 20% greater than values used by CalSim II to trigger Action 1.

[37] The sum of the unimpaired flows for the Sacramento River at Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River at Folsom.

SLMN_Mar_May
The parameter *SLMN_Mar_May* represents first level of steelhead loss density (8 fish/taf) trigger. If the first level of loss density exceeded, then Old and Middle River is held at no more negative than –3500 cfs for a minimum of 5 days.

SLMN_Mar_2
The parameter *SLMN_Mar_2* represents second level of steelhead loss density (12 fish/taf) trigger. If the second level of loss density exceeded, then Old and Middle River is held at no more negative than –2500 cfs for a minimum of 5 days.

OMR_Storm
The parameter *OMR_Storm* represents capture of peak flow during storm-related events. It has a constant negative value of –6250 cfs.

OMR_JanJun
The parameter *OMR_JanJun* represents Old and Middle River management action that maintains flow no more negative than –5000 cfs.

OMR_wet_an_bn_MAR_APR
The parameter OMR_wet_an_bn_MAR_APR has a constant negative value of –3500 cfs.

WIIN_Wetness
The parameter *WIIN_Wetness* indicates the Water Infrastructure Improvement for the Nation (WIIN) Act of 2016. The values are read from a csv file. The WIIN_Wetness values are estimated by ranking January and February inflows (Shasta, Folsom and Oroville).

DryJanCheck
The parameter DryJanCheck identifies dry January based on *WIIN_Wetness*.

7.4.4.5.2 (USFWS) Action 2

Action 2 is implemented as an adaptive process following Action 1 and is intended to protect pre-spawning adult delta smelt from entrainment after the winter pulse. Action 2 limits Delta exports so that OMR flows are no less negative than -5,000 cfs to -3,500 cfs depending on existing conditions within the Delta, with a 5-day running average within 25 percent of the monthly criteria, i.e., no more negative than -6,250 cfs or -4,375 cfs. SacWAM uses the previous month X2 location as an indicator of Delta conditions. Action 2 continues until the onset of Action 3.

A flow peaking analysis, developed by Hutton (2008b), is used to determine the likelihood of a 3-day flow average greater than or equal to 90,000 cfs in Sacramento River at Rio Vista and a 3-day flow average greater than or equal to 10,000 cfs in San Joaquin River at Vernalis occurring within the month. It is assumed that when the likelihood of these conditions occurring exceeds 50 percent, Action 2 is suspended for the full month, and OMR flow requirements do not apply. The likelihood of these conditions occurring is evaluated each month, and Action 2 is suspended for one month at a time whenever both of these conditions occur. The frequency of occurrence for the Rio Vista 3-day average flow exceeding 90,000 cfs are determined as follows:

- Q_f < 50,000 cfs: frequency = 0%

- $Q_f + Q_{yb}$ 50,000 – 85,000 cfs: frequency = (0.00289 Q_f – 146)%
- Q_f > 85,000 cfs: frequency = 100%

Where: Q_f is the average monthly flow for the Sacramento River at Freeport and Q_{yb} is the average monthly flow for the Yolo Bypass at the Lisbon Weir.

The frequency of occurrence for the Vernalis 3-day average flow exceeding 10,000 cfs are determined as follows:

- Q_v < 6,000 cfs: frequency = 0%
- Q_v 6,000 – 16,000 cfs: frequency = (0.00901 Q_v – 49)%
- Q_v > 16,000 cfs: frequency = 100%

Where: Q_v is the average monthly flow for the San Joaquin River at Vernalis.

Freeport_YoloBypass
Freeport_YoloBypass represents the combined flow of the Sacramento River at Freeport and the Yolo Bypass at the Lisbon Weir. It is set equal to time series data read from the file *Data\Delta\SACVAL_Freeport-YoloBypass.csv.* These flows are taken from a previous model run.

RioVista_Threshold
The parameter *RioVista_Threshold* is the trigger for temporary suspension of Action 2 based on the combined flow Sacramento River flow at Freeport and Yolo Bypass at Lisbon Weir. Using the Hutton relationship (2008b), the probability of occurrence of a 3-day average flow at Freeport exceeding 90,000 cfs is 50 percent when the combined monthly flow is 67,820 cfs. Therefore, *RioVista_Threshold* is assigned this value, calculated as (50+146)/0.00289.

RioVista_Trigger
RioVista_Threshold is a flag that taken the value of '0' or '1'. A value of 1 indicates that *Freeport_YoloBypass* has a value greater than *RioVista_Threshold.*

OMR_Target_X2_E_Roe
The parameter *OMR_Target_X2_E_Roe* is the Action 2 lower bound OMR flow when the location of X2 is east of Roe Island. Although, the model is set-up to vary the requirement as a function of the Sacramento Valley Water Year Type, it currently is assigned a constant value of -3,500 cfs.

OMR_Target_X2_W_Roe
The parameter *OMR_Target_X2_W_Roe* is the Action 2 lower bound OMR flow when the location of X2 is west of Roe Island. Although, the model is set-up to vary the requirement as a function of the Sacramento Valley Water Year Type, it currently is assigned a constant value of -5,000 cfs.

X2_A2
The parameter *X2_A2* is determined based on the previous month X2 location. If this X2 location was east of Roe Island (>64 miles) the parameter is assigned a value of 1, otherwise it is set to zero.

A2_OMR_Target

The parameter *A2_OMR_Target* is the Action 2 lower bound OMR flow determined from the parameters *OMR_Target_X2_E_Roe, OMR_Target_X2_W_Roe*, and *X2_A2.* The considerations for setting the Action 2 OMR standards are summarized in Table 7-7.

Table 7-7. Action 2 Old and Middle River Standard

Sacramento Valley Water-Year Type	Minimum Flow (cfs)	
	X2 East of Roe (X2 > 64 km)	X2 West of Roe (X2 < 64 km)
Critical	-3,500	-5,000
Dry	-3,500	-5,000
Below Normal	-3,500	-5,000
Above Normal	-3,500	-5,000
Wet	-3,500	-5,000

Key:
cfs=cubic feet per second
km=kilometer

Vernalis

The parameter *Vernalis* is the San Joaquin River flow at Vernalis, which is an input to SacWAM.

Vernalis_Threshold

The parameter *Vernalis_Threshold* is the trigger for temporary suspension of Action 2 based on the San Joaquin River flow at Vernalis. Using the Hutton relationship (2008b), the probability of occurrence of a 3-day average flow at Vernalis exceeding 10,000 cfs is 50 percent when the Vernalis monthly flow is 10,988 cfs. Therefore, *Vernalis_Threshold* is assigned this value, calculated as (50 + 49)/0.00901.

Vernalis_Trigger

The parameter *Vernalis_Trigger* is assigned a value of 1 when the parameter *Vernalis* exceeds *Vernalis_Threshold*, so indicating the end of Action 2.

RioVista_Threshold

The parameter *RioVista_Threshold* is the trigger for ending Action 2 based on the Sacramento River flow at Rio Vista. Frequency of Rio Vista 3-day flow average > 90,000 cfs equals 50% when Freeport plus Yolo Bypass monthly flow is 67,820 cfs.

Using the Hutton relationship (2008b), the probability of occurrence of a 3-day average flow at Rio Vista exceeding 90,000 cfs is 50 percent when the combined monthly flow for the Sacramento River at Freeport and the Yolo Bypass at the Lisbon Weir is 67,820 cfs. Therefore, *RioVista_Threshold* is assigned a value of 67,820 cfs.

RPA_14day_SuspendA2

The USFWS BiOp Action 2 is suspended temporarily when the 3-day average flows at Rio Vista and Vernalis exceed 90,000 cfs (*RioVista_Threshold*) and 10,000 cfs (*Vernalis_Threshold*), respectively. SacWAM uses a flow peaking analysis, developed by Hutton (2008b), to determine the likelihood of a 3-day flow average greater than or equal to 90,000 cfs in Sacramento River at Freeport and a 3-day flow average greater than or equal to 10,000 cfs in San Joaquin River at Vernalis. The model suspends Action 2 for the entire month when the probability of both of these conditions occurring exceeds 50 percent.

7.4.4.5.3 (USFWS) Action 3

Action 3 is implemented as an adaptive approach intended to protect larval and juvenile delta smelt from entrainment. Similar to Action 2, Action 3 limits Delta exports so that OMR flows are no more negative than -5,000 to -1,250 cfs based on conditions within the Delta. SacWAM uses the previous month X2 location as an indicator of these Delta conditions.

OMR_Target_X2_E_Collinsville

The parameter *OMR_Target_X2_E_Roe* is the Action 3 lower bound OMR flow when the location of X2 is east of Collinsville. Although, the model is set-up to vary the requirement as a function of the Sacramento Valley Water Year Type, it currently is assigned a constant value of -1,250 cfs.

OMR_Target_X2_W_Roe

The parameter *OMR_Target_X2_W_Roe* is the Action 3 lower bound OMR flow when the location of X2 is west of Roe Island. Although, the model is set-up to vary the requirement as a function of the Sacramento Valley Water Year Type, it currently is assigned a constant value of -5,000 cfs.

OMR_Target_X2_Between

The parameter *OMR_Target_X2_Between* is the Action 3 lower bound OMR flow when the location of X2 is between Roe Island and Collinsville. Although, the model is set-up to vary the requirement as a function of the Sacramento Valley Water Year Type, it currently is assigned a constant value of -3,500 cfs.

X2_A3

The parameter *X2_A3* is determined based on the previous month X2 location. If this X2 location was east of Collinsville (>64 miles) the parameter is assigned a value of 1, if the location is west of Roe Island, it is assigned a value of 2, otherwise it is set to a value of 3.

A3_OMR_Target

The parameter *A3_OMR_Target* is the Action 3 lower bound OMR flow determined from the parameters *OMR_Target_X2_E_Roe, OMR_Target_X2_W_Roe*, *OMR_Target_X2_Between*, and *X2_A3.* The considerations for setting the Action 3 OMR standards are summarized in Table 7-8.

Table 7-8. Action 3 Old and Middle River Standard

Sacramento Valley Water-Year Type	Minimum Flow (cfs)		
	X2 East of Collinsville (X2 > 74 km)	X2 in between (64 km < X2 < 74 km)	X2 West of Roe (X2 < 64 km)
Critical	-1,250	-3,500	-5,000
Dry	-1,250	-3,500	-5,000
Below Normal	-1,250	-3,500	-5,000
Above Normal	-1,250	-3,500	-5,000
Wet	-1,250	-3,500	-5,000

Key:
cfs = cubic feet per second, km = kilometers.

Action 3 can be triggered either when the average temperatures from three stations within the Delta (Mossdale, Antioch, and Rio Vista) exceed 12°C or when spent female delta smelt appear in the Spring Kodiak Trawl Survey or at Banks or Jones pumping plants (*A3_Trigger_month* and *A3_Trigger_day*). These triggers are indicative of spawning activity and probable presence of larval delta smelt in the south and central Delta.

In SacWAM, both triggers are based on pre-processed data. Water temperature data from the three monitoring stations has been found to be highly correlated to measured air temperature at the Sacramento Executive Airport. Therefore, SacWAM uses a time series of trigger dates based on air temperature developed for the CalSim II/3.0 model. Because SacWAM has no good way of tracking biological triggers within the model, it must also pre-process these data. For present purposes, the model is set up such that biological trigger is activated each year on May 15.

<u>Temp_Trigger_Day</u>
The parameter *Temp_Trigger_Day* is the day of the month in which Delta water temperatures trigger the start of Action 3. It is read from the input file Data\Param\OMR_A3_startdates.csv.

<u>Temp_Trigger_Month</u>
The parameter *Temp_Trigger_Month* is the month in which Delta water temperatures trigger the start of Action 3. It is read from the input file Data\Param\OMR_A3_startdates.csv.

<u>Bio_Trigger_Day</u>
The parameter *Bio_Trigger_Day* is the day of the month in which salvage or trawl data trigger the start of Action 3. It is assigned a constant value of 30.

<u>Bio_Trigger_Month</u>
The parameter *Bio_Trigger_Month* is the month in which salvage or trawl data trigger the start of Action 3. It is assigned a constant value of 8, equivalent to May.

<u>A3_Trigger_Day</u>
The parameter *A3_Trigger_Day* is the day of the month in which Action 3 is triggered. It is a function of *Bio_Trigger_Day, Bio_Trigger_Month, Temp_Trigger_Day, and Temp_Trigger_Month.*

<u>A3_Trigger_Month</u>
The parameter *A3_Trigger_Day* is the month in which Action 3 is triggered. It is the earlier of *Bio_Trigger_Month* and *Temp_Trigger_Month*.

Action 3 is suspended after 30th June or once certain temperature thresholds have been reached, whichever comes first. The temperature off-ramp used to suspend Action 3 is triggered whenever water temperature reaches a daily average of 25°C for three consecutive days at Clifton Court Forebay. Unfortunately, there is no reliable correlation between water temperature at Clifton Court and nearby air temperature stations. Thus, for now, SacWAM uses only the temporal off-ramp criterion (June 30) to end Action 3.

<u>Temp_Offramp_Day</u>
The parameter *Temp_Offramp_Day* is the day of the month in which water temperature triggers the end of Action 3. It is assigned a constant value of 30.

<u>Temp_Offramp_Month</u>
The parameter *Temp_Offramp_Month* is the month in which water temperature triggers the end of Action 3. It is assigned a constant value of 9 (equivalent to June). The considerations for setting the USFWS BiOp OMR actions are summarized in Table 7-9.

7.4.4.5.4 OMR_background

The parameter *OMR_background* establishes the OMR condition in computing monthly values for partial month flow requirements. It is set to -5,000 cfs from January to March and -8,000 cfs from April to December based on assumptions adopted by DWR and Reclamation for CalSim II.

7.4.4.5.5 RPA_14day

The parameter *RPA_14day* is the maximum of *RPA_14day_Ave* and *RPA_NoA1.*

7.4.4.5.6 RPA_14day_Ave

The parameter *RPA_14day_Ave* is the day-weighted average OMR flow requirement resulting from Action 1, Action 2, and Action 3, which are described above.

7.4.4.5.7 RPA_5day

Flow actions specified in the 2008 USFWS BiOp place limits on OMR reverse flows in terms of 14-day averages, but with the requirement that the simultaneous 5-day averages are to be within 25% of the 14-day averages. The parameter *RPA_5day* is the 5-day average flow requirement. A value of -99999 indicates there is no flow requirement.

7.4.4.5.8 RPA_FWS

An analysis by Hutton (2009) investigated how frequently the 5-day OMR flows, rather than 14-day OMR flows, would controls project operation. SacWAM uses the results of this analysis to determine the more stringent of the 14-day and 5-day OMR requirement as represented by the parameter *RPA_FWS*. *RPA_FWS* also accounts for suspension of Action 2 during high flow events.

Table 7-9. Schedule of USFWS Biological Opinion Old and Middle River Actions

Action 1 Triggered	Action 3 Triggered	December	January	February	March	April	May	June
December	February	Background / Action 1	Action 2	Action 2 / Action 3	Action 3	Action 3	Action 3	Action 3
	March	Background / Action 1	Action 2	Action 2	Action 2 / Action 3	Action 3	Action 3	Action 3
	April	Background / Action 1	Action 2	Action 2	Action 2	Action 2 / Action 3	Action 3	Action 3
January	February	OMR Background	Action 1 / Action 2	Action 2 / Action 3	Action 3	Action 3	Action 3	Action 3
	March	OMR Background	Action 1 / Action 2	Action 2	Action 2 / Action 3		Action 3	Action 3
	April	OMR Background	Action 1 / Action 2	Action 2	Action 2	Action 2 / Action 3	Action 3	Action 3
February	February	OMR Background		Action 1 / Action 3	Action 3	Action 3	Action 3	Action 3
	March	OMR Background		Action 1 / Action 2	Action 2 / Action 3	Action 3	Action 3	Action 3
	April	OMR Background		Action 1 / Action 2	Action 2	Action 2 / Action 3	Action 3	Action 3
March	February	OMR Background		Action 3	Action 3	Action 3	Action 3	Action 3
	March	OMR Background			Action 1 / Action 3	Action 3	Action 3	Action 3
	April	OMR Background			Action 1 / Action 2	Action 2 / Action 3	Action 3	Action 3
Not triggered	February	OMR Background		Action 3	Action 3	Action 3	Action 3	Action 3
	March	OMR Background			Action 3	Action 3	Action 3	Action 3
	April	OMR Background				Action 3	Action 3	Action 3

Note: Action 3 may be triggered at any day of the month based on the pre-processed time series. (This is not shown in Table 7-9.)

Key:
OMR=Old and Middle River

7.4.4.5.9 RPA_NoA1

The parameter *RPA_NoA1* is the OMR flow requirement if Action 1 has not been triggered and before the onset of Action 3.

7.4.4.6 OMR and Health and Safety

This section computes the OMR RPA reverse flow limit and maximum allowable exports.

7.4.4.6.1 SODNetCU

The parameter *SODNetCU* represents the net consumptive use in the south Delta. It is derived from a mass balance between precipitation, runoff, irrigation diversions and return flows. In SacWAM, *SODNetCU* is read from data input files. Depending on a user-defined switch (*Simulate Delta Demands*) data input is derived either from CalSim II/3.0 input data or a previous model run of SacWAM in which the Delta catchment objects are activated.

7.4.4.6.2 CCWD_Estimated Diversions

The parameter *CCWD_EstimatedDiversions* is an estimate of Contra Costa WD diversions at Old River and Victoria Canal for the current time step. It is read from a data input file.

7.4.4.6.3 Q_SOD_HS

The parameter *Q_SOD_HS* is the total combined diversion and export from the south Delta, when exports equal the H&S requirement. It is calculated as the sum of CVP and SWP combined exports, Contra Costa WD diversions at Old River and Victoria Canal (*CCWD_EstimatedDiversions*), and net consumptive use in the south Delta (*SODNetCU*).

7.4.4.6.4 Q_OMR_HS

The parameter *Q_OMR_HS* is the OMR flow required to support H&S export levels. Its value is calculated using the Hutton equation and is a linear function of the San Joaquin flow at Vernalis (*SJatVernalis*) and combined south of Delta net diversions and exports (*Q_SOD_HS*).

7.4.4.6.5 Int_Freeport

The parameter *Int_Freeport* represents the trigger for USFWS RPA Action 2. It is read from the input file *Data\Delta\OMR_Triggers.csv*.

7.4.4.6.6 Q_OMR_Bound

SacWAM compares the OMR flow required to support H&S export levels and OMR flows to implement the USFWS RPA and sets the parameter *Q_OMR_Bound* to the minimum of the two.

7.4.4.6.7 Q_OMR_ReverseBound

The parameter *Q_OMR_ReverseBound* converts *Q_OMR_Bound* to a positive value, because reverse flows in SacWAM are represented as a positive flow on a north to south river arc. This limit is applied to flows in the OMR (see Section 8.24.1).

- **Available Export,** computes the available export capacity for CVP and SWP combined under the OMR reverse flows standard. This is used to split available export capacity between CVP and SWP (see *UDCs\OMR_BO_Actions\OMR Constraints\ShareAvailableExport*).

- **Int_Freeport,** time series input data that defines when Rio Vista flows are above the threshold for suspending OMR RPA Action 2.

7.4.4.7 RPAHealthandSafety

DWR and Reclamation believe that the minimum health and safety (H&S) export level at any one time will be a range and that 1,500 cfs is a reasonable cap on that range. Actual health and safety export levels will depend on a number of factors. It should take into account not only the need to deliver water directly for drinking water, sanitation, and fire suppression purposes, but also the need to store water now for blending later for H&S water quality considerations in the event that, without blending, Delta diversions become unusable later in the year.

The parameter *RPAHealthandSafety* represents the minimum H&S export amount. It is used only in association with RPA requirements for OMR (see Section 7.4.4.5) and for the San Joaquin inflow to export ratio (see Section 8.8.4). From December through June, it is assigned a value of 1,500 cfs. In all other months, it has a value of zero. However, SacWAM implements a minimum year-round pumping level based on the parameters *MinPump* for Banks and Jones pumping plants and the IFR objects *OPS CA Health and Safety* and *OPS DMC Health and Safety*.

7.4.4.8 SJR_EIRatio

The NMFS BO (2009) restricts combined CVP and SWP export rates during April and May to a proportion of the inflow to the Delta from the San Joaquin River at Vernalis. This restriction is defined under Action IV.2.1 and depends on the San Joaquin Valley 60-20-20 index as explained in Table 7-10. Three exceptions exist to the requirement as follows:

- Exports are not restricted when the San Joaquin River at Vernalis is at the flood warning stage of 24.5 feet (assumed to be equivalent to 21,750 cfs for modeling purposes).
- Exports may exceed the the restrictions if required for Health and Safety (see Section 7.4.4.6 - assumed to be a maximum of 1,500 cfs for modeling purposes).
- If the sum of the current and previous 2 years San Joaquin Valley 60-20-20 index indicator is 6 or less, and the New Melones index is less than 1 MAF, exports are limited to a 1:1 ratio with San Joaquin River at Vernalis flow. The New Melones Index is a summation of end of February New Melones Reservoir storage and forecasted inflow using 50% exceedance from March through September.

In SacWAM, maximum exports (*SJ_MaxExp*) are set to 99,999 cfs from June to the following March, and in April and May when *Vernalis Flow* is greater than 21,750 cfs. SacWAM does not simulate the multi-year off-ramp.[38]

[38] An examination of recent CalSim 3 model results released by DWR (2018) showed that the offramp is triggered in six years (1931, 1990, 1991, 1992, 2014, 2015). These years are all classified as crirically dry and thus the offramp has no effect.

Table 7-10. San Joaquin River Based Export Constraints

Month	San Joaquin Valley 40-30-30 Index		Maximum Allowable Export	
	Classification	**Indicator**	**SJ_MaxExp**[1]	
June – March	N/A	N/A	99,999 cfs	
April, May	Wet	5	The greater of Health and Safety levels and	Vernalis Flow/4
	Above Normal	4		Vernalis Flow/4
	Below Normal	3		Vernalis Flow/3
	Dry	2		Vernalis Flow/2
	Critically Dry	1		Vernalis Flow

Key:
cfs = cubic feet per second, Vernalis = San Joaquin River at Vernalis

7.4.4.8.1 PulseDays

Currently not used.

7.4.4.8.2 PulseExpCtrl

Currently not used.

7.4.4.8.3 SJ_MaxExp

The parameter *SJ_MaxExp* represents San Joaquin River based Export constraints (Table 7-10). Wet year exports can vary in scenarios (*Wetyr_MaxExp*).

7.4.4.8.4 FourToOne

The parameter *FourToOne* indicates Exports based on ratio of Export to Inflow.

7.4.4.8.5 FourToOne_curtailment

The parameter *FourToOne_curtailment* represents the difference in export between Available export and *FourToOne* export.

7.4.4.8.6 Wetyr_AprMaxExp

The parameter *Wetyr_AprMaxExp* indicates export curtailment from SWP and CVP. 2020 ITP lists curtailment limits on SWP as 150 TAF. Assuming Delta is in excess condition and COA splits are 40% for SWP and 60% for CVP, the total curtailment for both SWP and CVP is 375 TAF.

7.4.4.8.7 Wetyr_MayMaxExp

The parameter *Wetyr_MayMaxExp* represents Delta Outflow Offramp if Outflow is greater than 44,500 cfs.

7.4.4.8.8 Apr_curtailment

Currently not used.

7.4.4.8.9 Wetyr_MaxExp

The parameter *Wetyr_MaxExp* represents Wet year Offramp of export constraint for scenarios. For 2008-09 BiOps, the offramp is *FourToOne* and for other scenarios, the offramp is *Wetyr_AprMaxExp*.

7.4.4.8.10 Outflow_Offramp

The parameter *Outflow_Offramp* represents Delta Outflow Offramp if Outflow is greater than 44,500 cfs.

7.4.4.9 *SMSCG_Ops*

Suisun Marsh Salinity Control Gates (SMSCG) are operated (opened during ebb-tide, closed during flood-tide) from October through May each year to reduce salinity in Montezuma Slough and eastern marsh channels. In summer months, the gates are operated per California Department of Fish and Wildlife's 2020 ITP requirements. In SacWAM, October to May operations are implemented through *SMSCG_OP1* and Summer operations are implemented through *SMSCG_OP2* and *SMSCG_OP3*.

7.4.4.9.1 *MTZ_EC_7day*

ANN estimation of last 7-day average EC at Martinez from previous month.

7.4.4.9.2 *SMSCG_EC_Trigger1*

From September to May, the parameter *SMSCG_EC_Trigger1* indicates trigger values for Martinez EC

7.4.4.9.3 *SMSCG_OP1*

Based on trigger values, the gate operations flags are: 0 for tidally operating and 1 for opening all gates.

7.4.4.9.4 *wyt_sac_prevMay*

Currently not used.

7.4.4.9.5 *wyt_sac_mod*

Currently not used.

7.4.4.9.6 *wyt_sac_frcst*

Currently not used.

7.4.4.9.7 *SMSCG_EC_Trigger2*

The parameter *SMSCG_EC_Trigger2* represents SMSCG summer operations of upto 60 days for Wet years and consecutive 60 days for Above Normal and Below Normal years.

7.4.4.9.8 *SMSCG_wytflag2*

The parameter *SMSCG_wytflag2* indicates flag based on water year type operations.

7.4.4.9.9 *SMSCG_OP2*

The parameter *SMSCG_OP2* represents summer gate operation for Wet, Above Normal and Below Normal year with 0 means tidally operated and 1 means openning all gates.

7.4.4.9.10 *SMSCG_OP2_Count*

The parameter *SMSCG_OP2_Count* counts how many months SMSCG gate will operate in *SMSCG_OP2*.

7.4.4.9.11 *SMSCG_wytflag3*

The parameter SMSCG_wytflag3 indicates flag based on water year type operations. It represents SMSCG summer operations of 60 days for Dry year following Wet and Above Normal years, and 30 days for Dry year following Below Normal years.

7.4.4.9.12 SMSCG_OP3

The parameter *SMSCG_OP3* represents summer gate operation for Dry years following Wet and Above Normal or Below Normal year with 0 means tidally operated and 1 means openning all gates.

7.4.4.9.13 SMSCG_OP3_Count

The parameter *SMSCG_OP3_Count* counts how many months SMSCG gate will operate in SMSCG_OP3.

7.4.4.9.14 SMSCG_OP

The parameter *SMSCG_OP* indicates whether it is SMSCG Fall operations or summer operations.

7.4.4.9.15 ave_last_7days

It is an ANN average type key input. It has a constant value of 37 for average last 7 days.

7.4.4.9.16 MTZ_ANN

It is an ANN location key input. It has a constant value of 21 for Martinez.

7.4.4.9.17 SMSCG_op_on

The parameter *SMSCG_op_on* has a constant value of 0 which means it is tidally operated.

7.4.4.9.18 SMSCG_op_off

The parameter *SMSCG_op_off* has a constant value of 1 which means all gates are open.

7.4.4.9.19 EM_b_SMSCG_on

Get intercept when SMSCG is on for constraint “Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)”

7.4.4.9.20 EM_m_SMSCG_on

Get slope when SMSCG is on for constraint “Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)”

7.4.4.9.21 EM_b_SMSCG_off

Get intercept when SMSCG is of for constraint “Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)”

7.4.4.9.22 EM_m_SMSCG_off

Get slope when SMSCG is off for constraint “Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)”

7.4.4.9.23 EM_ignore

Logical expression. It has value of 0 or 1.

7.4.4.9.24 EM_Sac_on

Estimate how much Sacramento Inflow needs when SMSCG is on. The flow is determined from the following equation, “Sacramento Inflow at Hood = (Combined Export – b)/m”

7.4.4.9.25 EM_Sac_off

Estimate how much Sacramento Inflow needs when SMSCG is off. The flow is determined from the following equation, "Sacramento Inflow at Hood = (Combined Export – b)/m"

7.4.4.9.26 EM_SMSCG_costSac_ops

Estimate how much flow is needed to operate SMSCG in summer months when Emmaton is controlling.

7.4.4.9.27 JP_b_SMSCG_on

Get intercept when SMSCG is on for constraint "Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)"

7.4.4.9.28 JP_m_SMSCG_on

Get slope when SMSCG is on for constraint "Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)"

7.4.4.9.29 JP_b_SMSCG_off

Get intercept when SMSCG is off for constraint "Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)"

7.4.4.9.30 JP_m_SMSCG_off

Get slope when SMSCG is off for constraint "Combined Export <= Slope (m) * Sacramento Inflow at Hood + Intercept (b)"

7.4.4.9.31 JP_ignore

Logical expression. It has value of 0 or 1.

7.4.4.9.32 JP_Sac_on

Estimate how much Sacramento Inflow needs when SMSCG is on. The flow is determined from the following equation, "Sacramento Inflow at Hood = (Combined Export – b)/m"

7.4.4.9.33 JP_Sac_off

Estimate how much Sacramento Inflow needs when SMSCG is off. The flow is determined from the following equation, "Sacramento Inflow at Hood = (Combined Export – b)/m"

7.4.4.9.34 JP_SMSCG_costSac_ops

Estimate how much flow is needed to operate SMSCG in summer months when Jersey Point is controlling.

7.4.4.9.35 SMSCG_Dyr_watercost

Estimate water cost for Dry year following Wet and Above Normal (60 days) or Below Normal (30 days) SMSCG operations in summer months. Assuming Emmaton or Jersey Point is controlling. Rock Slough is very less likely to control in summer months. Collinsville never controls in summer months.

7.4.4.9.36 cum_SMSCG_Dyr_watercost

Calculate cumulative water cost.

7.4.4.10 ITP_100TAF

The ITP requires that the SWP operate to provide a flexible block of water to enhance Delta Outflow during the spring, summer, or fall months. The Projects shall provide 100 TAF of water to supplement Delta Outflow (Additional 100 TAF) in addition to outflow required to meet the criteria in Table 9-A of the SWP Incidental Take Permit (CDFW, 2020). This table is reproduced in Table 7-11.

Table 7-11. Criteria Required to be Met Through Imlementation of the Summer-Fall Action

<table>
<tr><th rowspan="2">Month</th><th colspan="5">Water Year Type (SVI)</th></tr>
<tr><th>Wet</th><th>Above Normal</th><th>Below Normal</th><th>Dry</th><th>Critical</th></tr>
<tr><td>June</td><td rowspan="3">Additional 100 TAF Delta outflow, June through October[2]</td><td rowspan="3">Criteria: Operate SMSCG for 60 days[1]

Additional 100 TAF Delta outflow, June through October[2]</td><td rowspan="5">Criteria: Operate SMSCG for 60 days[1]</td><td rowspan="5">Criteria: In dry years following below-normal years operate SMSCG for 30 days[1]
Criteria: In dry years following wet or above-normal water years operate SMSCG for60 days[1,3]</td><td rowspan="5">No action</td></tr>
<tr><td>July</td></tr>
<tr><td>August</td></tr>
<tr><td>September</td><td rowspan="2">Criteria: 30-day average X2 <80 km</td><td rowspan="2">Criteria: 30-day average X2 <80 km</td></tr>
<tr><td>October</td></tr>
</table>

Source: Reproduced from Table 9-A, Incidental Take Permit for Long-Term Operations of the State Water Project in the Sacramento-San Joaquin Delta. CDFW. 2020.

Notes:

[1] Water necessary to implement SMSCG operations may be provided through export curtailments supported by the SWP Contractors through a commitment pursuant to Voluntary Agreements or as early implementation of such agreements.

[2] If approved by CDFW the Additional JOO TAF may be deferred and redeployed to supplement Delta outflow the following water year duriog the March - October timeframe, unless the following water year is critical (see Condition of Approval 8.19). This use of the redeployed water is not intended to serve as a criterion.

[3] CDFW anticipates deferring a portion of the 100 TAF received from an above normal or wet year when the following year Is dry to facilitate SMSCG operation for 60 days in the absence of other available water.

7.4.4.10.1 DO_req_X2_ITP

In Wet, Above Normal, and Below Normal years, an additional 100 TAF carryover should be released to support 80 km X2 in summer months.

begday_80km

Set the begin day to maintain X2 at 80 km.

X2_est_base

ANN estimation of X2 for D-1641.

daysX2_80km_mod

Modify the day based on any changes in days for Confluence standard.

endday_80km

Set the end day to maintain X2 at 80 km.

DO_req_X2_80km_init

ANN estimation of Delta outflow required to maintain X2 at 80 km.

DO_req_X2_80km
Filter for non-zero Delta Outflow.

DO_req_X2_ITP_temp
Track how much Delta Outflow is required to meet D-1641 and maintain X2 at 80 km.

chs_days_mrdo
Set the days for standard at Chipps Island.

roe_days_mrdo
Set the days for standard at Roe Island.

X2_80km_days_mrdo
Set the days to maintain X2 at 80 km.

7.4.4.10.2 JunAug 80km VolReq

Currently not used.

7.4.4.10.3 WetAN Carryover

ITP carryover of 70 TAF in Wet and Above Normal years.

7.4.4.10.4 Prev TS Oroville Spill CumuVol

Calculate cumulative volume of spill from Lake Oroville.

7.4.4.10.5 WetAN May OutflowVol

Calculate May Oroville releases for Delta Outflow in Wet and Above Normal years.

7.4.4.10.6 BN May OutflowVol

Calculate May Oroville releases for Delta Outflow in Below Normal year.

7.4.4.10.7 Dry May OutflowVol

Calculate May Oroville releases for Delta Outflow in Dry year.

7.4.4.10.8 ITP May OutflowVol

Total May Oroville releases for Delta Outflow in all years. There is no ITP action in Critical year.

7.4.4.10.9 min_carryover

Currently not used.

7.4.4.10.10 Aug_ExpCut

Define Additional 100 TAF Delta Outflow.

7.4.4.10.11 likely_spill_threshold

The parameted *likely_spill_threshold* represents September Oroville Top of Conservation in August.

7.4.4.10.12 remain_aug_ExpCut
The parameter *remain_aug_ExpCut* represents remaining additional Delta Outflow after ITP carryover (*WetAN Carryover*).

7.4.4.10.13 ExpCut_X2
Determine Delta Outflow required to maintain X2 at 80 km.

7.4.4.10.14 ExpCut_X2_used
Track how much of additional 100 TAF Delta Outflow is used to maintain X2 at 80 km.

7.4.4.10.15 ITP_unused
Calculate unused Delta Outflow after maintaining X2 at 80 km.

7.4.4.10.16 ExpCut_remain
Calculate remaining Delta Outflow in September after maintaining X2 at 80 km.

7.4.4.11 Vernalis Flow
This parameter is the flow data for the San Joaquin River at Vernalis, obtained from *Supply and Resources\River\Inflow at Vernalis: Headflow*[CFS]. This flow plays a key role in several regulatory export constraints, including D-1641 30-day pulse period requirements, Clifton Court Forebay inflows under USACE permit, NMFS BiOp RPA Action IV.2.1 (San Joaquin River to export ratio), and USFWS BiOp RPA Action 2.

SacWAM does not consider San Joaquin River water management operations upstream from Vernalis. Instead, the model reads pre-processed time series of flows at Vernalis. The model offers two options for San Joaquin River flows: (1) CalSim II simulated flows at Vernalis or (2) time series of Vernalis flows developed by State Water Board as part of Phase 1 of the update to the Bay-Delta Plan. These flows are specified in SacWAM in the Data Tree under *Key Assumptions\Use Water Board Vernalis Inflow* (see Section 9.17.

7.4.4.12 Mendota Pool Demands
Mendota Pool Demands is the sum of all CVP allocations that are delivered from the Mnedota Pool or Sack Dam. It is used to constrain exports at Jones Pumping Plant and prevent excess outflow from the Delta-Mendota Canal to the San Joaquin River.

7.4.4.13 VA Export Reduction
Constraints were added to reduce exports at Banks and Jones Pumping Plants from VA baseline pumping rates in March and April. The reductions shown in Table 7-12 are first applied in March but are not reduced below 3,000 cfs. If the volumes listed in the table are not achieved in March, the remaining volume is reduced in April with a minimum total export of 1,500 cfs. To reduce the effects of system reoperation, total Banks and Jones exports are maintained above VA baseline exports between when OMR limits are initiated (December or January) and June.

Table 7-12. Assumed Reduction in CVP and SWP Exports in the VA Scenario

Water Year	Export Reduction (TAF)
Critical	3
Dry	179
Below Normal	200
Above Normal	265
Wet	27

Key:
TAF = thousand acre-feet

7.4.4.13.1 AvailableExport_VA_AprWAN_MarBNDC

The parameter *AvailableExport_VA_AprWAN_MarBNDC* represents export reduction in April for Wet and Above Normal years, and in March for Below Normal and Dry years. If the volumes of export reduction are not achieved in these months, the remaining volumes are reduced in the following months.

7.4.4.13.2 AvailableExport_DeltaVA

The parameter "AvailableExport_DeltaVA" represents the total volume of export reduction.

7.4.4.13.3 Delta VA Additional Flow

The parameter "*Delta VA Additional Flow*" represents difference in export between VA and no VA scenarios.

7.4.4.13.4 Available Export_NoVA

It works with a switch to determine whether Available Export is based on VA or no VA scenario.

7.4.4.13.5 OMR_Limit

The parameter "OMR_Limt" represents Available Export under the OMR constraint for exports.

7.4.5 Folsom Flood Curve

The *Folsom Flood Curve* is based on the recently updated flood space diagram whereby between 400 and 600 TAF of flood space is specified, depending on creditable flood space in three upstream reservoirs—French Meadows (*FrenchM_FloodSpace*), Hell Hole (*HellH_FloodSpace*), and Union Valley (*UnionV_FloodSpace*). (*UpperAmer_CredSpace* sums the three to get the total upstream creditable space.) For purposes of computing creditable space, French Meadows can have a maximum of 45 TAF, Hell Hole can have a maximum of 80 TAF, and Union Valley can have a maximum of 75 TAF. If the maximum 200 TAF of creditable space exists upstream, Folsom's flood space is 600 TAF. If there is 0 TAF of creditable space upstream, Folsom's flood space is 400 TAF. In between, the volume of flood space is interpolated, using the same rules as used in the CalSim II model. The full allowed volume of flood space is operated to in November through February, while flood space is 0 in May and June. The other months reflect a drawdown in the fall and a refill curve in the spring, both of which are also interpolated based on upstream creditable space. Table 7-13 shows the flood curve and flood space values by month. Maximum storage in Folsom is 977 TAF.

Table 7-13. Folsom Flood Space Rules

Month	Flood Curve (TAF)	Flood Space (TAF)
October	670-720	257-307
November-Februrary	377-577	400-600
March	583-682	295-394
April	800	177
May-June	975	0
July	950	25
August	800	175
September	760	215

Key:
TAF = thousand acre-feet

7.4.5.1 Apr
Variable to set Folsom Flood Curve to 802 TAF in April.

7.4.5.2 FrenchM_FloodSpace
Variable to compute flood storage space in French Meadows reservoir. Computed as a difference between storage capacity and current storage in the reservoir.

7.4.5.3 HellH_FloodSpace
Variable to compute flood storage space in Hell Hole reservoir. Computed as a difference between storage capacity and current storage in the reservoir.

7.4.5.4 JulySep
Variable to set Folsom Flood Curve to fixed values from July through September. The values for July through September are 952 TAF, 802 TAF, 762 TAF respectively.

7.4.5.5 Mar
Variable to set Folsom Flood Curve in March to the value from the flood curve between 583 and 682 depending on credit for flood space based on forecasted storage in the Upper American River Basin.

7.4.5.6 MayJune
Variable to set Folsom Flood Curve to 977 TAF from May through June.

7.4.5.7 NovFeb
Variable to set Folsom Flood Curve from November through February to the value from the flood curve between 377 and 577 depending on credit for flood space based on forecasted storage in the Upper American River Basin.

7.4.5.8 Oct
Variable to set Folsom Flood Curve in October to the value from the flood curve between 670 and 720 depending on credit for flood space based on forecasted storage in the Upper American River Basin.

7.4.5.9 UnionV_FloodSpace
Variable to compute flood storage space in Union Valley reservoir. Computed as a difference between storage capacity and current storage in the reservoir.

7.4.5.10 UpperAmer_CredSpaceBasedonForecastedStorage
Variable to compute credit for Upper American Flood Storage space by combining available space in Union Valley, French Meadows and Hell Hole reservoirs.

7.4.5.11 UpperAmer_CredSpaceBasedonPreviousMonthStorage

Variable to compute credit for Upper American flood space based on previous month storage. Not currently used.

7.4.6 North Bay Aqueduct

The North Bay Aqueduct is part of the State Water Project (SWP,) delivering water to Solano County WA and Napa County FC&WCD, which are both long-term SWP water contractors. Under agreements with Solano County WA, water from the North Bay Aqueduct is delivered to the Cities of Benicia, Fairfield, Vacaville, and Vallejo. The North Bay Aqueduct also is used to convey Vallejo Permit Water and Settlement Water.

Water demands for the City of Fairfield (U_FRFLD), City of Benicia (U_BNCIA), and City of Vacaville (U_20_25_PU) are disaggergated into two demand sites named using the suffix "_PU" and "_SU." Disaggregating demand sites facilitates modeling delivery of water with different water right priorities.

Demand sites with the suffix _PU are assigned a high priority to represent delivery of SWP Table A water and/or Vallejo Permit Water. Dual transmission links to each demand site differentiates between these two types of water. The *Maximum Flow Volume* property is used to constrain flow through the transmission link according to the SWP table A allocation or the amount of remaining Vallejo Permit Water. SacWAM v.1.05 uses the user-defined variables V*PWRemainingTotal* to track use of Vallejo Permit water. The total volume may not exceed 17.287 TAF per year. The combined monthly flow rate to demand units using permit water may not exceed 31.52 cfs.

Each month, any unmet demand is assigned to the demand site denoted by _SU, which has a low assigned priority. The purpose of the _SU demand sites is to represent delivery of Settlement Water, which is subject the SWRCB Term 91. SacWAM v.1.05 uses the user-defined variables *SettlementWaterRemainingBenicia*, *SettlementWaterRemainingFairfield*, *SettlementWaterRemainingVacaville* to track use of Settlement water. The total annual volumes may not exceed 10.50 TAF, 11.80 TAF, and 9.32 TAF – a total of 31.62 TAF per year.

For demand sites that receive water from both the Putah South Canal and North Bay Aqueduct, Putah South Canal water is assigned a higher preference. For water conveyed through the North Bay Aqueduct, SWP Table A water is assigned a higher preference than Vallejo Permit water.

7.4.6.1 SettlementWater

Logic to track the Settlement Water availability and delivery for Benicia, Fairfield and Vacaville.

7.4.6.1.1 SettlementWaterRemainingBenicia

Variable to track settlement water remaining to be delivered for Benicia. This is reset to 10.50 TAF every October and then set to the difference of previous month's remaining water and the delivery to U_BNCIA_SU from the North Bay Aqueduct for the current timestep from November onwards.

7.4.6.1.2 SettlementWaterRemainingFairfield

Variable to track settlement water remaining to be delivered for Fairfield. This is reset to 11.80 TAF every October and then set to the difference of previous month's remaining water and the delivery to U_FRFLD_SU from the North Bay Aqueduct for the current timestep from November onwards.

7.4.6.1.3 *SettlementWaterRemainingVacaville*
Variable to track settlement water remaining to be delivered for Vacaville. This is reset to 9.32 TAF every October and then set to the difference of previous month's remaining water and the delivery to U_20_25_SU from the North Bay Aqueduct for the current timestep from November onwards.

7.4.6.2 *VallejoPermitWater*

7.4.6.2.1 *VPWRemainingBenicia*
VPWRemainingBenicia is currently not used in SacWAM simulation.

7.4.6.2.2 *VPWRemainingFairfield*
VPWRemainingFairfield is currently not used in SacWAM simulation.

7.4.6.2.3 *VPWRemainingNapa*
VPWRemainingNapa is currently not used in SacWAM simulation.

7.4.6.2.4 *VPWRemainingTotal*
VPWRemainingTotal tracks use of Vallejo Permit water. The total volume may not exceed 17.287 TAF per year. The combined monthly flow rate to demand units using permit water may not exceed 31.52 cfs.

7.4.6.2.5 *VPWRemainingVacaville*
VPWRemainingVacaville is currently not used in SacWAM simulation.

7.4.6.2.6 *VPWRemainingVallejo*
VPWRemainingVallejo is currently not used in SacWAM simulation.

7.4.7 San Luis

San Luis Reservoir is an off-stream facility in the eastern part of the Diablo Range, west of the San Joaquin Valley. Water from the Delta is delivered to San Luis Reservoir via the California Aqueduct and Delta-Mendota Canal for temporary storage during the rainy season. During the dry season, this stored water is released for use by CVP and SWP water contractors south of the Delta. San Luis Reservoir also provides water to the Santa Clara Valley Water District and the San Benito County Water District. Water is delivered to these users through CVP's San Felipe Division on the west side of the reservoir.

In SacWAM, San Luis Reservoir is represented using two reservoir objects, one for the CVP pool and one for the SWP pool, as shown in

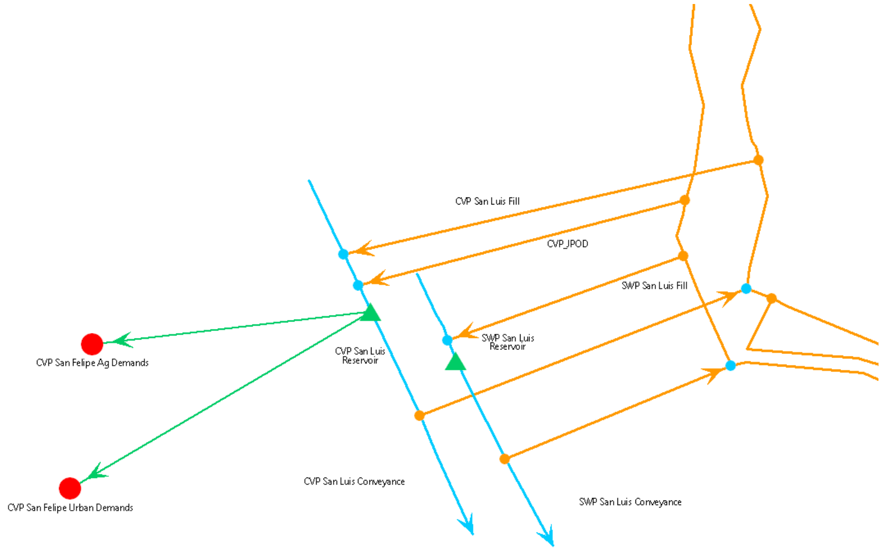


Figure 7-3. This was done to simulate the complex operations of the reservoir more accurately. Each reservoir has two routes for receiving water from their supply canals. Water is first drawn into the reservoir to fill the reservoir to its 'rule curve' subject to water availability in north-of-Delta reservoirs and restrictions on flows in the Delta. If there is excess water available in the Delta, additional water is drawn into the reservoir using priorities that differentiate between volumes above (conservation storage) and below (buffer storage) rule curve. This allows the reservoir to be filled using 'excess' water that is most typically present in wetter months of winter.

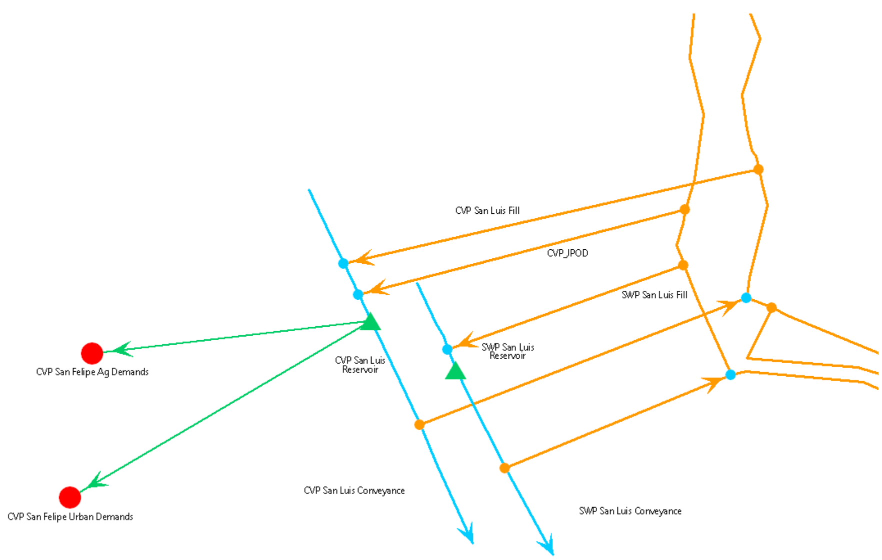


Figure 7-3. Schematic Representation of San Luis Reservoir

San Luis Reservoir is set up within SacWAM to fill during the fall and winter (October through March) and release during the spring and summer (April through September). This is accomplished by using a combination of priorities, target storages, and pumping limits. The priority for storage in San Luis Reservoir is set such that water is pumped into the reservoir only after all other demands (agricultural, urban, and environmental) have been met, including meeting target storage for CVP/SWP reservoirs north of the Delta. The target storage for San Luis Reservoir is set to fill the reservoir from its low point—generally at the end of August—to its maximum capacity (2.04 million acre-feet, or MAF) by the end of March. Target storages defined by the rule curves define the desired volume of water to be released from north-of-Delta reservoirs to be pumped into San Luis.

There are separate parameters for CVP and SWP operations, which are identical to the parameters used in the CalSim II model. These parameters are explained in the following sections.

7.4.7.1 CVP

7.4.7.1.1 Capacity
Static values; 972 TAF for CVP, 1,067 TAF for SWP. The sum represents total capacity of San Luis Reservoir (2.04 MAF).

7.4.7.1.2 Delivery Target
Annual delivery target for South-of-Delta deliveries.

7.4.7.1.3 Drain Target
For CVP this is 90 TAF plus 10% of CVP South-of Delta Annual Delivery Target minus 2000 TAF. For SWP this is 110 TAF.

7.4.7.1.4 Fill Target
Defines the target fill volume based on the *Delivery Target*.

7.4.7.1.5 Inactive Storage
Static values; 45 TAF for CVP, 55 TAF for SWP. Sum represents inactive storage at San Luis Reservoir (100 TAF).

7.4.7.1.6 NOD_Storage
Total storage at the beginning of the month in Shasta, Folsom, and Trinity reservoirs. This variable is a relic of model development and is not referenced by any other parameters in SacWAM v 1.12.

7.4.7.1.7 Observed
This parameter reads historical values of CVP and SWP San Luis storage.

7.4.7.1.8 Rule_Cap_Shasta
CVP only: Maximum rule curve value based on Shasta storage.

7.4.7.1.9 Rule_max
This variable sets the maximum allowable storage in CVP San Luis. It has a static value of 1,100 TAF.

7.4.7.1.10 Rule_Sha_Cut
CVP only: Cut in rule curve based on low Shasta storage conditions.

7.4.7.1.11 RuleCurve
Final calculation of rule curve, not less than *InactiveStorage* or more than *Capacity.*

7.4.7.1.12 RuleCurveCalc
Calculation of rule curve based on reservoir fill and release requirements.

7.4.7.1.13 SanFelipeAdjust
This variable is a relic of model development and is not referenced by any other parameters in SacWAM v 1.12.

7.4.7.1.14 SLCVP_storage
Previous month storage in CVP San Luis.

7.4.7.1.15 RemainingDemand
Total demand remaining through the end of September in TAF.

7.4.7.1.16 Req_Exp_NowToSep
Required exports calculated by taking a difference between the San Luis Storage for CVP and total demand remaining for the rest of the year plus the drain target.

7.4.7.1.17 Required Exports
Monthly required inflow required (in TAF), computed by dividing the (p) Req_Exp_NowToSep by the number of months remaining upto September.

7.4.7.1.18 Change_SL
Estimated change in San Luis CVP storage (in TAF).

7.4.7.1.19 SL_UpperBound
Upper bound on San Luis CVP storage based on a mass balance computation and forecasted demands/exports.

7.4.7.1.20 SL_UpperBound_MaySep
Time series for San Luis upperbound for May to September.

7.4.7.2 Evaporation
The sub-branches in this section are used to estimate the total evaporative losses from San Luis reservoir and to partition those losses between CVP and SWP accounts based on their storage values relative to the total storage in San Luis. For example, if total storage in San Luis is 1,000 TAF in any one month and SWP should have 600 TAF in storage, then 60 percent of the estimated evaporative losses will be taken from SWP storage in San Luis and the remaining 40 percent will be taken from CVP storage in San Luis Reservoir.

SacWAM represents evaporative losses from San Luis Reservoir using the 'Loss to Groundwater' parameter.

7.4.7.2.1 Eref_ft

The current month's reference evaporation for San Luis reservoir. Units are converted from millimeters to feet such that SacWAM can calculate a volumetric equivalent using the Volume-Elevation relationship.

7.4.7.2.2 Evap_CVP

End result of calculations to estimate the evaporative loss from CVP San Luis. It is determined by multiplying *Frac_CVP* by the difference between *Stor_last_taf* and *Sto_new_taf*. It has units of TAF.

7.4.7.2.3 Evap_SWP

End result of calculations to estimate the evaporative loss from SWP San Luis. It is determined by multiplying *Frac_SWP* by the difference between *Stor_last_taf* and *Sto_new_taf*. It has units of TAF.

7.4.7.2.4 Frac_CVP

The fraction of total storage in San Luis Reservoir that belongs to CVP. It is a number between 0 and 1 and is estimated by divding the beginning of month storage in CVP by the beginning of month total storage in San Luis Reservoir.

7.4.7.2.5 Frac_SWP

The fraction of total storage in San Luis Reservoir that belongs to SWP. It is a number between 0 and 1 and is determined by subtracting *Frac_CVP* from 1.

7.4.7.2.6 Stor_last_ft

Storage elevation (in feet) of combined CVP and SWP San Luis storage at the beginning of the month. This is estimated using Stor_last_taf and the San Luis Volume-Elevation relationship.

7.4.7.2.7 Stor_last_taf

Combined CVP and SWP storage (in TAF) at the beginning of the month.

7.4.7.2.8 Stor_new_ft

Storage elevation once evaporative losses (i.e., *Eref_ft*) are removed.

7.4.7.2.9 Stor_new_taf

Combined CVP and SWP storage (in TAF) once evaporative losses are removed. This is estimated using *Stor_new_ft* and the San Luis Reservoir Volume-Elevation relationship.

7.4.7.2.10 CVP_new_taf

CVP storage (in TAF) once evaporative losses are removed.

7.4.7.2.11 CVP_new_ft

CVP storage (in ft) once evaporative losses are removed.

7.4.7.2.12 CVP_Evap_mm
CVP share of evaporative losses in mm.

7.4.7.2.13 SWP_new_taf
SWP storage (in TAF) once evaporation is removed.

7.4.7.2.14 SWP_new_ft
SWP storage (in ft) once evaporation is removed.

7.4.7.2.15 SWP_evap_mm
SWP share of evaporative losses in mm.

7.4.7.3 SWP

7.4.7.3.1 Capacity
SWP share of total San Luis Reservoir capacity (1067 TAF)

7.4.7.3.2 Carryover_est
SWP Only: Estimate of SWP carryover deliveries based on relationship with Oroville storage in CalSim II. WEAP does not simulate carryover deliveries, but this value is used so that SWP San Luis rule curve mimics CalSim II in October-December.

7.4.7.3.3 Delivery Target
SWP delivery target (in TAF) based on final allocation.

7.4.7.3.4 Drain Target
For SWP the drain target is 110 TAF.

7.4.7.3.5 EoJunCVPstor
CVP San Luis storage at the end of June.

7.4.7.3.6 FillTarget
Target reservoir fill (in TAF) based on the computed Delivery target.

7.4.7.3.7 InactiveStorage
SWP share of San Luis Dead Storage (55 TAF)

7.4.7.3.8 NOD_Storage
Previous month storage in Lake Oroville (in TAF)

7.4.7.3.9 Observed
Historical SWP storage in San Luis Reservoir (in TAF)

7.4.7.3.10 OroDrainAmt4SL
SWP only: Volume that can be moved from Oroville to SWP San Luis through the end of September, based on *OroSepTarg* and space available in SWP San Luis.

7.4.7.3.11 OroDrainAmtMon
SWP only: Volume that could be moved from Oroville to SWP San Luis in current month.

7.4.7.3.12 OroSepTarg
SWP only: End of September storage target for Oroville.

7.4.7.3.13 Orovillestorage
SWP only: Previous month storage in Oroville.

7.4.7.3.14 Rule_Cap_Oroville
SWP only: Maximum rule curve value based on Oroville storage.

7.4.7.3.15 RuleCurve
Final calculation of rule curve, not less than *InactiveStorage* or more than *Capacity.*

7.4.7.3.16 RuleCurveCalc
Calculation of rule curve based on reservoir fill and release requirements.

7.4.7.3.17 SLSWP_Storage
Previous month storage in SWP San Luis.

7.4.7.3.18 SWPdemfinal
Variables related to computation of SWP final demands are included in this sub-arc.

Percent_act
SWP final allocation percentage

SWP_demprofile
Lookup variable based on Percent_act.

SWPdem_May
Variable giving lookup value based on SWP_demprofile for total SWP demands in May (in TAF)

For SWP_demprofile = 30, SWPdem_May = 362 TAF

For SWP_demprofile = 50, SWPdem_May = 282.5 TAF

For SWP_demprofile = 100, SWPdem_May = 364.1 TAF

SWPdemfinal_May
Final SWP demand for month of May (SWPdem_May multiplied by percent allocation)

SWPdem_Jun
Variable giving lookup value based on SWP_demprofile for total SWP demands in June (in TAF)

For SWP_demprofile = 30, SWPdem_Jun = 589.5 TAF

For SWP_demprofile = 50, SWPdem_Jun = 504 TAF

For SWP_demprofile = 100, SWPdem_Jun = 446.1 TAF

SWPdemfinal_Jun
Final SWP demand for month of June (SWPdem_Jun multiplied by percent allocation)

SWPdem_Jul
Variable giving lookup value based on SWP_demprofile for total SWP demands in July (in TAF)

For SWP_demprofile = 30, SWPdem_Jul = 743.1 TAF

For SWP_demprofile = 50, SWPdem_Jul = 673.3 TAF

For SWP_demprofile = 100, SWPdem_Jul = 469.6 TAF

SWPdemfinal_Jul
Final SWP demand for month of July (SWPdem_Jul multiplied by percent allocation)

SWPdem_Aug
Variable giving lookup value based on SWP_demprofile for total SWP demands in August (in TAF)

For SWP_demprofile = 30, SWPdem_Aug = 680.9 TAF

For SWP_demprofile = 50, SWPdem_Aug = 706.1 TAF

For SWP_demprofile = 100, SWPdem_Aug = 510.0 TAF

SWPdemfinal_Aug
Final SWP demand for month of August (SWPdem_Aug multiplied by percent allocation)

SWPdem_Sep
Variable giving lookup value based on SWP_demprofile for total SWP demands in September (in TAF)

For SWP_demprofile = 30, SWPdem_Sep = 537.3 TAF

For SWP_demprofile = 50, SWPdem_Sep = 603.8 TAF

For SWP_demprofile = 100, SWPdem_Sep = 402.1 TAF

SWPdemfinal_Sep
Final SWP demand for month of September (SWPdem_Sep multiplied by percent allocation)

7.4.8 SWP Allocations

SacWAM simulates SWP delivery of Table A water and delivery of Article 21 (interruptible) water. However, SacWAM does not simulate the carryover provision of Article 56.[39] Delivery of Table A water is determined by the annual SWP allocation to its long-term contractors.[40] These allocations are based on

[39] Articles 12(e) and 56 of the contract between DWR and its long-term SWP contractors allow the contractors to take delivery of unused annual allocation of Table A water in the first 3 months of the following year. Undelivered water stored in San Luis Reservoir may be lost to the contractor if DWR needs the storage capacity, in which case, this water is gradually converted to SWP water.

[40] Before 2014, the same Table A percent allocation applied to all 29 SWP long-term, contractors. However, starting 2014, DWR calculates a separate Table A allocation for Solano County WA and Napa County FCWCD as provided in the SCWA v. DWR

storage conditions, forecasted inflows, contractor requests, other demands for project water, operational and regulatory restrictions, and other factors. Simulated Table A allocations are based on the approach adopted by DWR for CalSim II (SWP Reliability Report: DWR, 2014e) and has some similarities to the method used to calculate CVP allocations. The allocation logic starts by assessing the available water supply (*WaterSupplyEst*), which for the SWP is the sum of previous month storage in Lake Oroville and San Luis Reservoir, and the forecasted runoff (through September) of the Feather River at Oroville. This is the water supply index. Similar to the CVP allocation logic, a delivery index (*DemandIndex*) is calculated from water supply index, with values shown in Table 7-14 (where a linear interpolation is used between points on this curve).

Table 7-14. SWP Water Supply Index – Demand Index Curve

Water Supply Index (TAF)	Demand Index (TAF)
0	0
500	1,485
2,500	1,485
3,000	1,575
3,500	2,274
4,000	3,002
4,500	4,354
5,000	5,313
5,500	6,098
6,000	7,366
6,500	7,924
7,000	8,174
7,500	8,284
20,000	8,284

Key:
SWP = State Water Project, TAF = thousand acre-feet.

Unlike the procedure for the CVP, this allocation routine does not use a separate curve to separate the delivery and carryover storage components of the demand index. Instead, the routine assumes that the target carryover storage for SWP in Lake Oroville is 1,000 TAF plus half of the volume of water above 1,000 TAF carried over from the previous water year (i.e., one half end-of-September storage above 1,000 TAF). The initial allocation also assumes that the target SWP carryover storage in San Luis Reservoir is 110 TAF. Thus, the following equation was used to calculate and initial percentage allocation (*Allocation_Init*).

$$Allocation\_Init = Max\left\{0, \frac{Demand\ Index - 110\ TAF - 1000\ TAF}{SWP\ Table\ A\ + Maximum[0, \frac{1}{2}\ (Oroville\ Carryover\ Storage - 1000\ TAF)]}\right\}$$

where the numerator is the estimated total SWP delivery and the denominator is the adjusted total demand. Subsequently, SacWAM uses this allocation estimate to update the carryover target for SWP storage in San Luis Reservoir (*SWPRuleDrainTarget*) using the following equation.

Settlement Agreement, dated December 31, 2013. Currently, SacWAM does not simulate the separate North-of-Delta allocation.

$$SWPRuleDrainTarget = Min\begin{Bmatrix} SWP\ San\ Luis\ Storage\ Capacity, \\ 110\ TAF + Maximum[0, SWP\ Table\ A * (Initial\ Percent\ Allocation - 1) - 250\ TAF] \end{Bmatrix}$$

The purpose of the update is to allow greater drawdown of San Luis Reservoir in dry years when SWP allocations are low. This updated SWP San Luis Reservoir carryover target is then used to update the percentage allocation (*Allocation_Adjustment*).

$$Allocation\_Adjustment = Max\left\{0, \frac{Delivery\ Index - SWP\ San\ Luis\ Drainage\ Target - 1000\ TAF}{SWP\ Table\ A\ + Maximum[0, \frac{1}{2}\ (Oroville\ Carryover\ Storage - 1000\ TAF)]}\right\}$$

This equation forms the basis of the SWP Table A contract allocation. The allocation is first made in January, and updated February through May as the estimate of water supply becomes clearer. The allocation is also adjusted during the spring pulse period (April-May) when regulatory constraints limit the ability of the SWP to export water at the Banks Pumping Plant. The allocation of water during these two months assumes the bulk of water will be delivered from San Luis Reservoir after some minimum level of SWP export. Therefore, the April-May allocation is conditioned upon the available SWP water in San Luis Reservoir.

The procedure for setting the annual allocation to SWP Table A contractors is located in the data tree under *Other Assumptions\Ops\SWP Allocations*. The resulting allocation is referenced from each of the transmission links that deliver SWP water to the project's long-term water supply contractors. The monthly water demand for the SWP contractor demand sites is set equal to the product of their full Table A amount and monthly distribution pattern. The 'maximum flow percent of demand' property of the transmission link is set equal to the allocation.

The parameter TableA_xx, where 'xx' indicates the geographic region, is the combined Table A amount for all contractors in the region.

Table 7-15. Monthly Percentage of Annual Demand Under Different Table A Allocation Levels

	Percent Table A Allocation				
	0-30	30-45	45-60	60-70	70-100
October	11%	9%	11%	10%	9%
November	8%	9%	10%	9%	9%
December	10%	13%	9%	9%	9%
January	4%	4%	3%	5%	7%
February	4%	1%	3%	5%	6%
March	1%	2%	1%	5%	7%
April	1%	2%	5%	7%	8%
May	9%	8%	6%	7%	9%
June	13%	11%	10%	9%	8%
July	13%	14%	13%	11%	9%
August	14%	14%	15%	12%	10%
September	12%	13%	14%	11%	9%

Table 7-16. Percentage of Annual Demand Remaining Under Different Table A Allocation Levels

	Percent Table A Allocation				
	0-30	30-45	45-60	60-70	70-100
October	29%	31%	30%	28%	27%
November	18%	22%	19%	18%	18%
December	10%	13%	9%	9%	9%
January	100%	100%	100%	100%	100%
February	96%	96%	97%	95%	93%
March	92%	95%	94%	90%	87%
April	91%	93%	93%	85%	80%
May	90%	91%	88%	78%	72%
June	81%	83%	82%	71%	63%
July	68%	72%	72%	62%	55%
August	55%	58%	59%	51%	46%
September	41%	44%	44%	39%	36%

7.4.8.1 Central Coast and Tulare Lake (CCTL)

7.4.8.1.1 Cumulative Deliveries

The parameter *CumulativeDeliveries* tracks CCTL SWP deliveries of Table A water for the current calender year.

7.4.8.1.2 MakeUpWater

The parameter *MakeUpWater* is equal to the under delivery of SWP water in the prior months of the current calender year allocated over the remaining months of the year. *MakeUpWater* is delivered to CCTL only if the demands weren't met in the prior months.

7.4.8.1.3 MonthlyDemandPattern

The parameter *MonthlyDemandPattern* is the monthly distribution of Table A water for the calender year. It is a function of the SWP allocation.

7.4.8.1.4 RemainingDemandPattern

The parameter *RemainingDemandPattern* is the monthly distribution of Table A water for the remaining months of the calender year. It is a function of the SWP allocation.

7.4.8.1.5 TableA_CentralCoast_Tulare

Refer to Table 7-15 and Table 7-16.

7.4.8.2 ExportCapacity_Adjust

The subbranch *ExportCapacity_Adjust* groups parameters that are used to adjust the SWP allocation based on the ability of the SWP to export water at the Banks Pumping Plant. The SWP allocation procedure crecognizes that the capacity to pump water from the Delta varies throughout the year and may be adjusted based on hydrologic conditions within the San Joaquin Valley. Brief descriptions of sub-branches *Export Capacity_Adjust* are presented in Table 7-17.

Table 7-17. Parameters Used to Adjust SWP Allocation Based on Delta Export Index

Parameter	Description
EstSWPExp	Estimated capacity to export water from the Delta: Jan-3,750, Feb & Mar-4,250, Apr & May-1,000 cfs, Jun-2,500, Jul & Aug-7,000 cfs. Monthly values adjusted when San Joaquin River Index is wet or flows at Vernalis exceed 16,000 cfs
Fact_SWP	Fraction of remaining annual exports that occur in critical San Luis Reservoir drawdown season (i.e., April-August).
Buff_SWP	Buffer that reflects uncertainty in estimate of seasonal export capability. Set to 110 TAF from January through May.
SWPDelCapEst	Estimated delivery capacity to SWP export zone. Equal to estSWPExp plus SWP storage in San Luis minus buff_SWP
Deltar_Expmax	The annual volume available for delivery to SWP long-term contractors based on Delta conditions and export capability. This volume is determined in January and updated February through May. It is calculated as the seasonal availability of water (EstSWPExp) divided by a seasonal to annual conversion factor (fact_SWP).

Key:
cfs = cubic feet per second, SWP=State Water Project, TAF=thousand acre-feet.

7.4.8.2.1 Buff_SWP

Buffer that reflects uncertainty in estimate of seasonal export capability. Set to 110 TAF from January through May.

7.4.8.2.2 deltar_expmax

The annual volume available for delivery to SWP long-term contractors based on Delta conditions and export capability. This volume is determined in January and updated February through May. It is calculated as the seasonal availability of water (*EstSWPExp*) divided by a seasonal to annual conversion factor (*fact_SWP*).

7.4.8.2.3 estSWPExp

Estimated capacity to export water from the Delta: Jan-3,750, Feb & Mar-4,250, Apr & May-1,000 cfs, Jun-2,500, Jul & Aug-7,000 cfs. Monthly values adjusted when San Joaquin River Index is wet or flows at Vernalis exceed 16,000 cfs.

7.4.8.2.4 fact_SWP

Fraction of remaining annual exports that occur in critical San Luis Reservoir drawdown season (i.e., April-August).

7.4.8.2.5 SWPDelCapEst

Estimated delivery capacity to SWP export zone. Equal to *estSWPExp* plus SWP storage in San Luis minus *buff_SWP*

7.4.8.3 Final_Allocation

Parameters grouped under the Final_Allocation subbranch contain the final allocations associated with SWP operations. Brief descriptions of these parameters are given below.

Table 7-18. Parameters Associated with State Water Project Allocations

Parameter	Description
Allocation_2	Annual allocation expressed as a total volume – including canal conveyance losses. Minimum of Allocation_1 and total Table A amount.
Allocation_Final	Final allocation expressed as a total volume – including canal conveyance losses. Allocation for first 3 months of simulation set to 50% of total Table A amount. February through May allocations not allowed to decrease. Allocations after May set equal to May allocation. Fixes the allocation for the months outside the allocation period (July-January)
FSC_percent_delivery	Final allocation for SWP Feather River Settlement contractors, expressed as a fraction. Reduced to 50% only in critically dry years based on current and previous year Feather River runoff at Oroville.
SWP_percent_delivery	Final allocation as a percentage of Table A demands, expressed as a fraction. Calculated as Allocation_Final less the canal vonevyance loss, all divided by the total Table A amount.
TableA_Alloc	Time series (1922-2003) of CalSim II SWP Table A allocations (used for model comparison/calibration only).

Key:
SWP=State Water Project.

7.4.8.3.1 Allocation_2

Annual allocation expressed as a total volume – including canal conveyance losses. Minimum of Allocation_1 and total Table A amount.

7.4.8.3.2 Allocation_Final

Final allocation expressed as a total volume – including canal conveyance losses. Allocation for first 3 months of simulation set to 50% of total Table A amount. February through May allocations not allowed to decrease. Allocations after May set equal to May allocation. Fixes the allocation for the months outside the allocation period (July-January)

7.4.8.3.3 FSC_percent_delivery

Final allocation for SWP Feather River Settlement contractors, expressed as a fraction. Reduced to 50% only in critically dry years based on current and previous year Feather River runoff at Oroville.

7.4.8.3.4 SWP_percent_delivery

Final allocation as a percentage of Table A demands, expressed as a fraction. Calculated as Allocation_Final less the canal vonevyance loss, all divided by the total Table A amount.

7.4.8.3.5 TableA_Alloc

Time series (1922-2003) of CalSim II SWP Table A allocations (used for model comparison/calibration only).

7.4.8.3.6 FSC_1977

Variable to set allocation to 0.5 for Water Year 1977. This is used as a special case for water year 1977.

7.4.8.4 Initial_Allocation

The subbranch *InitialAllocation* groups parameters that are used to provide an initial estimate of the allocation to SWP Table A contractors for the current calender year. This allocation is expressed as a volume in TAF by the parameter *WSIDI_SWPdel.*

7.4.8.4.1 Allocation_adjustment

Updated SWP allocation based on revised target carryover storage for SWP share of San Luis Reservoir.

7.4.8.4.2 Allocation_init

Ratio of water available for delivery and storage to SWP Table A amount and target carryover storage.

7.4.8.4.3 DemandIndex

Determined from a lookup table as a function of the water supply index (*WaterSupplyEst*). It is an estimate of the water available for delivery and carryover storage.

7.4.8.4.4 DI_Buffer

Demand buffer. Currently, set to zero TAF.

7.4.8.4.5 DrainTarget_Buffer

Buffer amount to add to SWP target carryover storage. Set to 250 TAF.

7.4.8.4.6 init_SWPRuleDrainTar

Initial end-of-September target carrover storage for SWP share of San Luis Reservoir. Used for initial SWP allocation (Allocation_Init).

7.4.8.4.7 SWPRuleDrainTarget

See equation above for SWP San Luis Drainage Target

7.4.8.4.8 WaterSupplyEst

Water Supply Index. From April through May calculated as the sum of SWP storage plus forecasted Feather River runoff at Oroville.

7.4.8.4.9 WSIDI_SWPdel

Initial estimate of volume of water available to SWP contractors. Determined as the product of the total Table A amount (4,163.9 TAF) and the allocation adjustment plus the conveyance loss (64.5 TAF).

7.4.8.5 ORO

The parameter *ORO*/*BoM* is the beginning-of-month storage in Lake Oroville. The parameter *ORO/PrevSept* is the previous carryover storage in Lake Oroville. These two parameters are used in the procedure for setting initial SWP Table A allocations.

7.4.8.5.1 BoM

Variable for Beginning-of-month storage in Lake Oroville.

7.4.8.5.2 PrevSept

Previous September carryover storage in Lake Oroville.

7.4.8.6 South Bay Aqueduct (SBA)

Variables for South Bay Aqueduct deliveries

7.4.8.6.1 CumulativeDeliveries

Variable to track Cumulative Deliveries from the South Bay Aqueduct. The variable is reset to zero in January.

7.4.8.6.2 MakeUpWater

Make up water is calculated as a difference between the allocated Table A water for South Bay Aqueduct and the actual delivery till the current timestep.

7.4.8.6.3 MonthlyDemandPattern

Variable to set a monthly demand pattern for deliveries based on SWP Table A allocations.

7.4.8.6.4 RemainingDemandPattern

Variable to set a monthly remaining demand pattern for deliveries based on SWP Table A allocations.

7.4.8.6.5 TableA_SBA

Total South Bay Aqueduct Table A water. Set at 222.62 TAF (80.619TAF+42TAF+100TAF).

Refer to Table 7-15 and Table 7-16.

7.4.8.7 San Joaquin (SJ)

Variables for tracking San Joaquin River deliveries

7.4.8.7.1 CumulativeDeliveries

Variable to track Cumulative Deliveries from the San Joaquin River. The variable is reset to zero in January.

7.4.8.7.2 MakeUpWater

Make up water is calculated as a difference between the allocated Table A water for San Joaquin and the actual delivery till the current timestep.

7.4.8.7.3 MonthlyDemandPattern

Variable to set a monthly demand pattern for deliveries based on SWP Table A allocations.

7.4.8.7.4 RemainingDemandPattern

Variable to set a monthly remaining demand pattern for deliveries based on SWP Table A allocations.

7.4.8.7.5 TableA_SanJoaquin

Total San Joaquin Table A water set at 5.7 TAF.

7.4.8.8 SL_Adjust

The SWP allocation procedure considers that in some years there may be sufficient storage in San Luis Reservoir to justify an increase in the SWP allocation. This adjustment is made in the last two months of the allocation period (April and May).

7.4.8.8.1 Allocation_1

Allocation_1 is the adjusted SWP allocation based on comparison of AprMay_Dry with WSIDI_SWPExp and deltar_expmax.

7.4.8.8.2 MarMay_Dry

MarMay_Dry is the assessment of delivery capacity based on March-May storage in SWP San Luis Reservoir

7.4.8.9 SL_SWP

The parameter *ORO/BoM* is the beginning-of-month storage in SWP San Luis Reservoir. It is used in the procedure for setting initial SWP Table A allocations and for adjusting allocations based on an assessment of the Delta export capacity.

7.4.8.9.1 BoM

Beginning of month storage for San Luis. Set equal to previous month San Luis storage.

7.4.8.10 SOD_CumulativeDeliveries

Variable to track cumulative deliveries South of Delta. Computed as a sum of cumulative deliveries for South Bay Aqueduct, South Coast, San Joaquin River and Central Coast Tulare.

7.4.8.11 SOD_TableAShortage

Variable to track South of Delta Table A shortages. Computed as difference between total water allocated SWP Table A water and the table A water delivered including the make up water.

7.4.8.12 SouthCoast

Variables for tracking South Coast deliveries.

7.4.8.12.1 CumulativeDeliveries

Variable to track Cumulative Deliveries from the South Coast. The variable is reset to zero in January.

7.4.8.12.2 MakeUpWater

Make up water is calculated as a difference between the allocated Table A water for South Coast and the actual delivery till the current timestep.

7.4.8.12.3 MonthlyDemandPattern

Variable to set a monthly demand pattern for deliveries based on SWP Table A allocations.

7.4.8.12.4 RemainingDemandPattern

Variable to set a monthly remaining demand pattern for deliveries based on SWP Table A allocations.

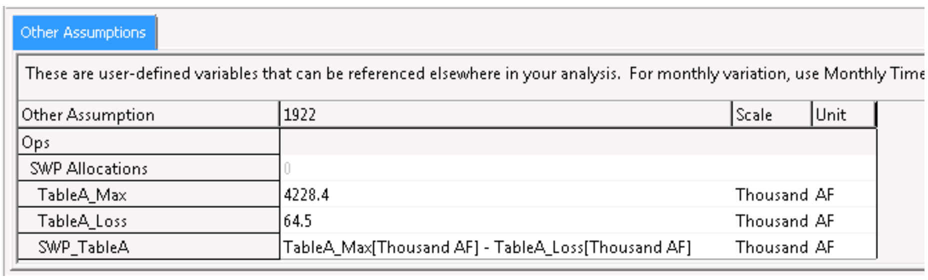
7.4.8.12.5 TableA_SouthCoast

Total South Coast Table A water set at 2623.10 TAF (141.4 TAF+95.2 TAF +138.35 TAF +5.8 TAF +55.75 TAF +2.3 TAF +1911.5 TAF +82.8 TAF +21.3 TAF +102.6 TAF +28.8 TAF +17.3 TAF +20 TAF)

Refer to Table 7-15 and Table 7-16.

7.4.8.13 *SWP_TableA*

SWP allocations are expressed as a percentage of Table A amounts. SacWAM assumes that the total Table A contract demand including canal conveyance losses is 4,228.6 TAF (*TableA_Max*) and that the annual delivery loss is 64.5 TAF (*TableA_Loss*). Thus, the maximum amount of Table A water for delivery (*SWP_TableA*) is 4,170.10 TAF.



Other Assumption	1922	Scale	Unit
Ops			
SWP Allocations	0		
TableA_Max	4228.4		Thousand AF
TableA_Loss	64.5		Thousand AF
SWP_TableA	TableA_Max[Thousand AF] - TableA_Loss[Thousand AF]		Thousand AF

7.4.8.14 *TableA_Loss*

The annual delivery loss is 64.5 TAF (*TableA_Loss*)

7.4.8.15 *TableA_Max*

SacWAM assumes that the total Table A contract demand including canal conveyance losses is 4,228.6 TAF (*TableA_Max*)

7.4.8.16 *FRSA*

Group of variables representing logic for Feather River Service Area (FRSA) allocations

7.4.8.16.1 WinterFloodUpDemand

Variable to compute winter flood up demand for Rice producing regions within FRSA. Computed as a sum of flood up demands for demand units 11_SA1, 11_SA2, 11_SA3, 11_SA4, 12_13_SA, 14_15N_SA, 15S_SA, 16_PA, 16_SA, 17_SA and 22_SA2.

7.4.8.16.2 ForecastedInflow

Forecasted Oroville Inflow read as input time series from a previous run of the model.

7.4.8.16.3 ReleaseforIFR

Variable to track the water released for Instream Flow requirements (IFR) on Feather River downstream of Oroville.

7.4.8.16.4 Allocation

Variable for allocation of SWP water to FRSA. Set at 100% for October through February. In March, if the Previous Month Storage + Forecasted Inflow – Water Release for IFR is greater than 900, then the allocation is based on a monthly pattern through September for the amount above 900 TAF. Otherwise, the allocation is set to zero.

7.4.8.16.5 PrevMonStorage

Variable for previous month storage in Lake Oroville.

7.4.9 Trinity Import

Trinity River water is imported into the Sacramento River basin through the Clear Creek tunnel and subsequently routed to the upper Sacramento River through the Spring Creek tunnel. This transfer is controlled in SacWAM using a constraint on the maximum diversion through the Clear Creek Tunnel and four instream flow requirements on Clear Creek Tunnel (*OPS Trinity Imort for Res Balancing*, *OPS Trinity Import Spills for Power*, *OPS Trinity Import for Clear Creek IFR*, and *Baseline Trinity Import*). Diversions through Clear Creek Tunnel are made after minimum IFRs below Lewiston Dam are satisfied.

SacWAM offers three methods for setting Trinity River imports: the first reads in a time series of flows based on a previous SacWAM model run, the second reads in a time series of historical flows into the Clear Creek Tunnel, and the third uses transfer logic that assesses current storage levels in Trinity and Shasta. Two switches have been set up to choose between these options. The first is located in *Key\Use Baseline Trinity Imports* (see Section 9.16) and the second is located in *Other\Calibration Switches\Simulate Trinity Imports* (see Section 7.2.10).

In the event that the user selects the first option (i.e., time series of flows based on previous SacWAM model run), then the Maximum Diversion constraint on Clear Creek Tunnel is fixed to the time series of flows that are read in from a .csv file. The Clear Creek flow requirement *Baseline Trinity Import* is also set equal to the same time series of flows. The other three flow requirements on Clear Creek tunnel may remain active and may at times exceed *Baseline Trinity Import*. However, actual transfers cannot exceed *Baseline Trinity Import* because the physical capacity is constrained by the Maximum Diversion.

When the user selects the second option for Trinity River imports (i.e., historical time series of flows), then transfers are constrained in a similar manner to the first option by constraining the Maximum Diversion constraint on Clear Creek Tunnel and the flow requirement *OPS Trinity Import for Res Balancing* to a historical time series of flows.

When the user selects the third option, then SacWAM estimates transfers using logic that is set up using the same approach used by CalSim II (SWP Reliability Report: DWR, 2014e) and is done in such a way as to balance reservoir storages in Trinity and Shasta. That is, imports are reduced when storage in Trinity is low or storage in Shasta is high. Storage levels in the two reservoirs at each time step are read as their respective storage volumes from the previous time step. There are three components to the import logic. The first is based on relative storage in the two reservoirs, as defined by reservoir zones, which are based on reservoir levels. The second triggers additional imports when the proportion of storage in each zone is different. The third triggers imports for power generation when Trinity is spilling. The first component exactly replicates the logic in CalSim II. The second and third components replicate the operation in CalSim II, but with different implementation methods appropriate to WEAP. Total imports are the sum of these three components. Component 1 is defined in the requirement *OPS Trinity Import,* and the requirement *OPS Import Spills for Powe*r pulls in additional water for components 2 and 3.

Imports here are based on a comparison of the relative storages in Shasta and Trinity, defined by whether storage is above or below a series of pre-defined levels. Details of this process of storage balancing are described below.

7.4.9.1 FloodConditionFlag

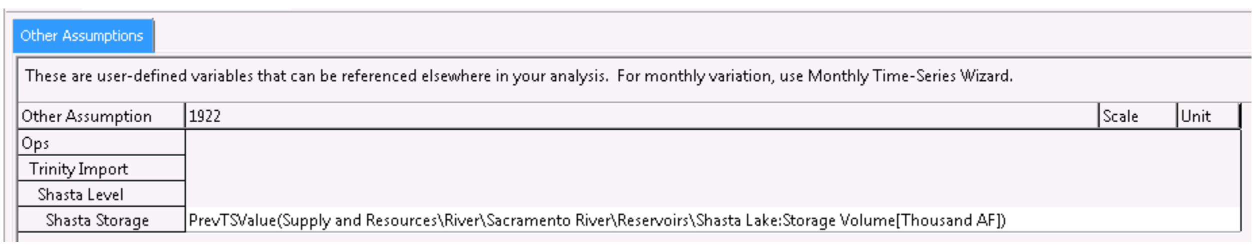
SacWAM implements a trigger to assure that no imports from the Trinity River are made during high flow months in which weirs along the Sacramento River are opened. This is achieved by including a flag that sets the Maximum Diversion constraint on Clear Creek Tunnel to zero. The flag is read in from a pre-processed csv file that was generated from a baseline SacWAM model run. This file needs to be updated when making changes to the model that potentially affect the timing of weir flows (e.g., alternative climate/hydrology, increasing storage capacity in Sacramento River basin, etc.).

7.4.9.2 Shasta at Flood Pool

In situations when Shasta is at the flood curve in the previous month, the import amount from Table 7-20 is reduced by 50% to conserve storage in Trinity as expressed in *Shasta at Flood Pool*.

7.4.9.3 Shasta Level

Similar to Trinity Lake, the *Shasta Storage* parameter reads the storage volume of Shasta Lake at the end of the previous time step.



The level of Shasta Lake is the other determining factor (along with Trinity Lake storage) in importing water from Trinity Lake to the Sacramento Basin. Shasta levels used in determining imports are summarized in Table 7-19.

Table 7-19. Shasta Lake Storage Levels for Determining Trinity River Imports

<table>
<tr><th rowspan="2">Shasta Level</th><th colspan="12">Storage Volume (thousand acre-feet)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td>Level 0</td><td colspan="12">0</td></tr>
<tr><td>Level 1</td><td colspan="6">1,600</td><td>2,200</td><td colspan="2">2,400</td><td>2,200</td><td>2,100</td><td>1,900</td></tr>
<tr><td>Level 2</td><td colspan="6">2,000</td><td>2,800</td><td>3,000</td><td>2,900</td><td>2,800</td><td>2,500</td><td>2,300</td></tr>
<tr><td>Level 3</td><td colspan="5">2,400</td><td>2,500</td><td>3,200</td><td>3,500</td><td>3,300</td><td>3,200</td><td>3,000</td><td>2,800</td></tr>
<tr><td>Level 4</td><td colspan="5">3,000</td><td>3,200</td><td>3,800</td><td>4,200</td><td colspan="2">3,800</td><td>3,600</td><td>3,400</td></tr>
<tr><td>Level 5</td><td>3,749</td><td colspan="2">3,149</td><td>3,399</td><td>3,799</td><td>4,299</td><td>4,529</td><td>4,550</td><td colspan="2">4,399</td><td>4,199</td><td>3,899</td></tr>
<tr><td>Level 6</td><td colspan="12">4,600</td></tr>
</table>

7.4.9.4 Transfer LevelX

Whether water is transferred from Trinity Lake to the Sacramento basin in each month is determined by Trinity and Shasta storage levels as presented above. The Transfer Level parameters correspond to Trinity Storage levels. For each Transfer Level, there is an *if* statement that determines the outcome for the different combinations of reservoir levels.

The SJWAM data tree contains variables for: Transfer Level1, Transfer Level2, Transfer Level3, Transfer Level4, and Transfer Level5.

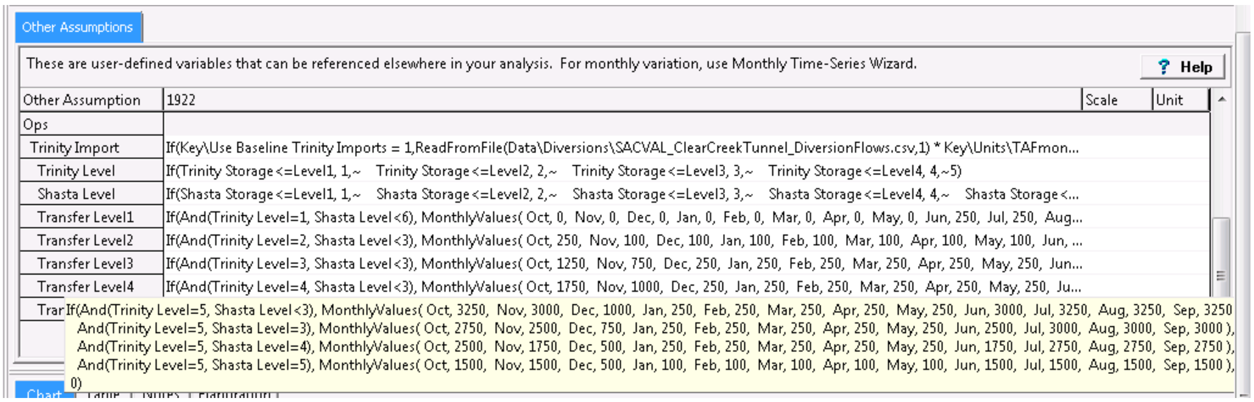


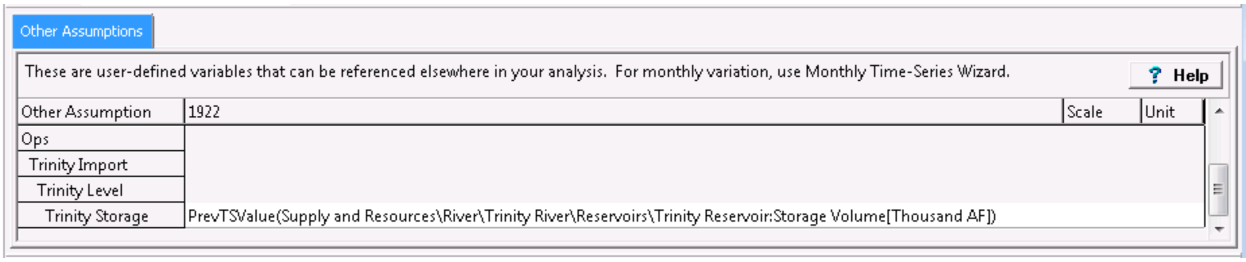
Table 7-20 shows the combinations of Trinity and Shasta storage levels (detailed in Table 7-21 and Table 7-19, respectively) that lead to various transfer amounts.

Table 7-20. Trinity River Imports

<table>
<tr><th rowspan="2">Trinity Storage Level</th><th rowspan="2">Shasta Storage Level</th><th colspan="12">Clear Creek Tunnel Flow (cubic feet per second)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td rowspan="2">Level 1</td><td>< Level 6</td><td colspan="8">0</td><td colspan="4">250</td></tr>
<tr><td>Level 6</td><td colspan="12">0</td></tr>
<tr><td rowspan="5">Level 2</td><td>< Level 3</td><td>250</td><td colspan="7">100</td><td>250</td><td colspan="2">1,500</td><td>1,000</td></tr>
<tr><td>Level 3</td><td>250</td><td colspan="7">100</td><td>250</td><td colspan="2">1,250</td><td>1,000</td></tr>
<tr><td>Level 4</td><td>250</td><td colspan="7">100</td><td>250</td><td colspan="2">1,000</td><td>750</td></tr>
<tr><td>Level 5</td><td>250</td><td colspan="7">0</td><td>250</td><td colspan="2">750</td><td>500</td></tr>
<tr><td>Level 6</td><td colspan="12">0</td></tr>
<tr><td rowspan="5">Level 3</td><td>< Level 3</td><td>1,250</td><td>750</td><td colspan="6">250</td><td>1,250</td><td colspan="2">2,500</td><td>1,750</td></tr>
<tr><td>Level 3</td><td>1,000</td><td>500</td><td colspan="6">250</td><td>1,000</td><td colspan="2">2,250</td><td>1,500</td></tr>
<tr><td>Level 4</td><td>750</td><td>500</td><td colspan="6">250</td><td>750</td><td colspan="2">1,750</td><td>1,500</td></tr>
<tr><td>Level 5</td><td>750</td><td>250</td><td colspan="6">100</td><td>750</td><td colspan="2">1,500</td><td>1,000</td></tr>
<tr><td>Level 6</td><td colspan="12">0</td></tr>
<tr><td rowspan="5">Level 4</td><td>< Level 3</td><td>1,750</td><td>1,000</td><td colspan="6">250</td><td>1,750</td><td colspan="3">3,250</td></tr>
<tr><td>Level 3</td><td>1,500</td><td>750</td><td colspan="6">250</td><td>1,500</td><td colspan="3">2,500</td></tr>
<tr><td>Level 4</td><td>1,250</td><td>500</td><td colspan="6">250</td><td>1,250</td><td colspan="3">2,000</td></tr>
<tr><td>Level 5</td><td>750</td><td>500</td><td colspan="6">100</td><td>750</td><td colspan="3">1,500</td></tr>
<tr><td>Level 6</td><td colspan="12">0</td></tr>
<tr><td rowspan="5">Level 5</td><td>< Level 3</td><td>3,250</td><td>3,000</td><td>1,000</td><td colspan="5">250</td><td>3,000</td><td colspan="3">3,250</td></tr>
<tr><td>Level 3</td><td>2,750</td><td>2,500</td><td>750</td><td colspan="5">250</td><td>2,500</td><td colspan="3">3,000</td></tr>
<tr><td>Level 4</td><td>2,500</td><td>1,750</td><td>500</td><td colspan="5">250</td><td>1,750</td><td colspan="3">2,750</td></tr>
<tr><td>Level 5</td><td>1,500</td><td>1,500</td><td>500</td><td colspan="5">100</td><td colspan="4">1,500</td></tr>
<tr><td>Level 6</td><td colspan="12">0</td></tr>
</table>

7.4.9.5 Trinity Level

The *Trinity Storage* parameter reads the volume storage of Trinity Lake at the end of the previous month. The SacWAM data tree contains variables for: *Level0*, *Level1*, *Level2*, *Level3*, *Level 4*, and *Level5*.



The Trinity storage conditions used to determine transfer amounts are summarized in Table 7-21.

Table 7-21. Trinity Lake Storage Levels for Determining Trinity River Imports

<table>
<tr><th rowspan="2">Storage Level</th><th colspan="12">Storage Volume (thousand acre-feet)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td>Level 0</td><td colspan="12">0</td></tr>
<tr><td>Level 1</td><td colspan="4">700</td><td colspan="2">750</td><td colspan="2">800</td><td>750</td><td colspan="3">700</td></tr>
<tr><td>Level 2</td><td colspan="4">1,200</td><td colspan="2">1,250</td><td colspan="2">1,300</td><td>1,250</td><td colspan="3">1,200</td></tr>
<tr><td>Level 3</td><td colspan="3">1,550</td><td>1,600</td><td>1,650</td><td>1,700</td><td colspan="2">1,800</td><td>1,650</td><td colspan="3">1,550</td></tr>
<tr><td>Level 4</td><td colspan="2">1,975</td><td colspan="2">2,000</td><td>2,050</td><td>2,100</td><td colspan="2">2,200</td><td>2,050</td><td colspan="3">1,975</td></tr>
<tr><td>Level 5</td><td colspan="12">2,500</td></tr>
</table>

7.4.10 TrinityShata_balancing

SacWAM implements balancing of reservoir storage between Shast and Trinity lakes based on how proportionally full the different reservoir zones are. Trinity Lake is divided into 5 zones. Shasta Lake is divided into 6 ones. Trinity River imports are determined by the relative storages in zones 2, 3, and 4 in the two reservoirs, and if Trinity has a larger proportion of storage in the appropriate zone, more imports will be made. This logic is in the branch *TrinityShasta_balancing.*

7.4.10.1 Extraimports

ExtraImports is calculated as the product of 10,000 cfs and *Zoneallratio*.

7.4.10.2 Shastalevel2

Shastalevel2 is the top of storage Zone 2 in Shasta Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.3 Shastalevel3

Shastalevel3 is the top of storage Zone 3 in Shasta Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.4 Shastalevel4

Shastalevel4 is the top of storage Zone 4 in Shasta Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.5 Shastalevel5

Shastalevel5 is the top of storage Zone 5 in Shasta Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.6 Trinitylevel2
Trinitylevel2 is the top of storage Zone 2 in Trinity Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.7 Trinitylevel3
Trinitylevel3 is the top of storage Zone 3 in Trinity Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.8 Trinitylevel4
Trinitylevel4 is the top of storage Zone 4 in Trinity Lake and is read from the file *Data\Reservoir\CalSim_TrinityShasta_rulecurves.csv.*

7.4.10.9 Zone2ratio
Zone2ratio is the Trinity to Shasta storage ratio for Zone2 determined at the end of the previous timestep.

7.4.10.10 Zone3ratio
Zone3ratio is the Trinity to Shasta storage ratio for Zone2 determined at the end of the previous timestep.

7.4.10.11 Zone4ratio
Zone4ratio is the Trinity to Shasta storage ratio for Zone2 determined at the end of the previous timestep.

7.4.10.12 Zoneallratio
Zoneallratio is the sum of *Zone2ratio*, *Zone3ratio*, and *Zone4ratio*. Values are sometimes negative.

7.4.11 Frenchman

Parameters related operation of Frenchman reservoir are defined as follows.

7.4.11.1 LLCID Allocation
Variable for Little Last Chance Irrigation District Allocation. Depending on forecasted Carryover Storage without any delivery, the allocation is made as follows:

If Carryover Storage > 38.5 + 15, LLCID Allocation = 15 TAF

If Carryover Storage > 27.5 + 12, LLCID Allocation = 12 TAF

If Carryover Storage > 21.5 + 7, LLCID Allocation = 7 TAF

7.4.11.2 ForecastInflowAprtoSep
Total forecasted inflow to Frenchman Lake from April to September

7.4.11.3 EvaporationAprtoSep
Total forecasted evaporation from Frenchman Lake from April to September

7.4.11.4 MinFlowAprtoSep
Total minimum flow required downstream of Frenchman Lake from April to September

7.4.11.5 CarryoverStorageNoDelivery
Variable giving the forecasted end of September carryover storage with no deliveries from Frenchman Lake.

7.4.12 Davis

The Davis branch contains parameters related to the operation of Lake Davis.

7.4.12.1 Apr1Storage
Apr1Storage is the storage in Lake Davis on April 1. For modeling purposes, it is the March end-of-month storage.

7.4.13 Coordinated Operation Agreement (COA)

The COA (Reclamation and DWR, 1986, 2018) established a framework under which the projects operate to ensure that both the CVP and SWP receive an equitable share of the Central Valley's available water, while meeting their joint responsibilities for meeting water quality standards and providing water for other (senior) legal uses of water within the Sacramento Valley (in-basin uses [IBU]). The COA formulae are implemented using a mix of user-defined decision variables and constraints.

7.4.13.1 CVP UWFE
CVP UWFE is the CVP share of unstored water for export. It has a value of 0.55 or 55% of the total.

7.4.13.2 CVP IBU
CVP IBU is the CVP share of responsibility for meeting in-basin use. Its value varies between 60% to 80% of the total depending on the water year type (Sacramento Valley Index water year classification. In Wet and Above Normal years, it has a value of 0.80, in Below Normal years a value of 0.75, in Dry years a value of 0.65, and in Critical years a value of 0.60.

7.4.13.3 SWP UWFE
SWP UWFE is the SWP share of unstored water for export. It has a value of 0.45 or 45% of the total, calculated as 1 – *CVP UWFE.*

7.4.13.4 SWP IBU
SWP IBU is the SWP share of responsibility for meeting in-basin use. Its value varies depending on the water year type between 20% to 40% of the total, calculated as 1 – *CVP IBU.*

7.4.13.5 SacValley 403030
SacValley403030 is the water year type based on Sacramento Valley (40-30-30) Index.

7.4.13.6 CVP ExpCapShare
CVP ExpCapShare is the CVP share of regulatory export capacity. It has a value of 0.6 or 60% of the total allowable export under a given regulatory export constraint.

7.4.13.7 SWP ExpCapShare
SWP ExpCapShare is the SWP share of regulatory export capacity. It has a value of 0.4, calculated as 1 – *CVP ExpCapShare*.

7.4.13.8 Output
Output variables for COA implementation

7.4.13.8.1 UnusedFS
UnusedFS is an output variable set to the value of the user-defined LP variable for SWP export of unused CVP water as defined by COA.

7.4.13.8.2 UnusedSS
UnusedSS is an output variable set to the value of the user-defined LP variable for CVP export of unused SWP water as defined by COA.

7.5 Ops\Delta Channels

This section describes the simulation of (a) flow through the Delta Cross-Channel gates, (b) flow from the San Joaquin River into the Head of the Old River.

7.5.1 Delta Cross Channel (DXC)

The Delta Cross Channel diverts flows from the main channel of the Sacramento River into the Mokelumne River at Walnut Grove. The man-made channel and its head gates are part of the CVP's Delta Division and were constructed to maintain water quality of storage withdrawals from CVP reservoirs north of the Delta to the headworks of the Delta-Mendota Canal and Contra Costa Canal.

The Delta Cross Channel gates are operated in accordance with D-1641 (SWRCB, 2000) and the 2009 NMFS BO Action 4.1 to reduce direct and indirect mortality of emigrating juvenile salmonids and green sturgeon in November, December, and January.

For modeling purposes, it is assumed that during October 1 – December 14 the Delta Cross Channel gates may remain open if water quality is a concern. Using the ANN, the current month's chloride level at Rock Slough is estimated assuming DCC closure per NMFS BO. The estimated chloride level is compared against the Rock Slough chloride standard. If the estimated chloride level exceeds the standard, the gate closure is modeled in accordance with D-1641 schedule for the entire month. For modeling purposes, it is assumed that during December 15 through January 31 that the Delta Cross Channel gates are closed under all water quality conditions.

7.5.1.1 DXC_DaysOpen
DXC_DaysOpen is the number of days the Delta Cross Channel gates are open during a month. It is a function of *NMFSBO* and *FlushingFlowProbability*.

For modeling purposes, the Delta Cross Channel is also closed when the mean monthly flow for the Sacramento River at Hood/Walnut Grove exceeds a flow of 25,000 cfs. This condition is indicated by the user-defined integer variable *Int_above* defined under the Delta Cross Channel branch. From October to December, the number of days the DXC is open, *DXC_DaysOpen*, is calculated as:

DXC_NMFSBO(1- UDC\Delta Cross Channel\Int_above)*(1-FlushingFlowProbability)*

From January to September, the number of days the Delta Cross Channel is open, *DXC_DaysOpen*, is calculated as:

DXC_NMFSBO(1- UDC\Delta Cross Channel\Int_above)*

Since *FlushingFlowProbability* and *Int_above* depend on a decision variable (Sacramento River flow), *DXC_DaysOpen* is calculated at the end of the time step, after the water allocation problem has been solved by the XA solver. Therefore, the current time step value of *DXC_DaysOpen* cannot be used as a decision variable in the water allocation problem. Rather for determining Delta salinity, an initial estimate of the number of days that the DXC is opened is calculated as simply:

DXC_NMFSBO(1-UDC\Delta Cross Channel\Int_above)*

For an explanation of DXC operations, UDCs, and their associated parameters, see Section 8.7.

7.5.1.2 DXC_Flow

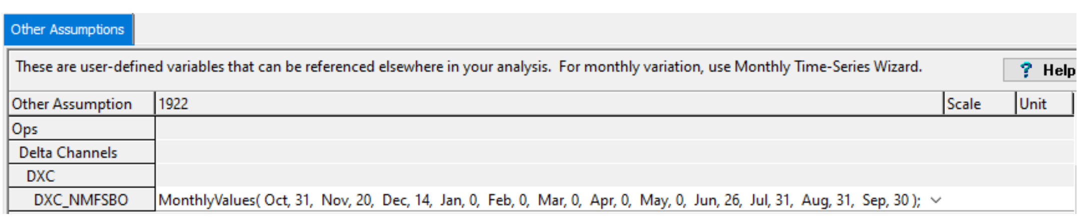
DXC_Flow is the flow through the Delta Cross Channel computed as a linear function of the upstream flow in the Sacramento River. Because the latter is a decsion variable, *DXC_Flow* is computed after the water allocation problem has been solved. It is no longer used in SacWAM.

7.5.1.3 DXC_NMFSBO

DXC_NMFSBO is the number of days the Delta Cross Channel gates are required to be open during a month according to the 2009 NMFS BO. For modeling purposes, BO requirements are layered on to D-1641 requirements. SacWAM assumes the following:

- From October 1-December 14, the Delta Cross Channel is closed based on an estimate of the number of days the Sacramento River flow at Wilkins Slough exceeds 7,500 cfs, a flow assumed to be sufficient to flush emigrating salmon into the Delta.
- From December 15-January 31, the Delta Cross Channel is closed under all flow conditions.

Combining the above assumptions with D-1641 results in an initial, flow-independent, set of days that the Delta Cross Channel is open, as represented by the parameter *DXC_NMFSBO*. Compared to D-1614, values for December are changed from 16 to 14 and for January are changed from 11 to zero.



7.5.1.4 DXC_Standardfraction

DXC_Standardfraction is *DXC_NMFSBO* expressed as a fraction of the number of days in the month.

7.5.1.5 FlushingFlowProbablity

The number of days that the Delta Cross Channel is open is subsequently modified in October, November, and December using an estimate of daily Sacramento River flows exceeding the 7,500 cfs ‘flushing flow’ threshold. The historical data for the Sacramento River below Wilkins Slough (USGS 11390500) is used to establish a linear relationship between the average monthly flow at Wilkins Slough and the number of days in month where the flow exceeds 7,500 cfs. SacWAM uses this relationship to estimate the number of days of DXC closure for the October 1 – December 14 time period.

The FlushingFlowProbability is calculated as:

(0.0064*Sacramento River Flow at Wilkins Slough – 36.175)/(days in the month)

7.5.1.6 D1641_days_open

D1641_days_open is the D-1641 requirement for maintaining the Delta Cross Channel open.

Other Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time-Series Wizard.

Other Assumption	1922	Scale	Unit
Ops			
Delta Channels			
DXC			
D1641_days_open	MonthlyValues(Oct, 31, Nov, 20, Dec, 16, Jan, 11, Feb, 0, Mar, 0, Apr, 0, May, 0, Jun, 26, Jul, 31, Aug, 31, Sep, 30);		

7.5.1.7 NMFS_days_open

NMFS_days_open is identical to *DXC_NMFSBO*. It is no longer used in SacWAM.

7.5.1.8 RS_estEC_zeroDXC

RS_estEC_zeroDXC is an estimate of the EC at Rock Slough when the Delta Cross Channel is closed for the entire month. The argument *Other\Ops\Delta Salinity\ANN\Inputs\Delta Cross Channel\DXC_est* is replaced with a value of zero. It is no longer used in SacWAM.

7.5.1.9 RS_estEC_halfDXC

RS_estEC_zeroDXC is an estimate of the EC at Rock Slough when the Delta Cross Channel is closed for half of the month. The argument *Other\Ops\Delta Salinity\ANN\Inputs\Delta Cross Channel\DXC_est* is replaced with a value of half the number of days in the month (*Days*/2). It is no longer used in SacWAM.

7.5.1.10 RS_estCL_zeroDXC

RS_estCL_zeroDXC is an estimate of the chloride concentration at Rock Slough when the Delta Cross Channel is closed for the entire month. It is calculated as a linear function of *RS_estEC_zeroDXC.* It is no longer used in SacWAM.

7.5.1.11 RS_estCL_halfDXC

RS_estCL_halfDXC is an estimate of the chloride concentration at Rock Slough when the Delta Cross Channel is closed for half the month. It is calculated as a linear function of *RS_estEC_zeroDXC.* It is no longer used in SacWAM.

7.5.1.12 RS_CL_STD_TEST

RS_CL_Std_Test is the Rock Slough water quality standard as specified in D-1641 as represented in SacWAM. It is set equal to *Other\Ops\Delta Salinity\ANN\Stations\Rock Slough\RS_CL_Std*.

7.5.1.13 RV_day_open

RV_day_open is the number of days that the Delta Cross Channel is kept open when the flow standard at Rio Vista is binding upstream CVP/SWP reservoir releases. The gates are closed for the entire month if the Rock Slough standard can be met. Alternatively, the gates remain open for 15 days if the Rock Slough standard can be met under this criterion. *RV_day_open* is no longer used in SacWAM.

7.5.1.14 MaxDaysOffTarget

MaxDaysOffTarget is the difference between D-1641 and NMFS BO for Delta Cross Channel gate closure requirements.

7.5.1.15 NMFSMaxExpDCCest

NMFSMaxExpDCCest is an average monthly export limit based on an export value of 2,000 cfs for the days when the NMFS BO requirement exceeds the D-1641 standard.

7.5.1.16 RS_estEC_noDXC

RS_estEC_noDXC is an estimate of the EC at Rock Slough when the Delta Cross Channel is closed in accordance with the NMFS BO. The argument *Other\Ops\Delta Salinity\ANN\Inputs\Delta Cross Channel\DXC_est* is replaced with a value of *DXC_NMFS_est*.

7.5.1.17 RS_estEC_noDXCmE

RS_estEC_noDXC is an estimate of the EC at Rock Slough when the Delta Cross Channel is closed in accordance with the NMFS BO. The argument *Other\Ops\Delta Salinity\ANN\Inputs\Delta Cross Channel\DXC_est* is replaced with a value of *DXC_NMFS_est* and the argument *D409* is relaced with *NMFSMaxExpDCCest*.

7.5.1.18 RS_estCL_noDXC

RS_estCL_noDXC is an estimate of the chloride concentration at Rock Slough when the Delta Cross Channel is closed in accordance with the NMFS BO and exports are limited. It is calculated as a linear function of *RS_estEC_noDXC.*

7.5.1.19 RS_estCL_noDXCmE

RS_estCL_noDXCmE is an estimate of the chloride concentration at Rock Slough when the Delta Cross Channel is closed in accordance with the NMFS BO and exports are limited to *DXC_NMFS_est*. It is calculated as a linear function of *RS_estEC_noDXCmE.*

7.5.1.20 NMFS_MaxExp_DCC

For the months of October through December, *NMFS_MaxExp_DCC* is used to limits exports to *NMFSMaxExpDCCest* when *RS_estCL_noDXC* is greater than the Rock Slough chloride standard and *RS_estCL_noDXCmE* is less than the Rock slough standard. The export constraint is implemented under *UDC\Delta Export Constraints\DXC\DXC_Total*.

7.5.2 South Delta

The purpose of the *South Delta* branch is to determine flow at the Head of the Old River. The SacWAM implementation is based on regression equations defined in Hutton (2008a).

7.5.2.1 coefA

The parameter *coefA* is used in a regression equation to determine flow from the San Joaquin River into the Head of Old River. This variable is equivalent to ‘C1’ in Table 7-22.

7.5.2.2 coefB

The parameter *coefB* is used in a regression equation to determine the net flow within Indian Slough. This variable is referenced in the User Defined Constraint described in Section 8.11.1.

7.5.2.3 CoefC

The parameter *coefC* is used in a regression equation to determine flows into the Head of Old River. This variable is equivalent to ‘C2’ in Table 7-22.

7.5.2.4 Head of Old River

Flows at the Head of Old River (HOR) are determined as a linear function of San Joaquin River flows at Vernalis using the following equation, based on the Hutton (2008a):

$$Q_{HOR} = C1 * Q_{Vernalis} + C2$$

Values for C1 and C2 vary depending upon the time of year and level of flows at Vernalis. Parameter values used in SacWAM are summarized in Table 7-22.

Table 7-22. Coefficients Used to Set Flows at Head of Old River

Condition	C1	C2
June, July, August	0.419	-26
April, May AND $Q_{Vernalis}$ < 5,000 cfs	0.079	69
October, November AND $Q_{Vernalis}$ < 5,000 cfs	0.238	-51
$Q_{Vernalis}$ < 16,000 cfs	0.471	83
16,000 cfs < $Q_{Vernalis}$ < 28,000 cfs	0.681	-3,008
$Q_{Vernalis}$ > 28,000 cfs	0.633	-1,644

Key:
cfs = cubic feet per second

SacWAM uses a WEAP diversion object to take water from the San Joaquin River into the Old River. Flows into this diversion are set using the *Fraction Diverted* parameter associated with the diversion model object, which is entered as a percentage of river flow above the diversion. This parameter references the branch of the Data Tree *Other\Ops\Delta\South Delta\Head of Old River\Percent_SJ_to_HOR,* which is defined as Q_{HOR} / $Q_{Vernalis}$.

7.5.2.4.1 Percent_SJ_to_HOR

The *Percent_SJ_to_HOR* is the flow ratio, expressed as a percent, Head of the Old River to the San Joaquin River at Vernalis.

7.5.2.4.2 Q_HOR

Q_HOR, the flow at the Head of Old River, is determined as a linear function of San Joaquin River flows at Vernalis (*SJatVernalis)*.

7.5.2.5 SJatVernalis

The variable *SJatVernalis* represents the flow in the San Joaquin River at the Airport Way bridge near Vernalis (San Joaquin River at Vernalis). These flows are read into SacWAM as monthly time series data. The variable is used here to simplify expressions that are used to determine flows at the Head of Old River.

7.6 Ops\Delta Salinity

This section describes the routines that are used to calculate flow requirements needed to satisfy X2 and D-1641 water quality standards within the Delta.

7.6.1 ANN

SacWAM includes an option to simulate Delta salinity using an ANN developed by DWR, or to use the G-model developed by Contra Costa WD. The switch to activate the ANN is discussed in Section 7.2.5.

The ANN was developed by DWR to integrate into the CalSim II model an accurate representation of the flow-salinity relationships as simulated by the Delta Simulation Model (DSM2). These relationships are used by CalSim II to set Sacramento River flow targets and export limits in order to meet salinity standards at various locations within the Delta. The ANN also determines salinity (micro-mhos/cm) at these locations for the previous time step given simulated Delta inflows, outflows, and exports and the position of Delta cross-channel. The ANN is described in more detail in several DWR reports (Finch and Sandhu 1995; DWR, 2000b; Hutton and Seneviratne, 2001; Wilbur and Munevar, 2001; Mierzwa, 2002; Seneviratne, 2002; and Smith, 2008).

The ANN has been refined over the years. The version of the ANN Used in SacWAM uses 7 inputs

- Northern Delta inflow (Sacramento River, Yolo Bypass, Mokelumne River, Cosumnes River, and Calaveras River inflows),
- Southern Delta inflow (San Joaquin River flow at Vernalis),
- Delta exports (Banks, Jones, and Contra Costa pumping plants),
- Delta cross-channel gate operation,
- Net Delta consumptive use,
- Tidal energy,
- And San Joaquin River inflow salinity at Vernalis.

A total of 148 days of values of each of these parameters is included in the correlation, representing an estimate of the length of memory in the Delta.

The ANN is configured as a Fortran-compiled Dynamic-Link Library (DLL) that contains several functions. These functions include routines for calculating Delta salinity in terms of electrical conductivity (EC) at various locations for previous time steps and for calculating the parameters used in equations to set flow targets and export constraints. The ANN has been updated several times since its first introduction. The ANN included with SacWAM is taken from the 'existing conditions' study included within the 2015 SWP Delivery Capability Report (DWR, 2015).

For the purposes of linking SacWAM to the ANN it was necessary to recompile the DLL such that it could be called from WEAP. This required creating new functions within the DLL that received from SacWAM a single double precision array of values, rather than several individual real and integer values as it is done with CalSim. The FORTRAN code was rewritten to create new functions callable from WEAP that are essentially 'wrappers' to the existing DLL functions. The DLL functions that are called by SacWAM are as follows:

- ANNECARRAY, which calculates previous month salinity at different stations within the Delta.
- ANNEC_MATCHDSM2ARRAY, which calculates the salinity from 2 months prior at different stations within the Delta.
- ANNLINEGENARRAY, which calculates the slope and intercept of the linear equation that is used to constrain Delta exports as a function of Sacramento River flows at Hood.

To access these routines within the DLL, SacWAM uses a 'Call' function, which takes the following form:

Call (DLLFileName ! DLLFunctionName, parameter1, parameter2, ...)

The DLLFileName is Ann7inp_ROA0SLR0cm_SA.dll and the DLLFunctionName is one of the three functions listed. The parameter sets differ between the three functions and are listed in Table 7-23, Table 7-24, and

Table 7-25.

In SacWAM, only the last function (AnnLineGen in CalSim and AnnLineGenArray in SacWAM) is needed to set flow targets and export constraints. The other two functions are called only to report Delta water quality for the previous month.

Table 7-23. List of Parameters for ANN Function AnnECArray

Parameter Number	Description	Parameter(s)
1-5	Sacramento River flows at Hood over previous 5 months	C400_5, C400_4, C400_3, C400_2, C400_1
6-10	CVP and SWP Delta Exports over previous 5 months	D409_5, D409_4, D409_3, D409_2, D409_1
11-15	San Joaquin River flows at Vernalis over previous 5 months	C639_5, C639_4, C639_3, C639_2, C639_1
16-20	Number of days the delta cross channel gates are open for each of the previous 5 months	DXC_5, DXC_4, DXC_3, DXC_2, DXC_1
21-25	Net in-Delta consumptive use over previous 5 months	net_DICU_5, net_DICU_4, net_DICU_3, net_DICU_2, net_DICU_1
26-30	Other Sacramento River Basin inflows to the Delta over previous 5 months	sac_oth_5, sac_oth_4, sac_oth_3, sac_oth_2, sac_oth_1
31-35	Other Delta Exports over previous 5 months	exp_oth_5, exp_oth_4, exp_oth_3, exp_oth_2, exp_oth_1
36-40	San Joaquin River water quality at Vernalis over previous 5 months	VernWQ_5, VernWQ_4, VernWQ_3, VernWQ_2, VernWQ_1
41-45	Number of days in the month over previous 5 months	daysin_5, daysin_4, daysin_3, daysin_2, daysin_1
46	Station identifier1	Jersey Point (JP) = 1, Rock Slough (RS) = 2 Emmaton (EM) = 3, Collinsville (CO) = 5
47	Average type2	Monthly average = 1 Maximum 14-day value = 6
48	Previous month index	Mo = 12 if October Otherwise, Mo = TS-1
49	Previous month water year	Year = Water Year - 1 if October, Otherwise, Year = Water Year

Notes:
[1] The ANN functions were developed to consider twelve different stations. However, only four are used.
[2] The average type is used for the functions that return estimates of water quality - i.e., AnnECArray and AnnEC_matchDSM2Array. There are eight different types of averages that can be calculated by various functions within the DLL. Only two are used in both CalSim II and WEAP.

Key:
CVP=Central Valley Plan, SWP=State Water Plan.

Table 7-24. List of Parameters for ANN Function AnnEC_matchDSM2Array

Parameter Number	Description	Parameter(s)
1-7	Sacramento River flows at Hood over previous 7 months	C400_7, C400_6, C400_5, C400_4, C400_3, C400_2, C400_1
8-12	CVP and SWP Delta Exports over previous 2 to 6 months	D409_6, D409_5, D409_4, D409_3, D409_2
13-19	San Joaquin River flows at Vernalis over previous 7 months	C639_7, C639_6, C639_5, C639_4, C639_3, C639_2, C639_1
20-24	Number of days the delta cross channel gates are open for each of the previous 2 to 6 months	DXC_6, DXC_5, DXC_4, DXC_3, DXC_2
25-29	Net in-Delta consumptive use over previous 2 to 6 months	net_DICU_6, net_DICU_5, net_DICU_4, net_DICU_3, net_DICU_2
30-34	Other Sacramento River Basin inflows to the Delta over previous 2 to 6 months	sac_oth_6, sac_oth_5, sac_oth_4, sac_oth_3, sac_oth_2
34-39	Other Delta Exports over previous 2 to 6 months	exp_oth_6, exp_oth_5, exp_oth_4, exp_oth_3, exp_oth_2
40-44	San Joaquin River water quality at Vernalis over previous 2 to 6 months	VernWQ_6, VernWQ_5, VernWQ_4, VernWQ_3, VernWQ_2
45-51	Number of days in the month over previous 7 months	daysin_7, daysin_6, daysin_5, daysin_4, daysin_3, daysin_2, daysin_1
52	Station identifier1	Jersey Point (JP) = 1, Rock Slough (RS) = 2 Emmaton (EM) = 3, Collinsville (CO) = 5
53	Average type2	Monthly average = 1 Maximum 14-day value = 6
54	Index for 2 months prior	Mo = 11 if October Mo = 12 if November Otherwise, Mo = TS-2
55	Water year for 2 months prior	Year = Water Year - 1 if October or November, Otherwise, Year = Water Year

[1] The ANN functions were developed to consider twelve different stations. However, only four are used.
[2] The average type is used for the functions that return estimates of water quality - i.e., AnnECArray and AnnEC_matchDSM2Array. There are eight different types of averages that can be calculated by various functions within the DLL. Only two are used in both CalSim II and WEAP.
Key: CVP=Central Valley Plan; SWP=State Water Plan.

Table 7-25. List of Parameters for ANN Function AnnLineGenArray

Parameter Number	Description	Parameter(s)
1-4	Sacramento River flows at Hood over previous 4 months	C400_4, C400_3, C400_2, C400_1
5-8	CVP and SWP Delta Exports over previous 4 months	D409_4, D409_3, D409_2, D409_1
9-12	San Joaquin River flows at Vernalis over previous 4 months	C639_4, C639_3, C639_2, C639_1
13	Estimate of current month's San Joaquin River flows at Vernalis	SJR_ann_est
14-17	Number of days the delta cross channel gates are open for each of the previous 4 months	DXC_4, DXC_3, DXC_2, DXC_1
18	Estimate of current month's number of days with delta cross channel gates open	DXC_est
19-22	Net in-Delta consumptive use over previous 4 months	net_DICU_4, net_DICU_3, net_DICU_2, net_DICU_1
23	Estimate of current month's net in-Delta consumptive use	Net_delta_cu
24-27	Other Sacramento River Basin inflows to the Delta over previous 4 months	sac_oth_4, sac_oth_3, sac_oth_2, sac_oth_1
28	Estimate of current month's inflow to Delta from other Sacramento River Basin sources	sac_oth_est
29-32	Other Delta Exports over previous 4 months	exp_oth_4, exp_oth_3, exp_oth_2, exp_oth_1
33	Estimate of current month's other Delta Exports	exp_oth_est
34-37	San Joaquin River water quality at Vernalis over previous 4 months	VernWQ_4, VernWQ_3, VernWQ_2, VernWQ_1
38	Estimate of current month's San Joaquin River water quality at Vernalis	VernWQ_est
39-42	Number of days in the month over previous 4 months	daysin_4, daysin_3, daysin_2, daysin_1
43	Number of days in current month	daysin
44	Water quality standards	Water year dependent, monthly varying EC standards at Jersey Point, Rock Slough, Emmaton, and Collinsville
45	Lower bound for linearization of export constraint[1]	JP_line_lo, CO_line_lo, EM_line_lo, RS_line_1_lo, RS_line_2_lo, RS_line_3_lo
46	Upper bound for linearization of export constraint[1]	JP_line_hi, CO_line_hi, EM_line_hi, RS_line_1_hi, RS_line_2_hi, RS_line_3_hi
47	Station identifier[2]	Jersey Point (JP) = 1 Rock Slough (RS) = 2 Emmaton (EM) = 3 Collinsville (CO) = 5
48	Constant type[3]	Slope = 1 Intercept = 2
49	ANN type[4]	Value = 1
50	Previous month index	Mo = 12 if October Otherwise, Mo = TS-1
51	Previous month water year	Year = Water Year - 1 if October, Otherwise, Year = Water Year
52	Other Parameter	Value = 1 for RS linearization #1 Value = 2 for RS linearization #2 Value = 3 for RS linearization #3 Value = 4 for JP, CO, and EM

Notes:

[1] Parameters and associated values derived directly from CalSim model inputs

[2] The ANN functions were developed to consider twelve different stations. However, only four are used.

[3] The constant type is used for the function (i.e., AnnLinGenArray) that returns to WEAP the constants that are used in equations that constrain Delta exports based on Sacramento River and Yolo Bypass flows.

Key:

CVP=Central Valley Plan, SWP=State Water Project.

7.6.1.1 Inputs

Each of the ANN input parameters listed in Table 7-23, Table 7-24, and

Table 7-25 were added as user-defined variables within SacWAM under the branch *Other\ Delta\Delta Salinity\ANN\Inputs*. This provides a short-hand method of referring to these flow components when calling the ANN (e.g., C400 compared to *Supply and Resources\River\Sacramento River\Reaches\Below Sacramento River RM 041:Streamflow*). Simulated data passed to the ANN include a mix of previous time step values and estimates of values for the current month.

Previous time step values passed to the ANN include: (1) combined exports at Banks and Jones pumping plant (*D409_1*); (2) Contra Costa WD diversions, Barker Slough Pumping Plant for the North Bay Aqueduct, and City of Stockton diversions (*exp_oth_1*); (3) Sacramento River flow at Hood (*C400_1*); San Joaquin River flow at Vernalis (*C639_1*); (4) Yolo Bypass flow at Lisbon Weir and Eastside streams inflow (*sac_oth_1*); (5) Delta net consumptive use (*Net_DICU_1*); (6) fraction of month that the Delta Cross Channel is open (*DXC_1*); and (7)the water quality of the San Joaquin River at Vernalis (*VernWQ_1*). Expressions for earlier months also are passed to the ANN. These values are calculated using WEAP's PrevTSValue function. The suffix _1, _2, _3…refer to one month, two months, and three months previous.

Estimates of current time step values passed to the ANN include: (1) Contra Costa WD diversions, Barker Slough Pumping Plant for the North Bay Aqueduct, and City of Stockton diversions (*exp_oth_est*); (2) San Joaquin River flow at Vernalis (*C639_est*; (3) Yolo Bypass flow at Lisbon Weir and Eastside streams inflow (*sac_oth_est*); (4) Delta net consumptive use (*Net_DICU_est*); (5) fraction of month that the Delta Cross Channel is open (*DXC_est*); and the water quality of the San Joaquin River at Vernalis (*VernWQ_est*).

The sections below provide additional information on each ANN input parameter, including the estimate of current time step values prior to solution of the water allocation problem by the LP solver. The implementation of the ANN to meet Delta water quality standards is implemented in SacWAM in *User-Defined LP Constraints* and is described in Section 8.8.5.1.

7.6.1.1 ANNCAP

Maximum flow from Sacramento River used as an upper limit on ANN. This is set to 12,000 cfs in dry and critical years and 15,000 cfs in other water year types.

7.6.1.2 AnnEC_matchDSM2_mo

AnnEC_matchDSM2_mo is a variable to match the DSM2 timestep. It is set to a value of '1' in December and '12' in November. However, the variable is no longer used in SacWAM.

7.6.1.3 AnnEC_matchDSM2_wy

AnnEC_matchDSM2_wy is a variable to match the DSM2 water year. It is set to the calendar year. However, the variable is no longer used in SacWAM.

7.6.1.4 ANNEC_mo_1

Month counter for ANN implementation starting in November (1) and ending in October (12).

7.6.1.5 AnnEC_wy

Water year counter for ANN impelementation starting in November and ending in October. Beyond 2003, 2003 is used as constant value through the end of simulation.

7.6.1.6 AnnLineGen_mo

Variable set equal to month (TS) counter.

7.6.1.7 AnnLineGen_WY
Variable set equal to Water Year (Year)

7.6.1.8 AnnSacReq
AnnSacReq is inherited from the CalSim logic. It is currently not used in SacWAM simulation.

7.6.1.9 EstCVPSodExp
Estimate of South of Delta CVP Exports based on contract amounts.

7.6.1.10 EstSWPSodExp
Estimate of South of Delta SWP Exports based on contract amounts.

7.6.1.11 EstTotExp
EstTotExp is currently not used in SacWAM simulation.

7.6.1.12 ExportCap
Upper limit on export of 1,500 cfs.

7.6.1.12.1 Inputs - Delta Cross Channel Gates
The DXC gates are operated in accordance with D-1641 (SWRCB, 2000) and the 2009 NMFS BO Action 4.1. Within the current time step, SacWAM estimates the number of days that the gates are open, based on these requirements, but assuming that no additional gate closures are triggered by Sacramento River flood flows (greater than 25,000 cfs at Walnut Grove), or flushing flows (greater than 7,500 cfs at Wilkins Slough) from October through December., Table 7-26 lists the assumed number of days that the gates are open in the current month for purposes of defining ANN inputs.

Table 7-26. Minimum Number of Days Open for Delta Cross Channel Gate

Month	Number of Days Open	Month	Number of Days Open
October	31	April	0
November	20	May	0
December	14	June	26
January	0	July	31
February	0	August	31
March	0	September	30

Previous months values of Delta Cross Channel gates (e.g., DXC_1) are calculated using the values in Table 7-26, modified by additional gate closures, where applicable, that are triggered by high flows in the Sacramento River, as discussed in Section 7.5.1.

7.6.1.12.2 Inputs – Delta Consumptive Use (DICU)

SacWAM estimates the current month's net in-Delta consumptive use (*Net_DICU*) using average monthly values derived from a 1950-2005 SacWAM baseline simulation (Table 7-27).

Table 7-27. Simulated Average Monthly Net in-Delta Consumptive Use by Water-Year Type

San Joaquin Valley Water-Year Type	Average Monthly Flow 1950-2005 (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	208	266	(358)	(499)	(306)	104	870	1,902	3,500	2,917	2,861	514
Above Normal	195	338	(277)	(467)	(362)	123	1,149	1,804	3,582	2,966	2,871	536
Below Normal	422	444	(144)	(215)	(75)	601	1,611	2,415	3,676	2,957	2,890	516
Dry	259	387	(149)	(193)	149	626	1,537	2,370	3,665	2,982	2,871	505
Critical	204	452	(71)	(44)	162	739	1,537	2,097	3,573	2,978	2,893	531

Previous months values of net in-Delta consumptive use (e.g., Net_DICU_1) are calculated using previous time step actual (not estimated) simulated values of Delta accretions and depletions.

7.6.1.12.3 Inputs - Delta Exports

For the purposes of the ANN, Delta exports is defined as the combined flow through Banks and Jones pumping plants. It is assigned to the variable *D409*. No estimate of current month exports is required. Previous months values of Delta exports (e.g., D409_1) are calculated using WEAP's PrevTSValue function and simulated values of exports.

7.6.1.12.4 Inputs - Other Delta Exports

Other Delta exports include Contra Costa WD Delta diversions at Rock Slough, Old River, and Victoria Canal; and City of Stockton Delta diversion to its water treatment plant (other Delta exports does not include North Bay Aqueduct diversions from Barker Slough). For the current month, these exports, which are assigned to the variable *exp_oth_est*, are estimated by the following equation:

> *exp_oth_est* = 0.90 * average monthly other exports +
> + 0.10 * previous month's other exports * monthly perturbation

where the monthly perturbation is the ratio of average current month's other exports over the average of the previous month's other exports and is shown with the average monthly other exports in Table 7-28. Previous months values of other Delta exports (e.g., exp_oth_1) are calculated using WEAP's PrevTSValue function and actual (not estimated) simulated values of exports.

Table 7-28. Simulated Average Monthly Other Delta Exports

San Joaquin Valley Water-Year Type	Average Monthly Flow 1950-2005 (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	238	262	231	231	231	253	294	347	429	391	375	249
Above Normal	238	263	231	231	231	251	308	336	433	393	375	249
Below Normal	241	266	232	231	231	267	328	367	436	392	376	249
Dry	238	265	232	231	234	270	325	366	436	393	375	249
Critical	238	266	232	232	234	274	325	351	432	393	376	249
Monthly Perturbation	0.96	1.11	0.88	1.00	1.01	1.13	1.20	1.12	1.23	0.91	0.96	0.66

7.6.1.12.5 Inputs - Other Delta Inflows

For purposes of the ANN, other Delta inflows comprise flows in Cache Slough (calculated as the Yolo Bypass at the Lisbon Weir less Barker Slough Pumping Plant diversions), Mokelumne River downstream from its confluence with the Cosumnes River, and Calaveras River at its confluence with the San Joaquin River. The Calaveras, Cosumnes, and Mokelumne are known as the Eastside Streams. The current month's estimate of other Delta inflows, assigned to the parameter *Sac_oth_est*, is determined using the following equation:

sac_oth_est = 0.75 * average monthly Mokelumne +Calaveras flows
+ 0.25 * previous month's Mokelumne +Calaveras flows * monthly perturbation

The monthly perturbation is the ratio of average current month's inflows over the average of the previous month's combined inflows and is shown with the average monthly values in Table 7-29. For the purposes of the ANN, the estimate of other Delta inflows in the current month ignores the contribution from the Yolo Bypass.

Previous months values of other Delta inflows are calculated using WEAP's PrevTSValue function and include the Yolo Bypass at Lisbon Weir.

Table 7-29. Simulated Average Monthly Eastside Streams Inflows to the Delta

San Joaquin Valley Water-Year Type	Average Monthly Flow 1950-2005 (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wet	980	688	2,619	6,052	7,078	6,371	4,773	2,897	863	474	363	681
Above Normal	1,523	1,229	3,029	3,554	5,404	3,625	2,570	1,507	676	438	360	555
Below Normal	937	562	1,159	1,804	2,362	2,080	2,318	1,175	550	344	270	387
Dry	1,329	640	1,091	1,437	2,054	1,821	1,182	740	439	320	275	391
Critical	1,129	355	401	552	843	1,195	1,029	560	357	240	197	195
Monthly Perturbation	2.67	0.59	2.39	1.61	1.32	0.85	0.79	0.58	0.42	0.63	0.81	1.51

7.6.1.12.6 Inputs – Sacramento Inflow

For the purposes of the ANN, Delta inflow from the Sacramento River is defined as the flow at Hood. It is assigned to the variable *C400*. No estimate of current month inflow is required. Previous months values of Delta inflows (e.g., C400_1) are calculated using WEAP's PrevTSValue function and simulated values of flows.

7.6.1.12.7 Inputs – San Joaquin Inflow

SacWAM does not simulate the San Joaquin River south of the Delta. San Joaquin River flows at Vernalis are inputs to SacWAM. Time series of flows were obtained from Phase 1 of the Bay-Delta Plan and stored in the data file Data\Headflows\SACVAL_Vernalis.csv and assigned to the parameter *VernWQ*.

Because San Joaquin River flow at Vernalis is an input to the model, the estimate flow in the current time step, *C639_est* is identical to the headflow in the arc *Inflow at Vernalis*. Previous months values of flows at Vernalis are calculated using WEAP's PrevTSValue function.

7.6.1.12.8 Inputs - VernalisWQ

SacWAM does not simulate the San Joaquin River south of the Delta. The flow and water quality of the San Joaquin River at Vernalis are inputs to SacWAM. Time series of flows were obtained from Phase 1 of the Bay-Delta Plan and time series of water quality were obtained from CalSim II modeling.[41] Water quality data are stored in the data file Data\Delta\VernalisWQ.csv and assigned to the parameter *VernWQ*. Because Vernalis water quality is an input to the model, the estimate of water quality in the current time step, *VernWQ_est*, is identical to *VernWQ*. Previous months values of Vernalis water quality are calculated using WEAP's PrevTSValue function.

7.6.1.13 Outputs

The variables defined under outputs are for reporting purposes only. *SalinityOutflowRqment_prevTS* is the previous month's outflow for salinity control. *ExcessDeltaOutflow_prevTS* is the net Delta outflow over and above D-1641 and BiOp requirements.

SalinityOutflowRqment_prevTS is calculated as the maximum of the individual outflow requirements for Collinsville, Emmaton, Jersey Point, and Rock Slough compliance.

ExcessDeltaOutflow_prevTS is calculated as the total Delta outflow less the maximum of the IFR requirements for MRDO, X2, and *SalinityOutflowRqment_prevTS.*

7.6.1.13.1 OutflowForSalinityControl_prevTS

CO_prevTS
Previous month value for slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Collinsville.

DeltaExports_prevTS – calsim
Total Delta exports in CalSim for the previous month

DeltaExports_prevTS – simulated
Total Delta exports in CalSim for the previous month

DeltaFlows_prevTS – Main_Inflows
Output variable giving previous value of a total of inflows from San Joaquin River, Little John's Creek, Calaveras River, Mokelumne River, Kellogg Creek and Marsh creek and also takes into account the outflows from Old River Pipeline, Rock Slough Intake, North Bay Aqueduct diversions and NetDICU.

DeltaFlows_prevTS – misc_inflows
Output variable giving previous value of total urban and agricultural return flows from demand units 60S_NU1, 60N_NU1, 25_PU, 26_NU3, 26_NU4, 26_PU4, 26_PU5, 60N_NU1, 60S_NU1, 61N_NU1,

[41] Based on a 1921-2003 CalSim II simulation of existing condition (1_DCR2015_Base_ExistingNoCC) from DWR's 2015 SWP Delivery Capability Report.

61N_NU2, 60N_NA3, 61N_NA1, 61N_NA3, 61N_PA, 25_PA, 60N_NA3, 60N_NA4, 60N_NA5, 60S_NA and 60S_PA.

EM_prevTS
Previous month value for slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Emmaton.

ExcessDeltaOutflow_prevTS
ExcessDeltaOutflow_prevTS is the portion of the previous month's Delta outflow that is over and above regulatory outflow requirements, including outflow for X2 and Delta salinity standards.

JP_prevTS
Previous month value for slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Jersey Point.

RS1_prevTS
Previous month value for slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Rock Slough. The relationship is piecewise linear, therefore, 3 slopes and 3 interecepts are required to define the relationship.

RS2_prevTS
Previous month value for slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Rock Slough.

RS3_prevTS
Previous month value for slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Rock Slough.

SalinityOutflowRqment_prevTS

7.6.1.14 PulseCap
PulseCap is calculated as the minimum of estimated combined exports at Banks and Jones pumping plants, and the estimated San Joaquin River flow at Vernalis or 1,500 cfs if greater)

7.6.1.15 Stations
Four branches under Stations contain input data associated with Collinsville, Emmaton, Jersey Point, and Rock Slough. Below is a description of the Collinsville data, which is representative of the other stations.

7.6.1.15.1 Collnsville (CO)

CO_Sac_ZeroExp
The required inflow from the Sacramento River at Hood to meet the Collinsville standard for zero exports.

COReqSac
The required inflow from the Sacramento River at Hood to meet the Collinsville standard for the estimated exports. *COReqSac* is currently not used in SacWAM simulation.

CO_m
The slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Collinsville.

CO_line_hi
The upper bound for linearization of export constraint assigned a value of 12,000 cfs.

CO_line_lo
The lower bound for linearization of export constraint assigned a value of 8,000 cfs.

CO_EC_STD
The D-1641 water quality standard for Collinsville in the current month, expressed in microSiemens.

CO_EC_month
A call to ANN to determine previous month mean monthly EC, expressed in microSiemens.

CO_condition
Defines the type of Delta conditions that exist, as implied by the coefficients returned by the ANN and the resulting export-inflow relationship required to meet D-1641 water quality standards.

CO_c1
It is ssigned a value of 0 or 1 depending on CO_condition.

CO_c2
It is assigned a value of 0 or 1 depending on CO_condition.

CO_c3
It is assigned a value of 0 or 1 depending on CO_condition.

CO_c4
It is assigned a value of 0 or 1 depending on CO_condition.

CO_c5
It is assigned a value of 0 or 1 depending on CO_condition.

CO_b
The y-axis intercept of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Collinsville.

CO
It is set to a value of 5, which informs the ANN that the station being considered is Collinsville.

7.6.1.15.2 Emmaton

Similar structure to that of Collinsville. An *EM* value of 3 informs the ANN that the station being considered is Emmaton.

EM_Sac_ZeroExp
The required inflow from the Sacramento River at Hood to meet the Emmaton standard for zero exports.

EMReqSac
The required inflow from the Sacramento River at Hood to meet the Emmaton standard for the estimated exports. *EMReqSac* is currently not used in SacWAM simulation.

EM_m
The slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Emmaton.

EM_line_hi
The upper bound for linearization of export constraint assigned a value of 12,000 cfs.

EM_line_lo
The lower bound for linearization of export constraint assigned a value of 5,000 cfs.

EM_EC_STD
The D-1641 water quality standard for Emmaton in the current month, expressed in microSiemens.

EM_EC_month
A call to ANN to determine previous month mean monthly EC, expressed in microSiemens.

EM_condition
Defines the type of Delta conditions that exist, as implied by the coefficients returned by the ANN and the resulting export-inflow relationship required to meet D-1641 water quality standards.

EM_c1
It is ssigned a value of 0 or 1 depending on EM_condition.

EM_c2
It is assigned a value of 0 or 1 depending on EM_condition.

EM_c3
It is assigned a value of 0 or 1 depending on EM_condition.

EM_c4
It is assigned a value of 0 or 1 depending on EM_condition.

EM_c5
It is assigned a value of 0 or 1 depending on EM_condition.

EM_b
The y-axis intercept of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Emmaton.

EM
It is set to a value of 3, which informs the ANN that the station being considered is Emmaton.

7.6.1.15.3 Intercept

Intercept is an argument in the ANN call requesting that the ANN returns the intercept of the linear relationship between exports and Sacramento River Delta inflow. It is set to a value of 2.

7.6.1.15.4 Jersey Point

Similar structure to that of Collinsville. A JP value of 1 informs the ANN that the station being considered is Jersey Point.

JP_Sac_ZeroExp
The required inflow from the Sacramento River at Hood to meet the Jersey Point standard for zero exports.

JPReqSac
The required inflow from the Sacramento River at Hood to meet the Jersey Point standard for the estimated exports. *JPReqSac* is currently not used in SacWAM simulation.

JP_m
The slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Jersey Point.

JP_line_hi
The upper bound for linearization of export constraint assigned a value of 12,000 cfs.

JP_line_lo
The lower bound for linearization of export constraint assigned a value of 5,000 cfs.

JP_EC_STD
The D-1641 water quality standard for Jersey Point in the current month, expressed in microSiemens.

JP_EC_month
A call to ANN to determine previous month mean monthly EC, expressed in microSiemens.

JP_condition
Defines the type of Delta conditions that exist, as implied by the coefficients returned by the ANN and the resulting export-inflow relationship required to meet D-1641 water quality standards.

JP_c1
It is ssigned a value of 0 or 1 depending on JP_condition.

JP_c2
It is assigned a value of 0 or 1 depending on JP_condition.

JP_c3
It is assigned a value of 0 or 1 depending on JP_condition.

JP_c4
It is assigned a value of 0 or 1 depending on JP_condition.

JP_c5
It is assigned a value of 0 or 1 depending on JP_condition.

JP_b

The y-axis intercept of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Jersey Point.

JP
It is set to a value of 1, which informs the ANN that the station being considered is Jersey Point.

7.6.1.15.5 Rock Slough

Similar structure to that of Collinsville. A RS value of 2 informs the ANN that the station being considered is Rock Slough. The representation of the required relationship between Sacramento River flows and Delta exports is represented using three linear segments.

RS_Sac_ZeroExp
The required inflow from the Sacramento River at Hood to meet the Rock Slough standard for zero exports.

RSReqSac, RSReqSac1, RSReqSac2, and RSReqSac3
The required inflow from the Sacramento River at Hood to meet the Rock Slough standard for the estimated exports. *RSReqSac, RSReqSac1, RSReqSac2, and RSReqSac3* are currently not used in SacWAM simulation.

RS_m_1, RS_m_2, and RS_m_3
The slope of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Rock Slough.

RS_line_1_hi
The upper bound for linearization of export constraint assigned a value of 4,000 cfs.

RS_line_1_lo
The lower bound for linearization of export constraint assigned a value of 2,000 cfs.

RS_line_2_hi
The upper bound for linearization of export constraint assigned a value of 8,000 cfs.

RS_line_2_lo
The lower bound for linearization of export constraint assigned a value of 6,000 cfs.

RS_line_3_hi
The upper bound for linearization of export constraint assigned a value of 12,000 cfs.

RS_line_3_lo
The lower bound for linearization of export constraint assigned a value of 10,000 cfs.

RS_EC_STD
The D-1641 water quality standard for Rock Slough in the current month, expressed in microSiemens.

RS_EC_month
A call to ANN to determine previous month mean monthly EC, expressed in microSiemens.

RS1_condition, RS2_condition, and RS3_condition
Defines the type of Delta conditions that exist, as implied by the coefficients returned by the ANN and the resulting export-inflow relationship required to meet D-1641 water quality standards.

RS1_c1, RS2_c1, and RS3_c1
It is ssigned a value of 0 or 1 depending on RS_condition.

RS1_c2, RS2_c2, and RS3_c2
It is assigned a value of 0 or 1 depending on RS_condition.

RS1_c3, RS2_c3, and RS3_c3
It is assigned a value of 0 or 1 depending on RS_condition.

RS1_c4, RS2_c4, and RS3_c4
It is assigned a value of 0 or 1 depending on RS_condition.

RS1_c5, RS2_c5, and RS3_c5
It is assigned a value of 0 or 1 depending on RS_condition.

RS1_c6, RS2_c6, and RS3_c6
It is assigned a value of 0 or 1 depending on RS_condition.

RS_b_1, RS_b_2, and RS_b_3
The y-axis intercept of a linear relationship between combined exports and Sacramento River flow at Hood that will satisfy D-1641 standard at Rock Slough.

RS
It is set to a value of 1, which informs the ANN that the station being considered is Rock Slough.

7.6.1.15.6 Slope

Slope is an argument in the ANN call requesting that the ANN returns the slope of the linear relationship between exports and Sacramento River Delta inflow. It is set to a value of 1.

7.6.1.16 WYT

WYT is the water year type using the Sacramento Valley Index.

7.6.2 GModel

The G-Model is fully implemented in SacWAM. Delta outflow requirements for salinity control, as calculated by the algorithm, are assigned to the SacWAM IFR *REG Delta Salinity GModel*. However, the use of the G-Model has been superseded by the later implementation of the ANN within SacWAM, and the G-Model remains as a legacy of early model development. No further description is provided in this report.

7.6.3 X2

X2 is the nominal location of the 2 parts per thousand (ppt) bottom isohaline (Jassby et al. 1995) as measured in kilometers upstream from the Golden Gate Bridge. Requirements for the X2 location are specified in both D-1641 (SWRCB 2000) and in the 2008 USFWS BiOp.

The 2008 USFWS BiOp for the long-term operation of the CVP and SWP concluded that aspects of these project operations jeopardize the existence of delta smelt and adversely affected delta smelt critical habitat. Component 3 of the RPA (Improve Habitat for Delta Smelt Growth and Rearing) included in the

BiOp established requirements for the adaptive management of Delta outflow in the fall following wet and above normal years. The fall outflow action is expected to improve habitat and contribute to increased growth rate of delta smelt. The RPA calls for Delta outflow to be managed such that fall X2 must average 74 km from the Golden Gate during each September and October if the water year defined in the preceding spring was classified as wet, and average 81 km in the same months if the water year type is defined as above normal. There is an additional storage related requirement to increase Delta outflow in November that does not have a specific X2 target.

SacWAM offers two methods to compute the net Delta outflow required to meet this standard. It can either call the same Delta ANN used to compute other salinity compliance or it can use the Kimmerer-Monismith equation (Jassby et al., 1995). Either approach can be selected by changing the value of the *Other\Ops\Simulation Options\X2* (where a value of 1 indicates SacWAM will use ANN and a value of 0 indicates that SacWAM will use the Kimmerer-Monismith equation). The default approach is to use ANN.

7.7 Ops\Flow Requirements

Each of these MFRs is associated with a Flow Requirement object in SacWAM. They all reference flow schedules that are defined in the Data Tree under *Other Assumptions\Ops\Flow Requirements* and are described in more detail below. This section will be expanded in a future version of this documentation. A complete list of instream flow requirements is provided in Section 6.1.3.

7.7.1 American River

SacWAM includes three flow requirements along the lower American River below Nimbus Dam.

7.7.1.1 Water Right Decision 893 (D893)

Flow requirements associated with D-893 (*D893*) were established in 1958. Table 7-30 shows D-893 flow requirements. The critical year requirement applies only if March through September unimpaired inflow into Folsom Lake is projected to be less than 600,000 AF. *D893* is assigned the 'Normal Year' values listed in Table 7-30.

Table 7-30. D-893 Requirements

Month[1]	Flow Requirements (cfs)	
	Normal Year	Critical Year
January – March	250	250
April-August	250	188
September	375	281
October-November	500	375
December	500	500

Note:
[1] The 250 cfs requirement in Normal Years applies from January 1 to September 14 inclusive.
Key:
cfs = cubic feet per second

7.7.1.1.1 D893WYT

D893WYT is the water year type associated with D-893 and defined in the *Memorandum of Operating Agreement for the Protection and Preservation of Fish Life in the American River as Affected by Folsom and Nimbus Dam (*Reclamation and CDFG, 1957*).* The water year type is read from the file

Data\WYT\CalSim WYTypes.csv. A value of '1' indicates a normal year. A value of '2' indicates a critically dry year. For the purposes of SacWAM, the water year type is updated every March using perfect foresight.

7.7.1.2 Flow Management Standard (FMS)

The Flow Management Standard (*FMS*) was established in 2006 as a framework to improve the condition of aquatic resources in the lower American, particularly fall-run Chinook and steelhead.

Developed jointly by Reclamation, NMFS, USFWS, CDFW, and the Water Forum, the FMS provides 800 cfs - 2,000 cfs in the lower American River depending on the time of the year. Minimum flow requirements are set by the FMS with consideration to hydrologic indices, which considers water availability conditions in the basin. In 2017, the Water Forum developed the Modified FMS to protect Folsom Lake from extreme draw-down under drought conditions as occurred in 2014 and 2015.

SacWAM is able to simulate both the original FMS (*FMS 2008*) and the Modified FMS (*FMS VA*). The flow standard is controlled by *Key\BiOp2019_ITP2020\FMS* and *Other\Ops\Flow Requirements\American\FMS*. The Modified FMS Folsom maximum release is disabled in all scenarios, but may be enabled by changing the expression at *Other\Ops\Flow Requirements\American\FMS\MFMS Max Release\Folsom_max_release*, as described below.

The implementation of the (original) FMS in SacWAM is based on the lower American River FMS 2008 Technical Report, which included revisions to an earlier 2006 report. Index Flows are the initial flows (nominal flows) identified using various water availability indices, and are subject to prescriptive and discretionary adjustments, which result in Minimum Release Requirements (MRR). The three main indicators of water availability to determine the Index Flows are:

- Four Reservoir Index (FRI),
- Sacramento River Index (SRI),
- and Impaired Folsom Inflow Index (IFII).

FRI is an index of the end-of-September combined carryover storage in Folsom, French Meadows, Hell Hole, and Union Valley reservoirs (*FRI*). FRI is used to define flow requirements early in the water year (i.e., October through December) when there is little or no data available to support runoff forecasts. Table 7-31 summarizes how SacWAM uses FRI to set October to December minimum flow requirements (*OctDecIndexFlow*).

Table 7-31. October-December Adjustments to Lower American River Flow Requirement

Four Reservoir Index (TAF)	Minimum Flow Requirement (cfs)
0	800
600	800
746	1,750
796	1,750
848	2,000
Maximum Storage	2,000

Key:
cfs = cubic feet per second, TAF = thousand acre-feet

In January and February, FMS uses SRI to define flow requirements on the Lower American River. SRI is an index of the forecasted water year runoff for the entire Sacramento River Basin and is a better measure of near-term water availability. SacWAM adjusts flow requirements based on SRI using the criteria presented in Table 7-32.

Table 7-32. January-February Adjustments to Lower American Flow Requirement

Sacramento River Index		Lower American River Flow Requirement
Runoff (MAF)	Water-Year Type	
>= 15.7	Above Normal, or Wet	1,750 cfs
>= 10.2 and < 15.7	Below Normal, or Dry	Minimum of 1,750 cfs or previous month MFR
< 10.2	Critically Dry	Maximum of 800 cfs or 85% of previous month MFR

Key:
cfs = cubic feet per second, MAF=million acre-feet, MFR= minimum flow requirement

The January and February flow requirement is subject to adjustment based on beginning-of-month storage in Folsom Lake. If Folsom Lake storage is less than 300 TAF in January or 350 TAF in February and storage is not at the flood control curve, then the flow requirement (*FMS\JanFeb*) is set to 85 percent of the previous month flow requirement or 800 cfs, whichever is greater.

The IFII is an index of the cumulative inflow to Folsom Lake from May through September after all legal diversions take place in the upstream watershed. The IFII is used to set flow requirements from March through the remainder of the water year, when water supply availability is reasonably certain and runoff forecasts can be used to make informed flow management decisions (Table 7-33 andcfs=cubic feet per second, TAF=thousand acre-feet

Table 7-34). SacWAM sets the flow requirement March-May (*MarMay*) based on the IFII and the forecasted end-of-May storage in Folsom Lake (*EoMayStorageEst*). It uses a similar approach for setting June-August MFRs (*JunAug*) based on the IFII (*InflowForecast*) and the end-of-September storage in Folsom Lake (*EoSepStorageEst*). The flow requirement in September is the weighted average of the flow requirements for the two parts of the month before and after Labor Day.

Table 7-33. March-Labor Day Adjustments to Lower American River Flow Requirement

Impaired Folsom Inflow Index (TAF)	Minimum Flow Requirement (cfs)
0	800
375	800
550	1,750
9,000	1,750

Key:
cfs=cubic feet per second, TAF=thousand acre-feet

Table 7-34. Post–Labor Day-September Adjustments to Lower American River Flow Requirement

Impaired Folsom Inflow Index (TAF)	Minimum Flow Requirement (cfs)
0	800
375	800
504	1,500
9,000	1,500

Key:
cfs=cubic feet per second, TAF=thousand acre-feet

However, if SacWAM estimates that the end-of-May Folsom storage will be less than 700 TAF when releasing the MFR, then the March-May MFR is set to the lesser of the IFII-based MFR and the February MFR. Similarly, if SacWAM estimates that the end-of-September Folsom storage will be less than 300 TAF when releasing the MFR, then the June-September MFR is set to the maximum of 250 cfs or the computed release throughout those months that will lead to an end-of-September storage of 300 TAF.

The FMS also has criteria for conference years and off-ramp conditions, which can apply in any month and if satisfied will reduce the flow requirement to the same as the D-893 Normal Year requirement. Conference years occur when the predicted March-November unimpaired inflow to Folsom Lake is less than 400 TAF. Off-ramp conditions are triggered during October through February when storage at the end of the current month is projected to fall below 200 TAF (*OctDecStorage*, *JanFebStorage)*. They are triggered March through September if the projected end-of-September storage is less than 200 TAF (*MarSepStorage*). Off-ramp conditions are halted whenever storage is projected to be above 200 TAF.

7.7.1.2.1 American Seepage

American Seepage is the fraction of lower American River flow that is lost to groundwater. It is set equal to *Supply and Resources\River\American River\Reaches\Below REG American at Fair Oaks:Groundwater Outflow Fraction*.

7.7.1.2.2 Chinook Redd Protection

minflowJanFeb_min

The modified FMS is designed to avoid dewatering the eggs of anadromous salmonids in their spawning nests (“redds”). The protections in the modified FMS applied to reservoir operations include that during January and February, the minimum release requirement (MRR) is limited at 70 percent of the December MRR.

7.7.1.2.3 Dec

Dec is the FMS flow requirement for the month of December. *Dec* is set equal to *OctDecIndexFlow*. The variable only has non-zero values for the month of December. There are no prescriptive adjustments in December.

7.7.1.2.4 EODec_Target

End of December Folsom Storage Target. Set at 275 TAF as per discussions with Reclamation. The 275 value for the planning minimum was used as a modeling placeholder, while actual operations would be determined through real time evaluation between Reclamation and the Water Forum.

7.7.1.2.5 *EOMay_Target*

Final variable for setting End of May Storage target for Folsom Lake.

7.7.1.2.6 *EOMay_Target_init*

Lookup variable for End of May Storage target for Folsom based on American River Index. Set at 900 for ARI values greater than or equal to 2200. It is linearly interpolated from 0 TAF at ARI value of 0, to 900 TAF at ARI value of 2200.

7.7.1.2.7 *Evap Folsom_JunDec*

Evap_Folsom

Evap_Folsom is an estimate of the cumulative evaporation from Folsom Lake from the current month through the end of September based on *Evap_coef* and the previous end-of-month storage.

Evap_coef_monthly

Evap_coef_monthly is the ratio of evaporation to storage.

Evap_Folsom_monthly

Evap_Folsom is an estimate of the current month's evaporation from Folsom Lake based on *Evap_coef_monthly* and the previous end-of-month storage.

Evap_coef

Evap_coef_monthly is the ratio of cumulative evaporation to storage.

7.7.1.2.8 *FMS 2008*

FMS 2008 is the final minimum flow requirement on the lower American River below Nimbus Dam when *Key\BiOp2019_ITP2020\FMS* has a value of '0'. For all but critical years, *FMS 2008* is equal to the components *Oct, Nov, Dec, JanFeb, MarMay, JunAug*, and *Sep*.

When the March-November unimpaired inflow to Folsom Lake is less than 400 TAF, flow requirements are based on the conference year provisions *OfframpConfYrflow*. Additionally, an off-Ramp condition applies if Folsom Lake storage is forecasted to fall below 200 TAF in any of the following 12 months. The year-round off-ramp condition is reassessed each month but continues in effect until Folsom Lake storage exceeds 200 TAF and is forecasted to remain above 200 TAF for the following 12 months. Flow requirements under this off-ramp provision are the same as for conference years.

7.7.1.2.9 *FMS VA*

FMS VA is the minimum flow requirement on the lower American River below Nimbus Dam based on the 2017 Modified Flow Management Standard and is active when *Key\BiOp2019_ITP2020\FMS* has a value of '1'. *FMS VA* is equal to *Other\Ops\Flow Requirements\American\FMS\Nimbus\minflowFMPAMer*, unless the specified release would be insufficient to meet the sum of D893 requirements and estimated diversions between Nimbus Dam and H Street.

7.7.1.2.10 FRI

FRI is the combined carryover storage in Folsom, French Meadows, Hell Hole, and Union Valley reservoirs. It is used in the calculation to establish minimum flow requirements for the months of October, November, and December (*OctDecIndexFlow)*.

7.7.1.2.11 JanFeb

JanFeb is the FMS flow requirement for the months of January and February. The flow requirement is set based on the SRI, the previous month's flow standard, and storage in Folsom Lake. JanFeb includes a prescriptive storage adjustment. When the end-of-December Folsom Lake storage is less than 300 TAF, the January flow requirement is 85% of that for December. When the end-of-January Folsom Lake storage is less than 350 TAF, the February flow requirement is 85% of that for January.

BelFldCurve

BelFldCurve is a flag indicating whether Folsom Lake storage is below flood control. If Folsom storage is below flood control, then the variable is set to '1', otherwise it is set to '0'. It is used in the calculation of *JanFeb*.

7.7.1.2.12 JunAug

JunAug is the FMS flow requirement for the months of June through August. The flow requirement is set based on the value of *IndexFlow*, *FlowReq_adj*, and the previous month's flow standard. *JunAug* includes a prescriptive storage adjustment based on the forecasted end-of-September Folsom Lake Storage. When the forecasted end-of-September storage is less than 300 TAF, then the flow requirement is the lesser of the IFII Index Flow or a storage-based flow requirement that results in Folsom Lake carryover storage of 300 TAF.

EoMayStorageEst

EoMayStorageEst is equal to *Inflow_est* less *Diversions_est* less *Evap_est*.

> *Diversions_est* is an estimate of cumulative diversions from Folsom and Natoma from June through September.
>
> *Evap_est* is an estimate of Folsom Lake cumulative evaporation from June through September.
>
> *FMSreqsum* is an estimate of FMS cumulative flow requirements from June through September.
>
> *Inflow_est* is an estimate of cumulative inflow to Folsom Lake from June through September.

Flowreq_adj

Flowreq_adj is a function of the *IndexFlow* and the estimated end of September storage in Folsom Lake.

IndexFlow

IndexFlow is a function of *InflowForecast*.

InflowForecast

InflowForecast is the estimate inflow to Folsom Lake from May through September.

7.7.1.2.13 JunSepOffRamp

JunSepOffRamp is currently not used.

7.7.1.2.14 MarMay

MarMay is the FMS flow requirement for the months of March through May. The flow requirement is set based on the value of *IndexFlow*, *FlowReq_adj*, and the previous month's flow standard. *MarMay* includes a prescriptive storage adjustment based on the forecasted end-of-May storage. When the forecasted end-of-May storage is less than 700 TAF, then the flow requirement is the lesser of the IFII Index Flow or the February flow requirement.

EoMayStorageEst

EoMayStorageEst is equal to *Inflow_est* less *Diversions_est* less *Evap_est*.

> *Diversions_est* is an estimate of cumulative diversions from Folsom and Natoma from March through May.
>
> *Evap_est* is an estimate of Folsom Lake cumulative evaporation from March through May.
>
> *FMSreqsum* is an estimate of FMS cumulative flow requirements from March through May.
>
> *Inflow_est* is an estimate of cumulative inflow to Folsom Lake from March through May.

Flowreq_adj

Flowreq_adj is a function of the *IndexFlow* and the estimated end of May storage in Folsom Lake.

IndexFlow

IndexFlow is a function of *InflowForecast*.

InflowForecast

InflowForecast is the estimate inflow to Folsom Lake from May through September.

7.7.1.2.15 MFMS Max Release

MFMS Max Release indicates the maximum Folsom release without changing the carryover storage target. When active, the maximum release is enforced through a soft constraint using a dummy network (see section 3.17) and associated UDC (see section 8.3.3) designed to minimize releases above the maximum release. The maximum release constraint is disabled in the current model version but may be enabled by changing the value of *Folsom_max_release*, as described below.

Folsom_max_release

Folsom_max_release controls whether the MFMS maximum Folsom release is implemented. To enable the constraint, *Folsom_max_release* should be configured to take on the value of *Folsom_max_release_calc*; to disable the constraint, it should be set equal to a large number, such as 99999.

Folsom_max_release_calc

Folsom_max_release_calc is the calculation of flow from end of month storage less carryover storage plus minimum release requirement.

Folsom_carryover

Folsom_carryover represents minimum storage required at the end of a given month.

Folsom_init

Folsom_init represents the initial estimate of end of month Folsom storage. In the current month, the initial estimate is defined as previous month storage – inflow – diversion – evaporation – minimum inflow requirement.

Folsom_carryover_init_JunNov

Maximum of either top of conservation or end of December storage target – available water in current month + minimum required flow.

Folsom_carryover_init_FebApr

Maximum of either top of conservation or end of May storage target – available water in current month + minimum required flow.

7.7.1.2.16 minflowFMP_tmp

Minimum flow requirement (cfs) for months other than January based on American River Index (TAF) as per Modified Flow Management Standard shown in Table 7-35.

Table 7-35 Minimum Flow Requirement Based on Sacramento River Index

February through March					
ARI (TAF)	0	800	1000	1958	>1958
MRR (cfs)	500	500	800	1750	1750
April through June					
ARI (TAF)	0	800	1000	2210	>2210
MRR (cfs)	500	500	800	1500	1500
July through September					
ARI (TAF)	0	800	1000	1200	>=1958
MRR (cfs)	500	500	800	1500	1750
October through December					
ARI (TAF)	0	800	1500	2210	>=2210
MRR (cfs)	500	500	800	2000	2000

7.7.1.2.17 minflowFMPJan_tmp

Minimum flow requirement (cfs) in January based on Sacramento River Index (MAF) as given in Modified Flow Management Standard shown in Table 7-36.

Table 7-36 Minimum Flow Requirement for January Based on Sacramento River Index

SRI (MAF)	0	5.5	7.8	11.5	>11.5
MRR (cfs)	500	500	800	1750	1750

Key:
cfs = cubic feet per second, MRR = minimum release requirement, SRI = Sacramento River Index, TAF = thousand acre-feet, MAF = million acre-feet.

7.7.1.2.18 Nimbus

Nimbus defines the Minimum Release Requirement (MRR) from Nimbus for the Modified Flow Management Standard.

MinflowFMPAMer

MinflowFMPAMer represents the calculation of the minimum release requirement from Nimbus.

minflowFMPAMer_FebMar_init

Minimum flow requirement (cfs) in February through March based on American River Index (TAF) as given in the Modified Flow Management Standard shown in Table 7-36.

minflowFMPAMer_AprJun_init

Minimum flow requirement (cfs) in April through June based on American River Index (TAF) as given in the Modified Flow Management Standard shown in Table 7-36.

minflowFMPAMer_JulSep_init

Minimum flow requirement (cfs) in July through September based on American River Index (TAF) as given in the Modified Flow Management Standard shown in Table 7-36.

minflowFMPAMer_Oct_init

Minimum flow requirement (cfs) in October based on American River Index (TAF) as given in the Modified Flow Management Standard shown in Table 7-36.

minflowFMPAMer_NovDec

Minimum flow requirement (cfs) in November through December based on American River Index (TAF) as given in the Modified Flow Management Standard shown in Table 7-36.

<u>minflowFMPAMer_FebMar</u>

Minimum of either 1750 or *minflowFMPAMer_FebMar_init.*

<u>minflowFMPAMer_AprJun</u>

Minimum of either 1500 or *minflowFMPAMer_AprJun_init*.

<u>minflowFMPAMer_JulSep</u>

Minimum of either 1750 or *minflowFMPAMer_JulSep_init.*

<u>minflowFMPAMer_Oct</u>

Minimum of either 1500 or *minflowFMPAMer_Oct_init.*

7.7.1.2.19 Nov

Nov is the FMS flow requirement for the month of November. Nov is calculated as a function of *OctDecIndexFlow*. It includes a Chinook salmon spawning flow progression prescriptive adjustment if the October through December FRI-based Index Flows are higher than 1,500 cfs.

The Chinook salmon spawning flow progression consists of two incremental step increases in flows. The first step (scheduled to occur on November 2) will increase lower American River flows from 1,500 cfs up to the Index Flow minus 250 cfs. Therefore, the first step increase will not occur unless the Index Flow is higher than 1,750 cfs. The second step increase in flow will occur seven days after the first step and will increase lower American River flows up to the Index Flow.

7.7.1.2.20 Oct

Oct is the FMS flow requirement for the month of October. During this month, the Index Flow (*OctDecIndexFlow)* will be between 800 cfs and 2,000 cfs based on *FRI*. *Oct* is calculated as the minimum of *OctDecIndexFlow* and 1,500 cfs. There are no prescriptive adjustments in September.

7.7.1.2.21 OctDecIndexFlow

OctDecIndexFlow is used to define October to December minimum instream flow requirements. The October 1 through December 31 index flows range from 800 cfs to 2,000 cfs. If *FRI* is greater than or equal to 848 TAF, then the Index Flow will be 2,000 cfs. If the FRI is between 746 TAF and 796 TAF, then the Index Flow will be 1,750 cfs. If the FRI is less than or equal to 600 TAF, then the Index Flow will be 800 cfs.

7.7.1.2.22 Offramp storage

The FMS includes non-discretionary adjustments to the Index Flows based on forecasted Folsom Lake storage. *Offramp storage* is computed as the sum of its components *OctDecStorageForecast, JanFebStorageForecast*, and *MarSepStorageForecast.*

<u>FMSreqsum</u>

FMS reqsum is the cumulative value of past FMS flow requirements beginning in March through the current month.

Mar is the FMS minimum flow requirement in month of March, computed in March.

MarApr is the sum of FMS minimum flow requirement for months of March and April, computed in month of April.

MarMay is the sum of FMS minimum flow requirement for months of March, April and May, computed in month of May.

Jun is the FMS minimum flow requirement for month June, computed in month of June.

JunJul Sum of FMS minimum flow requirement for months of June and July, computed in month of July.

JunAug Sum of FMS minimum flow requirement for months of June to August, computed in month of August.

Sep is the FMS minimum flow requirement in month of September, computed in September.

JanFebStorageForecast

JanFebStorageForecast is the forecasted storage in Folsom Lake for months of January and February.

MarSepStorageForecast

MarSepStorageForecast is the forecasted storage in Folsom Lake for months of March through September

MarSeptIndexflow

Forecasted cumulative FMS MFR for March to September

OctDecStorageForecast

Forecasted end of December storage in Folsom

7.7.1.2.23 OffRamp_MinFlow

Off-ramp criteria are triggered if forecasted Folsom Lake storage at any time during the next 12 months is less than 200 TAF. From January 1 through September 15, the minimum flow requirement may be reduced to as low as 250 cfs and from September 16 through December 31, the minimum flow requirement may be reduced to as low as 500 cfs. This variable gives the off-ramp minimum flow requirement calculated by linear interpolation.

7.7.1.2.24 OfframpConfYrflow

A Conference Year is designated when the predicted March through November unimpaired inflow (using the median March through September unimpaired inflow forecast plus 60 TAF) to Folsom Lake is less than 400 TAF. The Conference Year designation is reassessed each month, but continues in effect unless any one of the following occurs:

- Forecasted March through November unimpaired inflow to Folsom Lake exceeds 400 TAF.
- FRI is higher than 300 TAF.
- Folsom Lake releases are made for flood control purposes.
- SRI is higher than or equal to 15.7 MAF, indicating an above normal or wet year.

- IFII is higher than 250 TAF.

Conference Year minimum flow requirements, *OfframpConfYrflow*, are similar to those of D-893. From January 1 through September 15, no less than 250 cfs between Nimbus Dam and the mouth of the lower American River and from September 16 through December 31, no less than 500 cfs between Nimbus Dam and the mouth of the lower American River.

7.7.1.2.25 Pulse Flow

A spring flow is provided in the lower American River to provide an emigration cue to the fall-run Chinook salmon and steelhead before relatively low flow conditions and associated unsuitable thermal conditions later in the spring in the American River and downstream in the Sacramento River. The pulse flow is the maximum of the MRR, Steelhead protection requirements or the Chinook protection requirements. The pulse flow event should be provided only when the MRR from March 1 through March 31 ranged from 1,000 cfs to 1,500 cfs. This range of MRRs during this time period generally corresponds to dry and below normal water year types. The peak magnitude of the pulse flow should be three times the MRR base flows (pre-pulse flows), not to exceed a peak magnitude of 4,000 cfs. The pulse flow event should range in duration from 6 to 7.5 days, depending upon the initial MRR base flows (pre-pulse flows). Following variables are used to apply the pulse flow requirement in SacWAM.

MarPulseFlow

MarPulseFlow only has non-zero values in March and when *minflowFMPMarFlag* has a value of '1'. In this case it is calculated as the minimum of 4,000 cfs and 3 times *minflowFMPFebMay_tmp*.

MarPulseVol

MarPulseVol is the volume of the pulse flow. The pulse flow has a two-day peak, followed by reduction of 500 cfs per day to minimum release requirement.

minflowFMP_AprJun_Pulse_Red

If a pulse flow is triggered in March, the following months pulse flow volume is reduced to accommodate pulse flow volume of March.

minflowFMP_Mar_Pulse

MinflowFMP_Mar_Pulse is the *MarPulseVol* when *MinflowFMPFebMay_tmp* is in between 1,000 cfs and 1,500 cfs.

minflowFMPFebMay_tmp

MinflowFMPFebMay_tmp is the minimum flow requirement for corresponding months.

minflowFMPMarFlag

minflowFMPMarFlag is assigned a value of '1' when a pulse fow release is required. In March, a pulse flow is required when *minflowFMPFebMay_tmp is between 1,000 cfs and 1,500 cfs.* Once triggered *minflowFMPMarFlag* is assigned a value of '1' through May.

7.7.1.2.26 Sep

Sep is the FMS flow requirement for the month of September. It is equal to *IndexFlow* except in conference years when it is set equal to *OfframpConfYrflow*. There are no prescriptive adjustments in September.

IndexFlow

IndexFlow is the cumulative FMS MFR value for October 1 to September 15.

7.7.1.2.27 Steelhead Dewatering

Redd dewatering protective adjustments (RDPAs) are imposed on the MRR to limit potential redd dewatering due to reductions in the MRR from January through May. The RDPAs aim at limiting the amount the MRR can be reduced during this period. The Modifed FMS includes two RDPAs: (1) the Chinook salmon RDPA in January and February; and (2) the steelhead RDPA in February through May.

MIF_RDPA_base

MIF_RDPA_base has non-zero values for the months March throughMay. In March, *MIF_RDPA_base* is set equal to previous month's value of *Other\Ops\Flow Requirements\American\FMS\Nimbus\minflowFMPAMer*. Thereafter the previous month's flows must be maintained.

minflowFebMay_min

minflowFebMay_min is a function of *MIF_RDPA_base* and is used to establish the minimum flow requirements on th lower American River from February through May.

7.7.1.3 Hodge

As part of the Water Forum Agreement, the City of Sacramento agreed to limits its diversions from the American River to its Fairbairn WTP when river flows are below the 'Hodge Flow Criteria' issued by Judge Hodge in the *Environmental Defense Fund v. East Bay Municipal Utility District* litigation. Under the Water Forum Agreement, the city may divert up to 310 cfs, provided flows are above the Hodge Flow Criteria. When American River flows fall below these criteria, diversions are restricted to 100 cfs - 155 cfs based on the time of year.

In SacWAM, if flows (*Hodge flow*) are below the thresholds (*Hodge threshold*), a diversion limit is applied at the Fairbairn WTP (see Table 7-37 for thresholds and diversion limits). In cases where demands are greater than the diversion limit, additional water is diverted at the City's Sacramento River WTP. The Hodge decision is difficult to dynamically implement in SacWAM because Reclamation does not operate Folsom Lake to meet the Hodge flows. SacWAM reads input time series data (*data\WYT\IFII.csv*) that are an estimate of the flows below the Fairbairn intake based on a previous model simulation. The parameter *Hodge* is set to a value of 1 if the estimated flows are less than *Hodge threshold*, otherwise *Hodge* is set to zero. This parameter subsequently determines the maximum flow through the diversion arc *Fairbairn WTP*.

Table 7-37. Hodge Decision Flow Thresholds and Pumping Limits

Month	Threshold Flow at Fairbairn (cfs)	Diversion Limit at Fairbairn WTP (cfs)
October	1,879	100
November-December	2,000	100
January-February	2,000	120
March-May	3,000	120
June	3,000	155
July-August	1,750	155
September	1,750	120

Key:

cfs = cubic feet per second, WTP = water treatment plant.

7.7.1.3.1 Hodge Flow

Hodge Flow is pre-processed time series data read from the file *Data\WYT\IFII.csv*. The data represents the simulated flow in the American River at the Fairbairn intake. These flows are taken from a previous version (SacWAM_1.2) model run.

7.7.1.3.2 Hodge Threshold

Hodge Threshold are 12 monthly values of American River flow below which diversion limits apply.

7.7.2 Bear River

Minimum flow requirements are specified in South Sutter WD's water rights for both power and consumptive uses, and in Article 29 of the current FERC license. SacWAM simulates flow requirements both below Camp Far West Dam and below the downstream diversion dam.

7.7.2.1 BlwCampFarWest

7.7.2.1.1 MinFlow

Minimum flows below the diversion dam are 25 cfs from April 1 to June 30, and 10 cfs from July 1 to March 31 (*Other\Ops\Flow Requirements\Bear\BlwCampFarWest\ MinFlow*). During times when inflows into the reservoir are less than the downstream minimum flow, the total inflow must be bypassed. These requirements are constant every year.

In February 2000, DWR, South Sutter WD, and Camp Far West ID signed the Bear River Agreement (DWR, 2000c) to settle responsibilities of the two districts and other Bear River water right holders to implement the objectives of the 1995 Bay-Delta Plan. Under this agreement, South Sutter WD is obligated to release 4,400 acre-feet of water in dry and critical water years (Sacramento Valley 40-30-30 index), provided adequate water is stored in Camp Far West Reservoir. If the April 1 storage in Camp Far West is less than 33,255 acre-feet, the release volume is reduced to the difference between the April 1 storage and 33,255 acre-feet. No water need be released if the April 1 storage is below 28,855 acre-feet. Releases are met by increasing flows by 37 cfs for up to sixty days during July to September. SacWAM assumes release of settlement water begins July 16 and continues until a total of 4,400 acre-feet (or a lesser amount depending on April 1 storage) has been released (*Other\Ops\Flow Requirements\Bear\BlwCampFarWest\BDSA\FlowReq*). Settlement water is in addition to South Sutter WD FERC flow requirements described above.

7.7.3 Clear Creek

SacWAM defines a flow requirement on Clear Creek below Whiskeytown Reservoir according to the 1960 Memorandum of Agreement (MOA) with CDFW, flow and temperature requirements under the USFWS Anadromous Fish Restoration Program (AFRP), and the 2009 NMFS BiOp. The flow requirement (*BlwWKTN*) is the maximum of the MFRs set by the various regulations. The minimum flow schedules are summarized in Table 7-38. 1960 MOA flows are in branch *BlwWKTWN\MinFlow*. AFRP flows (*BlwWKTWN\CVPIA B2*) are released under authority CVPIA Section 3406(b)(2). The AFRP also has temperature requirements of 60 degrees F during July-Sep, so flow releases that will maintain those temperatures are also implemented (*BlwWKTWN\Temperature).* The values of these requirements were obtained from Derek Hilts and Matt Brown at USFWS. In addition to these flows, the 2009 NMFS BiOp requires a flow of 600 cfs for six days in May. Thus, the flow requirement below Whiskeytown in May is a daily weighted average of these pulse flows (*BlwWKTWN\NMFS)* and the maximum of other applicable requirements.

Table 7-38. Clear Creek Minimum Flow Requirements Below Whiskeytown

Regulation	Flow Requirement (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1960 MOA Shasta Critical years	30	70		30								
1960 MOA Otherwise	50	100		50								
AFRP (CVPIA b(2) flows)	200								150	85		150
AFRP flows for temperature	0								70	100		70

Key:
AFRP=Anadromous Fish Restoration Program, CVPIA= Central Valley Project Improvement Act, MOA=Memorandum of Agreement.

7.7.4 Delta Outflow

SacWAM includes Delta standards that are specified in the 1995 Bay-Delta Plan (SWRCB, 1995) and D-1641[42] (SWRCB, 2000). Modeled standards for the Delta include the following:

- Net Delta Outflow Index (NDOI), expressed as a flow.
- Salinity standards at Emmaton and Jersey Point expressed in electrical conductivity (EC)
- X2 location, expressed in kilometers.

The NDOI and the outflow requirements to meet the salinity and X2 standards, combine to determine the minimum required net Delta outflow (*OutflowRequirement*). The Net Delta Outflows to meet water quality objectives for fish and wildlife beneficial uses as defined under D-1641 are summarized in Table 7-39. These flow requirements are adjusted in January according to the Eight Rivers Index and in May and June according to the Sacramento Valley Index. Flow requirements are increased to 6,000 cfs in January if the Eight Rivers Index exceeds 800 TAF (*Jan_adjustment*). Flow requirements are decreased to 4,000 cfs in May and June if the Sacramento Valley Water Year Index is less than 8.1 MAF (*MayJun_adjustment*).

Outflow requirements to meet Delta salinity standards are discussed in detail in Section 7.6.

Table 7-39. Sacramento River Minimum Net Delta Outflow - D-1641

Mokelumne River Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	3,000	3,500		4,500	7,100					4,000	3,000	3,000
Dry	4,000	4,500			7,100					5,000	3,500	3,000
Below Normal	4,000	4,500			7,100					6,500	4,000	3,000
Above Normal	4,000	4,500			7,100					8,000	4,000	3,000

[42] Decision 1641 (or D-1641) is the implementation plan for the 1995 Bay-Delta Plan, with respect to the operation of California's State Water Project and the USBR's Central Valley Project. D-1641 was adopted by the State Water Board in December 1999 and subsequently revised in March 2000. It includes water quality objectives to protect beneficial uses for agriculture, municipal and industrial, and fish and wildlife in the Delta. It also defines water quality and flow objectives for various compliance monitoring stations throughout the Delta.

Wet	4,000	4,500	7,100	8,000	4,000	3,000

Key:
cfs = cubic feet per second

7.7.5 Feather River

Flow requirements on the Feather River are governed by a 1983 Memorandum of Understanding (MOU) between DWR and CDFW (formerly California Department of Fish and Game) and a 2010 State Water Board order (WQ 2010-016). The 1983 MOU establishes MFRs on the Feather River within the low-flow channel (i.e., main channel of Feather River below Oroville and above Thermalito Afterbay outlet) and the high-flow channel (i.e., Feather River below Thermalito Afterbay outlet and Verona at the confluence with the Sacramento River). Under WQ 2010-016 the low-flow channel requirements (*LowFlowChannel*) were increased from 600 cfs year-round to 800 cfs from September 9 to March 31, and 700 cfs the remainder of the time. The flow requirement in the high-flow channel (*DFG_DWR 1983 MOA*) varies from 1000 to 1700 cfs, depending on the month and on whether the April-to-July unimpaired inflow to Oroville (*DFG_DWR 1983 MOA/PrevAprJulRunoff*) is less than 55 percent of normal (*DFG_DWR 1983 MOA/PercentOfNormal*). Under certain low storage conditions in Oroville these requirements are lowered to an off-ramp level of flows. The storage criteria for this off-ramp is not explicitly modeled in SacWAM, but a time series of off-ramp periods is taken from CalSim II (*DFG_DWR 1983 MOA/Offramp*). These high-flow channel requirements are summarized in Table 7-40. A final aspect of the high-flow channel requirement is that if the highest peak streamflow between October 15 and November 30 is > 2500 cfs because of project operations and not flood flow, then the requirement for November to March is increased to 500 cfs below that peak flow (*Fall based HFC minflow*). In order to avoid this requirement, high-flow channel flows are constrained to be < 4000 cfs in October and 2500 cfs in November, except when Oroville is spilling (see *Fall based HFC minflow /HighFlow Channel max* and *User-Defined LP Constraints\Oroville Fall Operations*). Lastly, flows at the mouth of the Feather (*Verona*) are also maintained at the flow levels in Table 7-40.

Table 7-40. Feather River Minimum Flow from Thermalito Afterbay Outlet to Mouth

Forecasted April through July Unimpaired Runoff (percent of normal)	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
55 percent or greater	1,700						1,000					
Less than 55 percent	1,200					1,000						
Off-ramp flows	900					750						

Key:
cfs = cubic feet per second

7.7.6 Mokelumne River

Ther are two major water development projects within the Mokelumne River watershed: PG&E's Mokelumne River Hydroelectric Project (FERC Project 137) located on the North Fork and EBMUD's lower Mokelumne River Project (FERC Project 2916) on the mainstem. Both projects have flow requirements specified in their FERC licenses.

7.7.6.1 Mainstem

Flow requirements for the lower Mokelumne River below Camanche Dam are defined in the Mokelumne River Joint Settlement Agreement (JSA) (FERC Project 2916; Joint Settlement Agreement, 1996). These flow requirements are set below Camanche Dam (*blw Camanche*) and at Woodbridge (*Woodbridge*).

7.7.6.1.1 blw Camanche

Flow requirements below Camanche Reservoir for the months November through March (*blw Camanche\NovMar*; Table 7-41) are based on storage in Pardee and Camanche Reservoirs at the beginning of November (*blw Camanche\OctStorage*; Table 7-42). Flow requirements for the months April through October (*blw\AprOct*; Table 7-41) are based on the Mokelumne River hydrologic WYT (discussed in Section 7.8.11 on Hydrologic Indices in the Mokelumne). Additional flow (*blw Camanche\AprOct\Additional*) is possible in May normal and wet years when storage in the reservoirs is not far below the storage capacity less the flood space requirement (*blw Camanche\BMAS*).

Table 7-41. Mokelumne River Minimum Flow below Camanche Dam

<table>
<tr><th rowspan="2">Mokelumne River Water-Year Type</th><th colspan="12">Minimum Flow (cfs)</th></tr>
<tr><th>Oct[1]</th><th>Nov[2]</th><th>Dec[2]</th><th>Jan[2]</th><th>Feb[2]</th><th>Mar[2]</th><th>Apr[1]</th><th>May[1]</th><th>Jun[1]</th><th>Jul[1]</th><th>Aug[1]</th><th>Sep[1]</th></tr>
<tr><td>Critically Dry</td><td>115</td><td colspan="6">130</td><td colspan="5">100</td></tr>
<tr><td>Dry</td><td colspan="8">220</td><td colspan="4">100</td></tr>
<tr><td>Below Normal</td><td colspan="9">250</td><td colspan="3">100</td></tr>
<tr><td>Normal and Above Normal</td><td colspan="9">325</td><td colspan="3">100</td></tr>
</table>

Notes:
1 Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by annual water yield.
2 Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by beginning-of-November storage in Pardee and Camanche reservoirs.

Key:
cfs = cubic feet per second

Table 7-42. Mokelumne River Water-Year Type Based on Beginning-of-November Reservoir Storage

Water-Year Type	Beginning of November Pardee/Camanche Storage
Critically Dry	269 TAF or less
Dry	270 TAF to 399 TAF
Below Normal	400 TAF to Max Allowable
Normal/Above Normal	Max Allowable

Key:
TAF = thousand acre-feet

7.7.6.1.2 Woodbridge

The same as below Camanche, the flow requirements at Woodbridge (*Woodbridge*) for the months November through March (*Woodbridge\NovMar*; Table 7-43) are based on storage in Pardee and Camanche Reservoirs at the beginning of November (*blw Camanche\OctStorage*); and for April through October (*Woodbridge\AprOct*) on Mokelumne River hydrologic WYT (discussed in Section 7.8.11 on Hydrologic Indices in the Mokelumne).

Table 7-43. Mokelumne River Minimum Flow at Woodbridge

<table>
<tr><th rowspan="2">Mokelumne River Water-Year Type</th><th colspan="12">Minimum Flow (cfs)</th></tr>
<tr><th>Oct†</th><th>Nov*</th><th>Dec*</th><th>Jan*</th><th>Feb*</th><th>Mar*</th><th>Apr†</th><th>May†</th><th>Jun†</th><th>Jul†</th><th>Aug†</th><th>Sept†</th></tr>
<tr><td>Critically Dry</td><td>45</td><td colspan="6">75</td><td colspan="5">15</td></tr>
<tr><td>Dry</td><td colspan="6">80</td><td colspan="2">150</td><td colspan="4">20</td></tr>
<tr><td>Below Normal</td><td colspan="6">100</td><td>150</td><td colspan="2">200</td><td colspan="3">20</td></tr>
<tr><td>Normal and Above Normal</td><td colspan="6">100</td><td>150</td><td colspan="2">300</td><td colspan="3">25</td></tr>
</table>

Notes:

†Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by annual water yield.
*Indicates minimum flow below Camanche is based on the Mokelumne River water-year type as determined by beginning-of-November storage in Pardee and Camanche reservoirs.

Key:
cfs = cubic feet per second

7.7.6.2 North Fork Mokelumne River

FERC license P-137 defines flow requirements at the following locations:

- Bear River below Lower Bear Dam
- Cole Creek below Bear River Tunnel Diversion Dam
- North Fork Mokelumne River below Salt Springs Dam
- North Fork Mokelumne River below Tiger Afterbay Dam
- North Fork Mokelumne River below Electra Diversion Dam

The flow requirements typically consist of a minimum flow component and additional pulse flow and recreational requirements. Flow requirements vary by month and the North Fork Mokelumne water year type. SacWAM includes these flow requirements except for Cole Creek, which is not represented in the model.

7.7.6.2.1 LowerBearDam

Flow requirements below Lower Bear Dam, as simulated in SacWAM, are presented in Table 7-44.

Table 7-44. Mokelumne River Minimum Flows below Lower Bear Dam

North Fork Mokelumne Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	4	4	4	4	6	6	10	8	6	4	4	4
Dry	4	6	6	6	8	10	25	20	8	6	4	4
Below Normal	4	6	8	10	10	15	25	40	20	10	6	4
Above Normal	6	8	10	14	14	20	30	70	40	15	6	6
Wet	6	15	15	20	20	25	50	110	70	30	15	6

Key:
cfs = cubic feet per second

7.7.6.2.2 SaltSpringsDam

Flow requirements below Salt Springs Dam, as simulated in SacWAM, are presented in Table 7-45.

Table 7-45. Mokelumne River Minimum Flows Below Salt Springs Dam

North Fork Mokelumne Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	15	20	20	20	25	30	40	60	40	20	15	15
Dry	20	20	20	25	30	40	60	70	40	20	20	20
Below Normal	20	20	25	40	40	70	110	210	160	30	20	20
Above Normal	20	20	30	50	50	90	170	430	230	30	20	20
Wet	20	43	43	75	110	135	375	930	720	145	20	20

Key:
cfs = cubic feet per second

7.7.6.2.3 TigerCreekDiversionDam

Flow requirements below Electra Diversion Dam, as simulated in SacWAM, are presented in Table 7-46.

Table 7-46. Mokelumne River Minimum Flows Below Tiger Afterbay Dam

North Fork Mokelumne Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	15	20	20	20	25	30	40	60	40	20	15	15
Dry	20	20	20	25	30	50	80	95	50	20	20	20
Below Normal	20	25	30	40	40	80	135	250	180	35	20	20
Above Normal	20	20	40	60	60	110	190	490	270	40	20	20
Wet	20	50	50	90	120	150	400	980	850	145	30	20

Key:
cfs = cubic feet per second

7.7.6.2.4 ElectraDiversionDam

Flow requirements below Electra Diversion Dam, as simulated in SacWAM, are presented in Table 7-47.

Table 7-47. Mokelumne River Minimum Flows Below Electra Diversion Dam

North Fork Mokelumne Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	15	20	20	20	25	30	40	60	40	20	15	15
Dry	20	20	20	25	30	50	80	95	50	20	20	20
Below Normal	20	25	30	40	40	80	135	250	180	35	20	20
Above Normal	20	20	40	60	60	110	190	490	270	40	20	20
Wet	20	50	50	90	120	150	400	980	850	145	30	20

Key:
cfs = cubic feet per second

7.7.6.3 Lodi Rqmnts

The Lodi Decrees consist of a series of collective judgments defining the relative rights of Lodi, EBMUD, and PG&E. Under the Lodi Decree, PG&E is bound to a strict set of operating rules governed by storage and by precipitation. North Fork Mokelumne River flows below Electra Diversion Dam and Powerhouse have been established by two judgments, Calaveras Case No. 1950 and San Joaquin Case 22415. These requirements are included in SacWAM.

The baseflow requirement below Electra Powerhouse (*ElectraPowerhouse*) is 300 cfs in May, June, and July and 200 in other months (*Lodi Rqmnts\Base*). Flow requirements are never below base values. The actual flow requirement is the maximum of the base and other monthly values, which are determined by whether PG&E storage in the previous May in the reservoirs of the Upper Mokelumne (*PGandEMayStorage*) was above 130 TAF (*Lodi Rqmnts\HiMayStorage*) or below 130 TAF (*Lodi Rqmnts\LoMayStorage*). The resulting flow requirements are presented in Table 7-48.

Table 7-48. Lodi Flow Requirements

<table>
<tr><th rowspan="2">Upper Mokelumne Reservoir Storage</th><th colspan="12">Minimum Flow (cfs)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td>Hi May storage (> 130 TAF)</td><td colspan="3">500</td><td>400</td><td colspan="3">200</td><td>300</td><td colspan="4">500</td></tr>
<tr><td>Low May storage (< 130 TAF)</td><td colspan="7">200</td><td colspan="5">300</td></tr>
</table>

Key:
cfs = cubic feet per second, TAF = thousand acre-feet

7.7.7 Sacramento River

SacWAM defines a flow requirement on the Sacramento River below Keswick Dam (*BlwKeswick*). The final requirement is the minimum of a series of flow requirements described here. Table 7-49 shows minimum flows under State Water Board WR90-5 (*WR90_5*). A flow requirement of 3250 cfs all year-round is also implemented in the model (*NMFS BiOp*), based on minimum flows in the 2009 NMFS BiOp and standard operations to meet downstream temperature requirements under WR90-5 and the 2009 NMFS BiOp. 3,250 cfs is a standard value used in the CalSim II model to represent minimum flows at Keswick for meeting temperature standards. Lastly, under CVPIA (b)(2) there are flow releases that are implemented in November and December under higher storage conditions. These requirements are 4,000 cfs in November, and the lower of 4,000 cfs or 75% of November flow in December. Values for these requirements are from Derek Hilts (USFWS). These requirements are implemented in WEAP (*CVPIA_B2*) when Shasta storage in the prior September is > 2,400 TAF.

Table 7-49. Sacramento River Minimum Flow below Keswick: State Water Board WR90-5

Sacramento Basin Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	2,800		2,000			2,300						2,800
Otherwise	3,250					2,300						3,250

Key:
cfs = cubic feet per second

Historically there has been a flow requirement of 5,000 cfs at Wilkins Slough to maintain flows for navigation (*NCP*). In order to conserve Shasta cold water pool storage for summer releases, the 2009 NMFS BiOp allows for relaxation of this requirement in lower storage conditions. Relaxation is done on a discretionary basis (i.e., no fixed rules have been defined), so in the model the requirement is relaxed when Shasta storage is lower than the thresholds shown in Table 7-50 (*NCP_base*). This operation approximately mimics the current operation in the CalSim II model. Because of the distance between Shasta Dam and Wilkins Slough and the unpredictability of downstream unregulated flows, CalSim II includes an increase in reservoir releases in some months to consider this uncertainty. This additional release requirement is included in SacWAM as a calibration factor (*Daily adjustment*) that can be turned on to facilitate comparisons to the CalSim II model. The default setting is to have this adjustment off.

Table 7-50. Sacramento River Minimum Flow for Navigation at Wilkins Slough

Shasta Storage (TAF) in April	Requirement (cfs)
<= 2,500	3,250
<= 3,500	3,500
<= 3,900	4,000
<= 4,100	4,500
Otherwise	5,000

Key:
cfs = cubic feet per second, TAF = thousand acre-feet.

State Water Board Decision 1641 includes flow requirements on the Sacramento River at Rio Vista as part of the suite of actions intended to protect water quality within the Delta. SacWAM implements these flow requirements according to Table 7-51 (*at Rio Vista*).

Table 7-51. Sacramento River Minimum Flow at Rio Vista - D-1641

Sacramento Basin Water-Year Type	Minimum Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Critically Dry	3,000	3,500	3,500	0								3,000
Otherwise	4,000	4,500	4,500	0								3,000

Key:
cfs = cubic feet per second

7.7.8 San Joaquin River

Parameters listed under the San Joaquin subbranch have been deactivated and are no longer used.

7.7.9 Trinity River

Trinity River flow requirements are based on the December 19, 2000, Trinity River Mainstem Record of Decision, which allocates 368.6 TAF to 815 TAF annually for Trinity River flows. These are contained in the parameter *BlwCLE* and are summarized in Table 7-52.

Table 7-52. Lewiston Dam Releases to the Trinity River

<table>
<tr><th rowspan="2">Trinity River Water-Year Type</th><th colspan="12">Minimum Flow (cfs)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td>Critically Dry</td><td>373</td><td colspan="5">300</td><td>600</td><td>1,498</td><td>783</td><td colspan="3">450</td></tr>
<tr><td>Dry</td><td>373</td><td colspan="5">300</td><td>540</td><td>2,924</td><td>783</td><td colspan="3">450</td></tr>
<tr><td>Normal</td><td>373</td><td colspan="5">300</td><td>477</td><td>4,189</td><td>2,120</td><td>1,102</td><td colspan="2">450</td></tr>
<tr><td>Wet</td><td>373</td><td colspan="5">300</td><td>460</td><td>4,709</td><td>2,526</td><td>1,102</td><td colspan="2">450</td></tr>
<tr><td>Extremely Wet</td><td>373</td><td colspan="5">300</td><td>427</td><td>4,570</td><td>4,626</td><td>1,102</td><td colspan="2">450</td></tr>
</table>

Key:
cfs = cubic feet per second, TAF = thousand acre-feet.

7.7.10 Yuba River

SacWAM sets flow requirements for the Yuba River near Smartville (*nr Smartville*) and at Marysville (*nr Marysville*) as specified in the Lower Yuba River Accord (YCWA, 2007). Flow schedule determinations begin in February and are updated through May based on refinements of the North Yuba Index. Thresholds for the flow schedules are summarized in Table 7-53 and Key:
cfs = cubic feet per second, TAF = thousand acre-feet.

Table 7-54. The North Yuba Index values are defined under Hydrologic Indices.

Table 7-53. Yuba River Minimum Flow near Smartville

<table>
<tr><th rowspan="2">North Yuba Index (TAF)</th><th colspan="12">Minimum Flow (cfs)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td><= 820</td><td colspan="6">700</td><td>350</td><td colspan="4">0</td><td>700</td></tr>
<tr><td>Otherwise</td><td colspan="2">600</td><td colspan="4">550</td><td>300</td><td colspan="4">0</td><td>500</td></tr>
</table>

Key:
cfs = cubic feet per second, TAF = thousand acre-feet.

Table 7-54. Yuba River Minimum Flow at Marysville

<table>
<tr><th rowspan="2">North Yuba Index (TAF)</th><th colspan="12">Minimum Flow (cfs)</th></tr>
<tr><th>Oct</th><th>Nov</th><th>Dec</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>Jun</th><th>Jul</th><th>Aug</th><th>Sep</th></tr>
<tr><td><= 693</td><td colspan="6">350</td><td>425</td><td>450</td><td>225</td><td colspan="2">150</td><td>350</td></tr>
<tr><td><= 820</td><td>400</td><td colspan="5">500</td><td>550</td><td>500</td><td colspan="4">400</td></tr>
<tr><td><= 920</td><td>400</td><td colspan="5">500</td><td colspan="2">750</td><td colspan="4">400</td></tr>
<tr><td><= 1,040</td><td colspan="6">500</td><td>700</td><td>900</td><td colspan="4">500</td></tr>
<tr><td><= 1,400</td><td colspan="5">500</td><td>700</td><td>750</td><td>1,000</td><td>650</td><td colspan="3">500</td></tr>
<tr><td>Otherwise</td><td colspan="5">500</td><td>700</td><td>1,000</td><td>2,000</td><td>1,500</td><td>700</td><td>600</td><td>500</td></tr>
</table>

Key:
cfs = cubic feet per second, TAF = thousand acre-feet.

7.7.10.1 NBB Carryover Storage

The parameter *NBB Carryover Storage* equals the previous end-of-September storage in New Bullards Bar Reservoir. The parameter is used to make a dry-year storage adjustment to the flow requirement at the Marysville gauge. The lower Yuba River Accord states:

- If the September 30 New Bullards Bar Reservoir storage is less than 400,000 acre-feet, then the Marysville Gage instream-flow requirement will be 400 cfs from October 1 until the next February Bulletin 120 forecasts are available.
- If the September 30 New Bullards Bar Reservoir storage is less than 450,000 acre-feet but greater than or equal to 400,000 acre-feet, then, the River Management Team may decide to adjust the Marysville Gage instream-flow requirement to 400 cfs from October 1 until the next February Bulletin 120 forecasts are available.

SacWAM uses a threshold of 450,000 acre-feet for the dry-year adjustment.

7.8 Ops\Hydrologic Indices

SacWAM contains routines for calculating hydrologic indices for different watersheds within the Sacramento and San Joaquin river basins. These indices are used within the model to determine water year types, environmental flow requirements, and in certain cases to guide the curtailment of deliveries to water contractors. Water year types are defined in many regulatory processes including FERC licenses and State Water Board water quality plans and water right decisions. Table 7-55 summarizes the water year types used in SacWAM.

Table 7-55. Water Year Types Used in SacWAM

Hydrologic Index	Model Parameter	Water Year Types[2]	Month Determined[2]	Description
Folsom Unimpaired Inflow	FairOaksFNF_MarNov	N/A	February	March through November unimpaired runoff forecast for the American River at Folsom/Fair Oaks. Used to determine Flow Management Standards on the lower American River.
Folsom Unimpaired Inflow	FairOaksFNF_AprJul	N/A	February	April through July unimpaired runoff for the American River at Folsom/Fair Oaks. Used to determine flow requirements for El Dorado Project (P-184).
Folsom Unimpaired Inflow	FairOaksFNF_OctSep	N/A	February	Water year unimpaired runoff for the American River at Folsom/Fair Oaks. Used to determine flow requirements for Middle Fork Project (P-2079) and Upper American River Project (P-2101).
Eight River Index	EightRiverIndex	N/A	Each month	Defined in Water Right Decision 1641. January NDOI increased to 6,000 cfs if December Eight River Index greater than 800 TAF. February E/I ratio a function of January Eight River Index. Establishes required spring X2 location.
Trinity River Index	Trinity	1-5	April	Defined in Trinity River Mainstem Fishery Restoration EIS. Set flow requirement for Trinity River at Lewiston
Shasta Index	Shasta	1 or 4	March	Defined in CVP Sacramento River settlement contracts. Allocation to settlement contractors is 75% in Shasta critical years (parameter=4).
North Yuba Index[1]	NorthYuba	1-7 [2]	February	Defined in lower Yuba River Accord and Water Right Decision 1644. Set flow requirement for Yuba River at Smartville and Marysville gauges
Feather River Index	Feather	0 or 1	February	Defined in Feather River settlement agreements. Establishes water allocation to FRSA senior water right holders.
San Joaquin Valley 60-20-20 Index	San Joaquin	1-5	March	Defined in Water Right Decision 1641. NMFS 2009 Biological Opinion San Joaquin IE ratio (Action IV.2.1) restricts exports as a function of index.
Sacramento Valley 40-30-30 Index	SacWYT_forCCWD	1-5	March	Defined in Water Right Decision 1641. Used to define Contra Costa WD demands and size of emergency pool in Los Vaqueros Reservoir.
Sacramento Valley 40-30-30 Index	SacWYT	1-5	February	Defined in Water Right Decision 1641. Determines Delta outflow requirements.
Sacramento River Index	SRI_Forecast	N/A	January, February	Defined in Water Right Decision 1485. Determines flow requiremets on the lower American River as part of the Flow Management Standard.
Mokelumne River Index	JSA_AprSep_WYType	1-4	November, March	Defined in Mokelumne Joint Settlement Agreement and FERC P-2196 license. Establishes flow requirements below Camanche Dam and Woodbridge Diversion Dam. From October through March determined by November 5 combined storage in Pardee and Camanche reservoirs. From April through September determined by water year unimpaired runoff at Pardee.
North Fork Mokelumne Index	NorthFork_WYType	1-5	February	Defined in FERC P-137 license. Forecast of annual unimpaired inflow to Pardee Reservoir. Establishes flow requirements below Salt Springs Dam, Lower Bear Dam, Electra Diversion Dam, and Tiger Creek Diversion Dam.

Notes:
[1] The North Yuba Index consists of six flow schedules and an additional conference year provision.
[2] Water Year Types are typically updated from the month indicated through May.

SacWAM was initially designed to offer the user two methods for determining hydrologic indices for water year type determination: (1) to read historical values of unimpaired flows from an external csv file; or (2) use WEAP's internal hydrology module associated with catchment objects. The first method (*key assumptions\simulate hydrology = 0*) is used when the model is run with fixed time series of historical inflows for the upper watersheds. The second method is used when SacWAM's upper watershed catchment objects are activated (*key assumptions\simulate hydrology = 1*), and SacWAM dynamically simulates snow accumulation, snowmelt, and surface runoff. While this second method may introduce some error compared to historical flows, it provides forecasted flows with imperfect information rather than perfect foresight. It also allows the model to be run under climatic conditions that are different from the historical record. However, this second method is not fully functional in the current version of SacWAM.

When the hydrology routines are activated in SacWAM (method 2), annual water yields are typically estimated from February through May, matching the timing of DWR's Bulletin 120 forecasts of water supply conditions. Subsequently, threshold criteria are applied to these water yield estimates to determine water-year types. Annual water yields are estimated using a combination of cumulative runoff since the beginning of the water year and runoff forecasts for the remainder of the water year. Runoff forecasts are estimated using regression equations that are based on a combination of simulated snowpack and cumulative runoff as the independent variables. Regression equations were developed for each month from February through May to estimate runoff through the remainder of the water year. These regression equations take the following form:

$$\sum_{t}^{t=12} Q_t = C_1 + C_2 \sum_{t=1}^{t-1} Q_t + C_3 S_{t-1}$$

Where: *t* is the water-year month (i.e., *t*=1 for October and *t*=12 for September),

Q_t = the runoff at some location,

S_{t-1} = the snowpack at the end of the previous month,

C_1, C_2, and C_3 = regression coefficients.[43]

The correlation between runoff forecasts and the simulated runoff are generally initially poor a for February but become stronger as the runoff season progresses (April-May). In February, the two independent variables that are used (i.e., October-January runoff and end-of-January snowpack) are poor indicators of water-year hydrology; there is too much uncertainty this early in the water year. In later months, higher correlations between snowpack and runoff result in more reliable estimates of runoff forecasts. In locations where there is a strong correlation of runoff to snowpack, the regression equations tend to weight the snowpack more heavily in April and May. Correlations are stronger in high-elevation watersheds that have hydrographs dominated by spring snowmelt.

[43] For estimating runoff forecasts for the Sacramento River at Bend Bridge, snowpack values from four separate upstream watersheds are used: Upper Sacramento River, Pitt River, Clear Creek, and Cottonwood Creek. Thus, this equation is expanded to include six regression coefficients.

7.8.1 American

7.8.1.1 American_B120

American_B120 is the CDEC estimate of unimpaired flow for the American River at Folsom. It is read from the file *Data\Streamflow\UF_American_Fair_Oaks.csv*.

7.8.1.2 American_RivIndex

American_RivIndex is a measure of available water and is calculated as *American_B120* less *Folsom_Spill*.

7.8.1.3 FairOaksFNF

FairOaksFNF is the monthly unimpaired inflow to Folsom Lake and is read from the data file SACVAL_StreamflowFullNaturalFlow.csv.

7.8.1.4 FairOaksFNF_OctSep

FairOaksFNF_OctSep is the unimpaired inflow to Folsom Lake from October through September of the current water year. It is calculated using the *FairOaksFNF* (described above) and is used in the process of setting various instream flow requirements in the American River basin.

7.8.1.5 FairOaksFNF_AprJul

FairOaksFNF_AprJul is the unimpaired inflow to Folsom Lake from April through July of the current water year. It is calculated using the *FairOaksFNF* (described above) and is used in the process of setting various instream flow requirements in the American River basin.

7.8.1.6 Folsom_Spill

Folsom_Spill is an estimate of Folsom Lake calculated as the sum of *Folsom_Spill_init* from the start of the water year through the month of April.

7.8.1.7 Folsom_Spill_Init

Folsom_Spill_init is the portion, if any, of the flow at the mouth of the American River that is over and above 8,000 cfs.

7.8.1.8 SuperDryFlag

SuperDryFlag is an indicator of hydrologic conditions. If the total unimpaired inflow to Folsom Lake for the current water year (*FairOaksFNF_OctSep*) is less than 900 TAF and was less than 1,700 TAF in the previous water year, then the basin is flagged as 'super dry'. This flag is also activated if unimpaired inflows to Folsom Lake for the current water year and the previous two water years are all below 1,700 TAF. Once flagged, this variable is used to modify flow requirements on the American River near Placerville.

7.8.1.1 UIMarNov

UIMarNov is the unimpaired inflow to Folsom Lake from March through November of the current calender year. It is calculated using the variable *FairOaksFNF* that is described below.

7.8.2 EightRiverIndex

The *EightRiverIndex* is monthly time series data that is read from the input file *Data\WYT\EightRiver.csv*. Historical values are calculated as the sum of the unimpaired flows for the Sacramento River at Bend

Bridge, Feather River at Oroville, Yuba River at Smartville, American River at Folsom, Stanislaus River at New Melones, Tuolumne River at Don Pedro, Merced River at Exchequer, and San Joaquin River at Friant. It is used from December through May to set flow objectives as implemented in D-1641.

7.8.3 ExtremeDrought

ExtremeDrought is a flag used to identify Water Year 1977. Though defined, it is no longer used in model simulation.

7.8.4 Feather

The Feather River Index is based on the definition of 'drought' in DWR settlement agreements with senior water right holders on the Feather River. This definition of drought requires that:

- The April 1 through July 31 unimpaired runoff to Lake Oroville for the current water year, as forecasted by DWR on February 1 in Bulletin 120, and modified in subsequent months, is equal to or less than 600,000 acre-feet.
- Or the total accumulated deficiencies of unimpaired runoff to Lake Oroville below 2,500,000 acre-feet in the immediate prior water year or series of successive prior water years, each of which had runoff of less than 2,500,000 acre-feet, together with the predicted deficiency below 2,500,000 acre-feet for the current water year, exceed 400,000 acre-feet.

The parameter *Feather* is used to indicate the occurrence of drought (value '1') or not (value '0'). Values are read from the input file *Data\WYT\CalSim WYTypes.csv*.

7.8.4.1 CumInflow

CumInflow is not currently used in the model.

7.8.4.1 FNFatOroville_AprJul

The parameter *FNFatOroville_AprJul* is the forecasted unimpaired flow at Oroville from April through July. It is used in SacWAM to set instream flow requirements in the Feather River watershed (e.g., West Branch Feather River flow below Hendricks Diversion Dam). It is calculated by summing the monthly unimpaired flows (*Feather River\Streamflow Gauges\FNF Feather at Oroville*) using perfect foresight.

7.8.4.1 FNFatOroville_OctSep

The parameter *FNFatOroville_OctSep* is the forecasted unimpaired runoff at Oroville for the water year. It is used in SacWAM to set instream flow requirements in the Feather River watershed (e.g., West Branch Feather River flow below Hendricks Diversion Dam). It is calculated by summing the monthly unimpaired flows (*Feather River\Streamflow Gauges\FNF Feather at Oroville*) using perfect foresight. In SacWAM, this parameter is used to control drawdown of PG&E reservoirs in the upper Feather River watersheds.

7.8.4.2 Index

Index is not currently used in the model.

7.8.4.3 Runoff Forecast

The *Runoff Forecast* branch and subbranches (*C1, C2, C3, Snowpack*) are not currently used in SacWAM.

7.8.5 Feather_RivIndex

The parameter *Feather_RivIndex* is no longer used in the model.

7.8.6 Folsom Hydro Forecast

The Folsom Hydro Forecast branch contains hydrologic forecasts used in setting FMS requirements on the American River. There are forecasts of diversions for the various periods from March to September (specifically, end-of-month values *EoSep Diversion Forecast* and *EoMay Diversion Forecast*), which are based on the maximum of demands, water rights, and CVP allocation/contract amounts for each diversion in the basin. There are also forecasts of runoff for similar periods (*EoMay Runoff Forecast, EoSep Runoff Forecast*), based on estimates of inflows into Folsom.

7.8.6.1 CVP_Urb_for_Est

CVP_Urb_for_Est is equal to the CVP north-of-Delta M&I allocation, expressed as a fraction. Except, if *Key\VA\American VA*=1, the allocation is read from the file *SimulatedDatafromPreviousModelRun\CVP_Urb_PrevRun.csv*.

7.8.6.2 CVP_Urb_Est

CVP_Urb_Est is an estimate of the CVP north-of-Delta M&I allocation, expressed as a fraction. It is set to the previous month value of *CVP_Urb_for_Est*.

7.8.6.3 Diversion Estimate

Diversion Estimate is an estimate of the monthly diversion from Folsom Lake.

7.8.6.4 EoMay Diversion Forecast

7.8.6.4.1 MarMayDiversions

Cumulative diversions from Folsom Lake from March to May.

7.8.6.5 EoMay Runoff Forecast

Runoff forecast for Folsom Lake till end of May.

7.8.6.5.1 C1

Not used in SacWAM

7.8.6.5.2 C2

Not used in SacWAM

7.8.6.5.3 C3

Not used in SacWAM

7.8.6.5.4 CumInflow

Not used in SacWAM

7.8.6.5.5 Folsom Inflow

Inflow to Folsom Lake time series data.

7.8.6.5.6 MarMayinflow

Forecast for March to May Inflow to Folsom Lake from time series data.

7.8.6.5.7 Snowpack

Not used in SacWAM.

7.8.6.6 EoSep Diversion Forecast

Forecasted diversions from Folsom Lake until end of September.

7.8.6.6.1 JuneSeptDiversions

Variable for cumulative diversions from June to September

7.8.6.6.2 ToSeptDiversions

ToSepDiverions is the sum of *Mar, MarAp, MarMa, MarJun, MarJul, MarAug, and MarSep*.

Mar

Mar is the cumulative diversion from March through the current month.

MarApr

MaAprr is the cumulative diversions from March through the current month.

MarMay

MarMay is the cumulative diversions from March through the current month.

MarJun

MarJun is the cumulative diversions from March through the current month.

MarJul

MarJul is the cumulative diversions from March through the current month.

MarAug

MarAug is the cumulative diversions from March through the current month.

MarSep

MarSep is the cumulative diversions from March through the current month.

7.8.6.7 EoSep Runoff Forecast

Runoff Forecast for Folsom Lake till end of September. Associated variables are similar to end of May variables discussed earlier.

7.8.6.7.1 C1

Not used in SacWAM

7.8.6.7.2 C2

Not used in SacWAM

7.8.6.7.3 C3
Not used in SacWAM

7.8.6.7.4 CumInflow
Not used in SacWAM.

7.8.6.7.5 Folsom Inflow
Not used in SacWAM.

7.8.6.7.6 IFII_MaySeptIndlow
Not used in SacWAM.

7.8.6.7.7 Snowpack
Not used in SacWAM.

7.8.6.7.8 ToSeptInflow
ToSeptInflow is the sum of *Mar, MarAp, MarMa, MarJun, MarJul, MarAug, and MarSep*.

Mar

Mar is the cumulative inflow through the current month.

MarApr

MarApr is the cumulative inflow through the current month.

MarMay

MarMay is the cumulative inflow through the current month.

MarJun

MarJun is the cumulative inflow through the current month.

MarJul

MarJul is the cumulative inflow through the current month.

MarAug

MarAug is the cumulative inflow through the current month.

MarSep

MarSep is the cumulative inflow through the current month.

7.8.6.7.9 IFII_MarSeptInflow
IFII_MarSeptInflow is no longer used in SacWAM.

7.8.6.8 Monthly_DemandFrcst
Monthly demand forecast for Folsom Lake.

7.8.6.8.1 FebMayDiversions

FebMayDiversions is an estimate of future diversions from Folsom Lake.

7.8.6.8.2 JuntoSepDiversions

JunSepDiversions is an estimate of future diversions from Folsom Lake.

7.8.6.8.3 OctDecDiversions

OctDecDiversions is an estimate of future diversions from Folsom Lake.

7.8.6.8.4 DemandFrcst

DemandFrcst is an estimate of future diversions from Folsom Lake. It is the sum of *FebMayDiversions, JunSepDiversions,* and *OctDecDiversions.*

7.8.6.9 DepletionFrcst

DepletionFrcst os an estimate of the evaporative losses from Folsom Lake from June to December plus the forecast of demand.

7.8.6.10 InflFrcst_OctDec

InflFrcst_OctDec is the forecasted inflow to Folsom Lake for the forecoming months of October through December.

7.8.6.11 InflFrcst_FebSep

InflFrcst_FebSep is the forecasted inflow to Folsom Lake for the forecoming months of February through September.

7.8.6.12 InflFrcst

InflFrcst is the forecasted inflow to Folsom Lake for the forecoming months of October through December .

7.8.6.13 OctDecInf

OctDecInf is the forecasted inflow to Folsom Lake for the forecoming months of October through December.

7.8.6.14 FMPfrcst

FMPFrcst is the forecasted release from Folsom Lake to meet the FMS below Nimbus Dam.

7.8.6.15 IFll_Base

IFII_Base is the forecasted inflow to Folsom Lake for the forecoming months of October through December. It is read from the file ReadFromFile(Data\WYT\IFII.csv.

7.8.7 FolsomStorage

FolsomStorage is the previous end-of-month storage in Folsom Lake. It provides a short-hand method of referencing this value in other expressions. This variable is referenced by routines used to set the rule curve for the CVP portion of San Luis Reservoir storage and to set the American River FMS (see Section 7.7.1).

7.8.8 FolsomStorage_VSA

FolsomStorage_VSA is set to a value of zero.

7.8.9 JamesBypassFlowThruAug

JamesBypassFlowthruAug is the forecast of James Bypass inflow from the current month through August. It is used to estimate the water supply index (WSI) for CVP South-of-Delta allocations (see Section 7.4.3.1). Monthly values are read from the input file *Data\Headflows\SACVAL_MendotaPool.csv*.

7.8.10 JamesBypassInflow

JamesBypassInflow is monthly time series data that is read from the input file *Data\Headflows\SACVAL_MendotaPool.csv*. It represents the flow from the James Bypass into the Mendota Pool. Early historical values have been adjusted to include the effect of Pine Flat Dam on the Kings River.

7.8.11 Mokelumne

In 1998, as part of relicensing the Lower Mokelumne Project (FERC P-1916), EBMUD entered into an agreement with USFWS and CDFW to protect the fish and ecosystem of the lower Mokelumne River. This settlement agreement, known as the Joint Settlement Agreement (JSA), includes minimum required releases from Camanche Dam to the lower Mokelumne River and sets flows based on time of year and water year type. The State Water Board approved the JSA flows in 1999 and amended EBMUD's and Woodbridge ID permits/licenses to include the JSA flow provisions. The JSA defines five water year types.

7.8.11.1 AnnualUnimpairedFlowMokelumneHill

AnnualUnimpairedFlowMokelumneHill represents the annual unimpaired flow of the Mokleumne River at the USGS Mokelumne Hill gauge. It is determined in February as the sum of *unimpairedFlowMokelumneHill* from October through September. Forecasted flows are determined using perfect foresight.

7.8.11.1 AnnualUnimpairedFlowPardeeInflow

AnnualUnimpairedFlowPardeeInflow represents the annual unimpaired flow of the Mokelumne River at Pardee Dam. It is determined in February as the sum of *UnimpairedFlowPardeeInflow* from October through September. Forecasted flows are determined using perfect foresight.

7.8.11.2 JSAWYType

From October through March, the water year type is defined based on the November 5th combined storage in Pardee and Camanche reservoirs. From April through September, the water year type is defined based on the water year unimpaired runoff into Pardee Reservoir as forecasted by DWR in Bulletin 120, except when November 5 storage is projected to be less than 200,000 acre-feet. The water year types are defined in Table 7-56.

Table 7-56. Mokelumne River JSA April-to-September Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in SacWAM
Normal/Above Normal	>= 890	1
Below Normal	500 to 889	2
Dry	300 to 499	3
Critical	<=299	4

Key:
TAF = thousand acre-feet

7.8.11.1 JSAWYType and JSA_WYType

JSAWType is simply a container for various subbranches. *JSA_WYType* is the final water year type calculated as the sum of the two components *JSA_AprSep_WYType* and *JSA_AprSep_WYType.*

7.8.11.1.1 JSA_AprSep_WYType

JSA_AprSep_WYType is the water year type for the months of April through September determined based on the variable *AnnualUnimpairedFlowPardeeInflow.* For all other months it has a value of zero.

7.8.11.1.2 JSA_OctMar_WYType

JSA_OctMar_WYType is the water year type for the months of October through March determined based on *ForecastedOctoberStorage* for the month of October and *ActualOctoberStorage* for the months of November through March. For all other months it has a value of zero.

ActualOctoberStorage

ActualOctoberStorage is the combined storage in Pardee and Camanche reservoirs at the end of the previous October. It only has values from November through September. October values are zero.

ForecastedOctoberStorage

ForecastedOctoberStorage is a forecast of the combined storage in Pardee and Camanche reservoirs at the end of the following October. The forecast is made in October.

JSA_OctMar_WYType

JSA_OctMar_WYType is a repeat of the variable of the same name at a higher order of the data tree.

OctStorage

OctStorage is the combined storage in Pardee and Camanche reservoirs at the end of the previous October. October values refer to the previous October. It is no longer used in the model.

OctTopCon

OctTopCon is the combined storage capacity of Pardee and Camanche reservoirs less the flood control space requirement for th end of October (200,000 AF).

7.8.11.2 NorthFork_WYType

PG&E owns and operates the Mokelumne Hydroelectric Project (FERC Project No. 137) on the North Fork Mokelumne River. Project facilities include a total of 13 reservoirs and five powerplants. Four old and smaller PG&E reservoirs are located at high elevation (Upper Blue, Lower Blue, Twin, and Meadow Lakes in Alpine County) and have no associated hydropower generation facilities.

Water year types, defined in the FERC license for the Mokelumne Hydroelectric Project, are based on the annual unimpaired flow for the Mokelumne River at the Mokelumne Hill gauge. *NorthFork_WYType* determines these water year types using the *AnnualUnimpairedFlowMokelumneHill* and the thresholds presented in Table 7-54.

Table 7-57. North Fork Mokelumne River Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in SacWAM
Wet	>= 958.7	1
Normal/Above Normal	724.4 to 958.7	2
Below Normal	518.1 to 724.4	3
Dry	376.1 to 518.1	4
Critical	<=376.1	5

Key:
TAF = thousand acre-feet

7.8.11.3 OctJunUnimpairedFlowPardeInflow

OctJunUnimpairedFlowPardeInflow is not currently used in SacWAM.

7.8.11.4 Runoff Forecast

The Runoff Forecast branch and subbranches are not currently used in SacWAM. Subbranches include *C1, C2, C3, CumulativeInflowtoDate*, and *Snowpack*.

7.8.11.1 UnimpairedFlowMokelumneHill

UnimpairedFlowMokelumneHill represents the unimpaired flow of the Mokleumne River at Mokelumne Hill. It is determined as the sum of unimpaired flows read from the input file *Data\Headflows\SACVAL_Headflows.csv*. It comprises local inflow to Salt Springs Reservoir, Upper Bear Reservoir, Tiger Creek, Cole Creek, North Fork Mokelumne, Middle Fork Mokelumne, South Fork Mokelumne, and Mokelumne River accretions above the USGS gauge at Mokelumne Hill.

7.8.11.2 UnimpairedFlowPardeeInflow

UnimpairedFlowPardeeInflow represents the unimpaired flow of the Mokleumne River at Pardee Dam. It is determined as the sum of *UnimpairedFlowMokelumneHill* and mainstem accretions between the Mokelumne Hill gauge and the dam. The latter is read from the input file *Data\Headflows\SACVAL_Headflows.csv*.

7.8.12 North Yuba Index

The North Yuba Index is a measure of the amount of water available in the North Yuba River at New Bullards Bar Reservoir. The index considers total inflow into New Bullards Bar for the current water year (including runoff forecasts) and carryover storage in New Bullards Bar from the previous water year less the Federal Energy Regulatory Commission (FERC) Project License minimum pool amount of 234 TAF. The index is used to determine different flow schedules for the Yuba River at the USGS Smartville and Marysville gauges.

The North Yuba Index is calculated as the sum of the following components:

- Previous September carryover storage in New Bullards Bar Reservoir less 234 TAF
- Cumulative inflow to New Bullards Bar Reservoir from October 1 through the current month
- Forecasted inflows to New Bullards Bar Reservoir from current month through September 30.

The index is first determined in February and subsequently updated each month through May. The May index remains in force until the following end of January.

7.8.13 Sacramento Valley Index (Sac403030)

The Sacramento Valley index (*Sac403030*) is determined using unimpaired runoff estimates from four locations: Sacramento River at Bend Bridge (*Sac Inflow Forecast*), Feather River inflow to Lake Oroville (*Fea Inflow Forecast*), Yuba River at Smartville (*Yub Inflow Forecast*), and American River inflow to Folsom Lake (*Amr Inflow Forecast*). The index also uses the previous year's value to account for antecedent conditions within the basin. The index is sometimes referred to as the Sacramento Valley 40-30-30 index, because it considers 40 percent of the April-July runoff forecast, 30 percent of the October-March runoff, and 30 percent of the previous water year's index to calculate the current year's index. The Sacramento Valley Index has five associated water-year classifications as presented in Table 7-58

Table 7-58. Sacramento Valley Water-Year Classifications

Water-Year Class	Index (TAF)	Code in SacWAM
Wet	>= 9,200	1
Above Normal	7,800 to 9,200	2
Below Normal	6,500 to 7,800	3
Dry	5,400 to 6,500	4
Critical	< 5,400	5

Key:
TAF = thousand acre-feet

7.8.1 San Joaquin Valley Index (SanJoaquin)

The parameter *SanJoaquin* represents the San Joaquin Valley 60-20-20 water year type as defined in D-1641. Values are read from the input file *Data\WYT\SJR602020.csv.* In SacWAM, the water year type is set in March and remains unchanged through the following February. It is used in SacWAM to set the San Joaquin River inflow to export ratio, CVP allocations, and estimates of Delta inflow for use in the ANN. The San Joaquin Valley Index has five associated water-year classifications as presented in Table 7-59.

Table 7-59. San Joaquin Valley Water-Year Classifications

Water-Year Class	Index (TAF)	Code in SacWAM
Wet	>= 3,800	1
Above Normal	3,100 to 3,800	2
Below Normal	2,500 to 3,100	3
Dry	2,100 to 2,500	4
Critical	< 2,100	5

Key:
TAF = thousand acre-feet

7.8.2 Shasta

Shasta Lake has its own index, which is used to reduce water allocations to CVP Settlement and Exchange contractors when the index drops below a critical threshold. Shasta Lake critical years are defined as years when the forecasted inflow to Shasta Lake is less than 3.2 MAF, or the total accumulated deficiencies below 4.0 MAF in the immediately prior water year, or series of successive prior water years (each of which had inflows of less than 4.0 MAF), together with the forecasted deficiency for the current water year, exceed 0.8 MAF. In these years, SSacraento River Settlement Contractors receive 75% of their full contract amount and San Joaquin River Exchange Contractors reveive approximately 77% of their full contract amount.

Shasta is the Shasta Lake water year type. For *Key\Simulate Hydrology* = '0', *Shasta* is set equal to the variable *UseHistorical*.

7.8.2.1 CumInflow

CumInflow is not currently used in the model.

7.8.2.2 Index

Index is not currently used in the model.

7.8.2.3 Runoff Forecast

The Runoff Forecast branch and subbranches are not currently used in SacWAM.

7.8.2.4 UseHistorical

UseHistorical is the historical water year type for Shasta Lake. Determined each March, values are read from the file *Data\WYT\CalSim WYTypes.csv.*

7.8.3 Shasta Storage

ShastaStorage is the previous end-of-month storage in Shasta Lake. It provides a short-hand method of referencing this value in other expressions. This variable is referenced by routines used to set Sacramento River in-stream flow requirements below Keswick (see Section 7.7.7), to set the rule curve for CVP portion of San Luis Reservoir storage, and to balance storage with Trinity (see Section 7.4.8.1).

7.8.4 Smartville

7.8.4.1 MonthlyUnimpairedFlow

MonthlyUnimpairedFlow is the monthly unimpaired flow of the Yuba River below the Deer Creek confluence at the site of the discontinued USGS gauge (USGS 11419000, Yuba River at Smartville).

7.8.4.2 AnnualUnimpairedFlow

AnnualUnimpairedFlow is the annual unimpaired flow of the Yuba River below the Deer Creek confluence. It is calculated by summing *MonthlyUnimpairedFlow* over the water year.

7.8.5 SRI Forecast

The parameter *SRI forecast* is a time series of forecasts of the Sacramento River Index for January and February. This forecast is used in setting FMS requirements on the American River in those months. The time series data are the same as that used in the CalSim II model.

7.8.1 Trinity

Trinity River water year types (Table 7-60) are based on the total annual (October-September) water yield upstream from Lewiston Dam. Five water-year classes are defined based on the Trinity Index

(USFWS and Hoopa Valley Tribe, 1999). *Trinity* is the Trinity River water year type. For *Key\Simulate Hydrology* = '0', *Trinity* is set equal to the variable *UseHistorical*.

Table 7-60. Trinity River Water-Year Classifications

Water-Year Class	Annual Water Yield (TAF)	Code in SacWAM
Extremely Wet	>= 2000	1
Wet	1350 to 2000	2
Normal	1025 to 1350	3
Dry	650 to 1025	4
Critically Dry	< 650	5

Key:
TAF = thousand acre-feet

7.8.1.1 CumInflow

CumInflow is not currently used in the model.

7.8.1.2 Index

Index is not currently used in the model.

7.8.1.3 Runoff Forecast

The Runoff Forecast branch and subbranches are not currently used in SacWAM.

7.8.1.4 UseHistorical

UseHistorical is the historical water year type for the Trinity River. Determined each April, values are read from the file *Data\WYT\CalSim WYTypes.csv.*

7.8.2 Trinity Storage

TrinityStorage is the previous end-of-month storage in Trinity Lake. It provides a short-hand method of referencing this value in other expressions.

7.9 Ops\Local Projects

The following sections describe SacWAM's simulation of local projects on tributaries to the Sacramento River. As previously stated, for the purposes of model documentation, additional sections have been inserted to describe the details of particular projects that are not described elsewhere.

7.9.1 Cache Creek

Clear Lake, located in Lake County northwest of Sacramento, is a source of surface water for irrigated agriculture in Yolo County. The lake is one of the oldest lakes in North America with sediments at least 480,000 years old. The Cache Creek Dam was constructed in 1914 to add additional storage and to control lake releases to Cache Creek. Water released from the dam travels downstream into Yolo County and is used for irrigation by the Yolo County FC&WCD (A_20_25_NA1).

Parameters and vriables under the Cache Creek branch are used to determine annual water allocations to Yolo County FC&WCD based on available water in Clear Lake and Indian Valley Reservoir.

7.9.1.1 Allocation

Allocation is the fraction of the *Target Delivery* that is available for the year for use by Yolo County FC&WCD for irrigation deliveries, as determined on April 1.

7.9.1.2 AllocationVol

AllocationVol is the volume of water available for irrigation for the current. It is based on *Allocation*, *Target Delivery*, and an assumed *Monthly Distribution* of use.

7.9.1.3 Clear Lake Apr 1 Storage

Clear Lake Apr 1 Storage is the allowable seasonal withdrawl from Clear Lake as defined by the Solano Decree.

7.9.1.4 Indian Valley Apr 1 Storage

Indian Valley Apr 1 Storage is the previous end-of-month storage in Indian Valley Reservoir. It is only referenced in the month of April.

7.9.1.5 Indian Valley Carryover Target

Indian Valley Carryover Target is the end-of-September target carryover storage in Indian Valley Reservoir. In SacWAM, a constant value of 20 TAF is used, as suggested by Yolo County FC&WCD staff.

7.9.1.6 Indian Valley Evaporation AprtoSep

Indian Valley Evaporation AprtoSep, as its name suggests, is an estimate of seasonal evaporation losses. It is assumed to be approximately 11 TAF, based on SacWAM simulation.

7.9.1.7 Monthly Distribution

Monthly Distribution is the monthly pattern of the demand for surface water. It is based on 2007 observed diversions at Cache Creek Dam.

7.9.1.8 Solano Decree

Releases of water from Clear Lake are controlled by the Solano Decree, an agreement between Lake and Yolo counties that was drafted in 1978. The Decree is used to determine the total amount of water available for the entire irrigation season as a function of the lake level on April 1.

The other assumptions in this section are used to determine the lake level at the end of March. If the level is greater than or equal to 7.56 feet Rumsey (a local datum) then the district may divert up to 150 TAF of water from the lake. If the lake level is less than 3.22 feet at Rumsey, then no water is available for release. For lake levels between these thresholds, the equations in *RumseyEquation* are used to determine the volume that can be released. The amount is recalculated at the beginning of May using *RumseyAdjEquation*. The amount available in a month is calculated using *Solano Decree\Monthly Allocation*. *Monthly Allocation* is used to restrict releases from Clear Lake using the *Maximum Hydraulic Outflow* parameter in *Supply and Resources\River\Cache Creek\Reservoirs\Clear Lake\Physical\Maximum Hydraulic Outflow*.

7.9.1.8.1 Allowable Seasonal Withdrawal

The *Allowable Seasonal Withdrawal* is the total quantity of water that may be withdrawn from Clear Lake storage during any year between April 1 and October 31, as determined by the Solano Decree. In April, *Allowable Seasonal Withdrawal* is the determined by *RumseyEquation. In May, this volume is redefined by RumseyAdjEquation*. The May values are subsequently unchanged until the following April.

7.9.1.8.2 AllowableMonthlyWithdrawal

The *AllowableMonthlyWithdrawal* is the volume of water that may be withdrawn from Clear Lake in any month. It is calculated as the sum of *Monthly Allocation* and *Carryover* determined by applying the following percentages to the allowable seasonal withdrawal established by paragraph 1-a of Solano decree with final prorated adjustments made in May to reflect the differences between estimated and final withdrawal values in acre-feet.

7.9.1.8.3 CarryOver

CarryOver is used to account for monthly carryover of allowable withdrawals from Clear Lake.

7.9.1.8.4 Gysers

Gysers represents subsurface inflow to the lake. In SacWAM it is assigned a constant monthly value of 0.662 TAF.

7.9.1.8.5 HydraulicConstraint

At low lake levels (less than 0.1 ft Rumsey), the outflow from Clear Lake is physically constrained by the hydraulics of the gated outflow channel. *HydraulicConstraint* is the outflow capacity calculated using a quadratic equation based on Clear Lake stage. WEAP's Maximum Hydraulic Outflow property of reservoir objects is used to restrict releases from Clear Lake.

7.9.1.8.6 Monthly Allocation

MonthlyAllocation is the monthly allowable storage withdrawals from Clear Lake. It is the product of *MonthlyWithdrawalPercent* and *AllowableSeasonalWithdrawal*.

7.9.1.8.7 Monthly Withdrawal Percent

MonthlyWithdrawalPercent defines the monthly pattern of storage withdrawals from Clear Lake established in paragraph 1-a of the Solano Decree. The percentage rates are used to compute monthly withdrawals from Clear Lake. The percentage withdrawals are given in Table 7-61.

Table 7-61. Monthly Withdrawal Percentage for Clear Lake

Month	Percent
April	7.0
May	18.6
June	20.6
July	21.0
August	19.9
September	10.5
October	2.4

7.9.1.8.8 NoWithdrawalStorage

NoWithdrawalStorage is the quantity of water that would have been contained in Clear Lake if no storage withdrawals had been made from the lake to meet water requirements. It is the sum of the previous end-of-month storage in Clear Lake plus the total Clear Lake controlled withdrawals, i.e., excluding withdrawals made for flood control purposes.

7.9.1.8.9 PrevDistrictRelease

PrevDistrictRelease is the previous month's total release from Clear Lake for both flood control and water supply purposes.

7.9.1.8.10 PrevFloodRelease

PrevFloodRelease is the previous month's release from Clear Lake for flood control purposes.

7.9.1.8.11 PrevOutflow

PrevOutflow is the previous month's outflow from Clear Lake.

7.9.1.8.12 PrevStorage

PrevStorage is the previous end-of-month's storage in Clear Lake.

7.9.1.8.13 Rumsey Gage

Rumsey Gage is the elevation or water level in Clear Lake above 'Rumsey Zero' (1318.64 ft above sea level). As a legal measure, the Gopcevic Decree of 1920 establishes Zero Rumsey as 20.01 feet below the center of the large concrete star at the northeast corner of courthouse yard in Lakeport. Zero Rumsey is equivalent to 1318.25 feet above sea level (1929 NGVD) and full lake is established as 7.56 feet on the Rumsey gage.

7.9.1.8.14 Rumsey Gage Adj

Rumsey Gage Adj is the gauge adjustment made in May that is calculated as a linear function of *NoWithdrawalStorage*.

7.9.1.8.15 RumseyAdjEquation

The *RumseyAdjEquation* is the May 1 adjustment of seasonal release from Clear Lake (in AF). It is similar to *RumseyEquation* described below.

7.9.1.8.16 RumseyEquation

The *RumseyEquation* is the seasonal release from Clear Lake (in AF) based on a table in the Solano Decree that defines the relationship between Rumsey Gauge elevation and storage in Clear Lake. The seasonal withdrawal is zero for a Clear Lake storage elevation of 3.22 ft Rumsey Gauge. Thereafter, the seasonal storage withdrawal is computed using a linear equation as follows:

- Rumsey Gauge < 3.22 ft, Seasonal withdrawal = 0 AF
- Rumsey Gauge 3.22 ft – 5.7 ft, Seasonal withdrawal = 27,765*Rumsey Gauge (ft) – 89,420 AF
- Rumsey Gauge 5.7 ft – 7.56 ft, Seasonal withdrawal = 43,129*Rumsey Gauge (ft) – 175,447 AF
- Rumsey Gauge > 7.56 ft, Seasonal withdrawal = 150,000 AF

7.9.1.8.17 SeasonIndex

SeasonIndex is a flag to indicate the April 1 to October 31 season. A value of '0' indicates the off-season, a value of '1' represents the season.

7.9.1.9 Stream Seepage abv Div Dam

Stream Seepage abv Div Dam is the fraction of stream flows that are lost to seepage in the reach between Clear Lake and the downstream diversion dam. It is set to zero in SacWAM.

7.9.1.10 Stream Seepage blw Div Dam

Stream Seepage blw Div Dam is the fraction of stream flows that are lost to seepage in the reach below the diversion Dam.

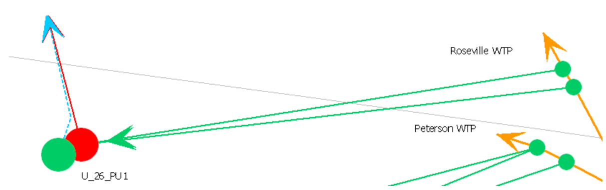
7.9.1.11 SWRCB IFR AprtoSep

SWRCB IFR AprtoSep is the sum of the proposed State Water Board flow requirements over a six-month period from the current month (April) forward.

7.9.2 City of Roseville (Roseville)

The City of Roseville predominantly uses surface water to meet all of its service area demands. Surface water is delivered from Folsom Lake to the city's water treatment plant on Barton Road. Historically, groundwater has been used as a backup supply or during drought years when surface water supplies are scarce. However, the city has started to use its wells for aquifer storage and recovery (ASR) in a conjunctive use management strategy. The City of Roseville does not hold any water rights but has signed water contracts with Reclamation, Placer County WA, and San Juan WD for the delivery of surface water to its water treatment plant. The CVP contract is for a maximum of 32,000 acre-feet per year. The city's contract with Placer County WA is for delivery of 10,000 acre-feet per year of MFP water, with options for an additional 20,000 acre-feet per year. The City of Roseville also signed a wholesale contract with San Juan WD for 4,000 acre-feet per year. This water is derived from part of San Juan WD's contract with Placer County WA for 25,000 acre-feet of MFP water. It is only available in normal and wetter years when the unimpaired inflow to Folsom Lake is projected to be above 950,000 acre-feet.

The City of Roseville's use of CVP water and MFP is represented in the model using two transmission links from the water treatment plant to the demand unit; one transmission link conveys CVP water, the other transmission link conveys MFP water. CVP water is assigned first supply preference, the MFP water assigned second preference.



7.9.2.1 CVPRemainingSupply

The City of Roseville contract with Reclamation is for up to 32,000 acre-feet per year of CVP water. The CVP water is subject to the CVP Municipal and Industrial Water Shortage Policy. The CVP contract year begins on March 1. Initial allocations in this March are updated in April and May. The variable *CVPRemainingSupply* tracks the amount of CVP water used in the current contract year, prior to the current month, and determines the remaining amount of CVP water that is available. The UDC *Roseville_CVPWater* limits use of CVP water to *CVPRemainingSupply*.

7.9.2.2 MFPRemainingSupply

The City of Roseville has signed a contract with Placer County WA providing for the delivery of 10,000 acre-feet per year of MFP water, with options for an additional 20,000 acre-feet per year. The city also has an agreement with San Juan WD for an additional 4,000 acre-feet, if needed. The variable

MFPRemainingSupply tracks the amount of MFP water used in the current water year, prior to the current month, and determines the remaining amount of MFP water that is available at the beginning of the month. SacWAM assumes a maximum of 14,000 acre-feet of MFP water is used in a water year. The UDC *Roseville_MFPWater* limits use of MFP water to *MFPRemainingSupply*.

7.9.3 Contra Costa WD (CCWD)

Contra Costa WD provides treated water to approximately 500,000 people in Contra Costa County and sells untreated water to the Cities of Antioch, Martinez and Pittsburg, as well as to industrial and irrigation customers (CCWD, 2016).[44] The district's principal source of water is the Delta. Before 1997, all Delta water was diverted at Rock Slough, and to a lesser extent Mallard Slough, and conveyed to the district's service area through the 48-mile-long Contra Costa Canal. The Los Vaqueros Project, completed in 1997, added an additional intake on Old River and a 100 TAF capacity offstream storage reservoir located on Kellogg Creek.[45] In 2010, the district completed the construction of a second intake on Victoria Canal near Middle River. Water diverted at the Old River and Middle River intakes is pumped to a high elevation 'transfer station'. From the transfer station, water flows by gravity through the Los Vaqueros Pipeline to the Contra Costa Canal or is pumped into the Los Vaqueros Reservoir. Water stored in Los Vaqueros Reservoir is later released via the transfer station and Los Vaqueros Pipeline to the Contra Costa Canal. A single bi-directional pipeline connects the transfer station to Los Vaqueros Reservoir.

Los Vaqueros Reservoir is operated for water quality purposes. The reservoir is filled in the spring and early summer during periods of low Delta salinity. In the late summer and fall, releases from storage are typically blended with direct Delta diversions to achieve a delivered water quality target of 65 mg/L chloride. In addition, Los Vaqueros Reservoir provides water supply reliability in years with low CVP contract allocation and an emergency water supply. Los Vaqueros reservoir was expanded from 100 TAF to 160 TAF capacity in 2012.

Los Vaqueros and Contra Costa WD operations are not fully dynamic in SacWAM. Instead, SacWAM relies on preprocessed time series data furnished from a separate WRIMS-based model, which is described in the section below. The time series data are used to establish flow targets for the Los Vaqueros Transfer Pipeline, which is represented in SacWAM using two separate arcs – a 'fill' arc (Transfer to LV) and a 'release' arc (LV to Transfer).

7.9.3.1 WRIMS-Based Los Vaqueros Model

The Los Vaqueros Model was extracted from CalSim II (the version used for the 2015 SWP Delivery Capability Report) and formulated as a stand-alone WRIMS-based model.[46] The stand-alone model requires information pertaining to Delta water quality, X2, Delta exports, and surplus Delta outflow. The

[44] In SacWAM, deliveries to the City of Antioch from the Contra Costa Canal (transmission link from Contra Costa Canal CM 007 to U_ANTOC_NU) are set equal to zero. However, these deliveries are part of the overall water demand adopted for Contra Costa WD (demand unit U_CCWD_NU).

[45] The outflow from Kellogg Creek to the Delta, which typically conveys a 5 cfs flow requirement, has been disconnected from OMR to overcome a network looping error.

[46] The Water Resources Integrated Modeling System (WRIMS) is a generalized water resources software program developed by DWR's Bay-Delta Office. CalSim II is built on the WRIMS platform.

Los Vaqueros Model is described in the Los Vaqueros Reservoir Expansion Project Final EIS-EIR (Reclamation et al, 2010). The model represents Los Vaqueros Reservoir and Contra Costa WD's Delta intakes at Rock Slough, Old River, and Victoria Canal. However, it does not represent the district's intertie with the EBMUD Mokelumne Aqueduct or operation of the Mallard Slough intake. The model uses input times series of chloride concentration at district's intakes to determine where and when to divert to achieve a delivered water quality goal of less than or equal to 65 mg/L chloride concentration. Simulated district water demands vary from 111,000 acre-feet in wet years to 144,000 acre-feet in dry years. Simulated water supplies are as follows:

- **CVP water**: on May 10, 2005, Contra Costa WD signed a long-term contract with Reclamation for delivery of up to 195,000 acre-feet of water per year for M&I uses in the district's service area. The contract expires in 2045. Through a settlement agreement with EBMUD, Contra Costa WD may receive a portion of its CVP supplies from the existing intertie with the Mokelumne Aqueduct, however, this is not simulated in the Los Vaqueros Model.
- **Los Vaqueros water**: D-1629, issued by the State Water Board on June 2, 1994, gives Contra Costa WD the rights to divert and store water for beneficial uses. Under Water Right Permit No. 20749, the district may fill Los Vaqueros Reservoir from the intakes at Old River and Victoria Canal (aka Middle River intake). These rights are in addition to the contractual rights to divert and store CVP contract water, year-round. Up to 95,850 acre-feet per year may be diverted for storage between November 1 and June 30 at a maximum rate of 200 cfs. Diversion is limited to periods when the Delta is in excess water conditions, given that those diversions will not adversely impact the operations of the CVP and SWP. The district's diversions and filling of the reservoir are also subject to the provisions of the 1993 delta smelt and chinook salmon BOs and the 2009 incidental take permit.
- **Kellogg Creek water**: Under Water Right Permit No. 20750, Contra Costa WD may divert and store water from Kellogg Creek (up to 9,640 acre-feet per year). Diversion from Kellogg Creek is limited to flows above 5 cfs, since the first 5 cfs must be released downstream.
- **Mallard Slough water**: Under Water Right Permits No. 019856 and License No. 010514, Contra Costa WD may divert up to 26,780 acre-feet per year at Mallard Slough. However, diversions are unreliable due to frequent poor water quality conditions in the San Joaquin River at this point of diversion.[47]

Biological opinions impose certain restrictions on Contra Costa WD Delta diversions, including an annual 75-day no-fill period and a concurrent 30-day no-diversion period. The default dates for the no-fill and no-diversion periods are March 15 through May 31 and April 1 through April 30, respectively. These restrictions are waived if storage in Los Vaqueros Reservoir is at or below emergency levels of 70 TAF in wet, above-normal, or below-normal water years, and 44 TAF in dry or critically dry water years. The DFW incidental take permit requires an additional 15 no-fill days beginning February 15 if Los Vaqueros Reservoir storage is at or above 90 TAF on February 1, or 10 no-fill days beginning February 19 if storage is at or above 80 TAF, or 5 no-fill days beginning February 24 if storage is at or above 70 TAF. The

[47] In SacWAM, diversions from Mallard Slough (transmission link from Sacramento River RM 0 to U_CCWD_NU) are set equal to zero.

WRIMS-based Los Vaqueros Model uses the default no-fill and no-diversion periods. The additional February no-fill requirement based on Los Vaqueros Reservoir storage is not simulated.

The operations model fills Los Vaqueros Reservoir with water from the Delta of up to 65 mg/L chloride concentration. However, because of evaporation, it is possible for Los Vaqueros Reservoir to exceed 65 mg/L chloride concentration; under such a circumstance, filling with water above 65 mg/L chloride concentration is allowed as long as it lowers the salinity in the reservoir.

7.9.3.1.1 Los Vaqueros Model Implementation

SacWAM is initially run with Los Vaqueros Project operations constrained to mimic those simulated by CalSim II for the 2015 SWP Delivery Capability Report for existing conditions (DWR, 2015). Output from SacWAM subsequently becomes part of the input time series data for the WRIMS-based Los Vaqueros Model. These SacWAM outputs include ANN-generated water quality data and are as follows (the variable names are given in parenthesis):

- Previous month EC at Chipps Island (*CH_EC_Month_Prev*)
- Previous month EC at Old River intake (*LV_EC_Month_Prev*)
- Previous month EC at Rock Slough intake (*RS_EC_Month_Prev*)
- Previous month EC at Victoria Canal (*VI_EC_Month_Prev*)
- Previous month chloride concentration at Chipps Island (*CH_CL_Month_Prev*)
- Previous month chloride concentration at Old River intake (*LV_CL_Month_Prev*)
- Previous month chloride concentration at Rock Slough intake (*RS_CL_Month_Prev*)
- Previous month chloride concentration at Victoria Canal intake (*VI_CL_Month_Prev*)
- Previous month X2 location (*X2_last*)
- CVP allocation to North-of-Delta M&I water service contractors (*Perdel_cvpmi_sys*)
- Surplus Delta outflow assigned to the CVP under COA (*C407_cvp*)
- Surplus Delta outflow assigned to the SWP under COA (*C407_swp*)
- Allowable Delta export under D-1641 EI requirement (*EIExpCtrl*)
- Delta South-of-Delta exports (*D409*)

The WRIMS-based Los Vaqueros Model is run with the new inputs and updated simulated flows for the Los Vaqueros Project are subsequently stored in a csv file for later use by SacWAM – one csv file for existing conditions and one csv file for each unimpaired flow alternative. The transfer of data between the two models is accomplished using the Excel-based spreadsheet *LosVaqueros_Postprocesser.xlsx* and the Excel add-in for HEC-DSS. The WRIMS-based Los Vaqueros Model is located within the SacWAM file directory under *LVStandAloneModel*.

7.9.3.1.2 SacWAM Flow Requirements

For the 'Existing' model scenario, SacWAM reads time series data stored in the csv file *CalSimII_CCWD_Ops_Ex* to establish flow requirements at the following four locations:

- Rock Slough intake/Contra Costa Pumping Plant No.1 (IFR *OPS RS Pumping*)
- Transfer – Los Vaqueros Pipeline, fill direction (IFR *OPS TransfertoLV*)
- Transfer – Los Vaqueros Pipeline, release direction (IFR *OPS LVtoTransfer*)
- Mokelumne Aqueduct Intertie (IFR *OPS Mokelumne Intertie*)

Separate CSV files are defined for each unimpaired flow alternative (CalSimII_CCWD_Ops_35, CalSimII_CCWD_Ops_45, CalSimII_CCWD_Ops_55, CalSimII_CCWD_Ops_65, and CalSimII_CCWD_Ops_75). Priorities on the associated IFR objects are set equal to the parameter *Contra Costa WD Operational Objectives*, which is assigned a value of 35. The same priority is assigned to deliveries to the district from the Contra Costa Canal.

The WRIMS-based Los Vaqueros Model does not simulate the Mokelume Aqueduct – Los Vaqueros Pipeline Intertie. Therefore, time series data values for the IFR *OPS Mokelumne Intertie* are set to zero. The remaining three IFRs on the Rock Slough intake and the Transfer to Los Vaqueros Pipeline are sufficient to fully describe Los Vaqueros Project operations.

The SJWAM data tree is described in the sections below.

7.9.3.2 Demand_Fraction

Demand_Fraction is the assumed monthly distribution of Contra Costa WD's water demand/use.

7.9.3.3 Emergency Pool

Emergency Pool is the volume of water in Los Vaqueros Reservoir, which is maintained for emergency operations. In SacWAm it is assigned a value of 70 TAF in wet, abobe normal, and below normal years, otherwise a value of 44 TAF. It is no longer used in SacWAM.

7.9.3.4 Feb_Nofill

Feb_NoFill implements regulatory restrictions on February filling of Los Vaqueros Reservoir. It is no longer used in SacWAM.

7.9.3.5 LV_Fill_max

LV_Fill_Max is the physical capacity of the pump station and pipeline used to fill Los Vaqueros Reservoir. In SacWAM, it is assigned a value of 200 cfs. However, it is no longer used in SacWAM.

7.9.3.6 Max_fill_est

Max_fill_est is the upper bound on the current month's filling of Los Vaqueros from the Transfer Station. It is the minimum of *LV Fill time series* and the estimated space in the reservoir accounting for the current inflow from Kellogg Creek, reservoir evaporation, and minimum instream flow releases.

7.9.3.7 Max_Release_Est

Max_Release_Est is the physical capacity of the pipeline used to release Los Vaqueros Reservoir water to the Transfer Station. In SacWAM, it is assigned a value of 400 cfs. However, it is no longer used in SacWAM.

7.9.3.8 Min_Evap_Estcfs
Min_Evap_Estcfs is a monthly estimate of Los Vaqueros Reservoir evepaorative losses. It is no longer used in SacWAM.

7.9.3.9 MokelumneIntertie
The *MokelumneIntertie* is no longer used in SacWAM.

7.9.3.10 NoDiv_NoFill
NoDiv_NoFill is a parameter used to implement BO restrictions on diversions and filling of Los Vaqueros. It is currently set to a value of '1', which results in no limitations being imposed. However, it is no longer used to affect model simulation as operations are driven by predefined time series data.

7.9.3.11 Old_River_Max
Old_River_Max is the physical/regulatory capacity of the Old River intake. In SacWAM it is assigned a value of 250 cfs. However, April capacity is multiplied by the factor *NoDiv_NoFill*, which represents water right and biological opinion restrictions. It is no longer used in SacWAM.

7.9.3.12 OR_Pipeline_max
OR_Pipeline_Max is the physical/regulatory capacity of the Old River Pipeline. In SacWAM it is assigned a value of 320 cfs. However, April capacity is multiplied by the factor *NoDiv_NoFill*, which represents water right and biological opinion restrictions. It is no longer used in SacWAM.

7.9.3.13 OR_VC_CVP_Demand_Pattern
OR_CV_CVP_Demand_Pattern is no longer used in SacWAM.

7.9.3.14 OR_CV_LV_Demand_Pattern
OR_CV_LV_Demand_Pattern is no longer used in SacWAM.

7.9.3.15 OR_VC_Pump
OR_VC_Pump is no longer used in SacWAM.

7.9.3.16 OutputforWRIMSModel
SacWAM outputs a set of variables that are used as input to the WRIMS-based Los Vaqueros model. These variables are defined in the following sections.

7.9.3.16.1 CH_CL_Month_Prev
CH_CL_Month_Prev is the previous month chloride concentration at the Mallard Slough intake.

7.9.3.16.2 LV_CL_Month_Prev
LV_CL_Month_Prev is the previous month chloride concentration at the Los Vaqueros Old River intake.

7.9.3.16.3 RS_CL_Month_Prev
RS_CL_Month_Prev is the previous month chloride concentration at the head of the Contra Costa Canal.

7.9.3.16.4 VI_CL_Month_Prev
VI_CL_Month_Prev is the previous month chloride concentration at the Los Vaqueros Victoria Island intake.

7.9.3.16.5 X2_Last

X2_Last is the previous month's location of X2 in km.

7.9.3.16.6 Perdel_cvpmi_sys

Perdel_cvpmi_sys is the CVP north-of-Delta M&I allocation.

7.9.3.16.7 C407_cvp

C407_cvp is the current month export of CVP water.

7.9.3.16.8 C407_swp

C407_swp is the current month export of SWP water.

7.9.3.16.9 EIExpCtrl

EIExpCtrl is the allowable export under the E:I ratio for a given Delta inflow.

7.9.3.16.10D409

D409 is the combined CVP and SWP exports at Bnks and Jones pumping plants.

7.9.3.16.11CalSim II test

CalSim II test is no longer used in SacWAM.

7.9.3.16.12CH_EC_Month_Prev

CH_EC_Month_Prev is the previous month EC at the Mallard Slough intake.

7.9.3.16.13LV_EC_Month_Prev

LV_EC_Month_Prev is the previous month EC at the Los Vaqueros Old River intake.

7.9.3.16.14RS_EC_Month_Prev

RS_EC_Month_Prev is the previous month EC at the head of the Contra Costa Canal.

7.9.3.16.15VI_EC_Month_Prev

VI_EC_Month_Prev is the previous month EC at the Los Vaqueros Victoria Island intake.

7.9.3.17 PreOperations

At model runtime, simulated operations of Contra Costa WD Los Vaqueros facility is prescribed by time series data. These data are described in the following sections.

7.9.3.17.1 LV Fill time series

LV Fill time series is read from *Data\CCWD\CalSimII_CCWD_Ops_Ex.csv* and represents the filling (from Transfer) target for Los Vaqueros Reservoir.

7.9.3.17.2 LV Rel time series

LV Rel time series is read from *Data\CCWD\CalSimII_CCWD_Ops_Ex.csv* and represents the release (to Transfer) target for Los Vaqueros Reservoir.

7.9.3.17.3 Mallard Slough time series

Mallard Slough time series represents the diversion at Contra Costa WD's Mallard Slough intake. It is currently set to zero.

7.9.3.17.4 Mok Intertie time series

Mok Intertie time series is read from *Data\CCWD\CalSimII_CCWD_Ops_Ex.csv* and represents the filling of Los Vaqueros Reservoir from Mokelumne Aqueduct Intertie.

7.9.3.17.5 OR and VC time series

OR and VC time series is read from *Data\CCWD\CalSimII_CCWD_Ops_Ex.csv* and represents Delta diversions at Contra Costa WD's Old River and Victoria Canal intakes.

7.9.3.17.6 RS time series

RS time series is read from *Data\CCWD\CalSimII_CCWD_Ops_Ex.csv* and represents Delta diversions at Contra Costa WD's Rock Slough intake. However, April capacity is multiplied by the factor *NoDiv_NoFill*, which represents water right and biological opinion restrictions.

7.9.3.18 Rock_Slough_Max

Rock_Slough_Max is the physical/regulatory capacity of the Rock Slough intake at the head of the Contra Costa Canal. In SacWAM it is assigned a value of 350 cfs.

7.9.3.19 RS_Demand_Pattern

RS_Demand_Pattern is no longer used in SacWAM.

7.9.3.20 Victorica_Canal_Max

Rock_Slough_Max is the physical/regulatory capacity of the Victoria Canal intake. In SacWAM it is assigned a value of 250 cfs. However, April capacity is multiplied by the factor *NoDiv_NoFill*, which represents water right and biological opinion restrictions.

7.9.3.21 Water Accounting

7.9.3.21.1 CVP_ContractAmount

CVP_ContractAmount represents Contra Costa WD's annual CVP allocation. In SacWAM, it is set to the product of 195 TAF and the CVP M&I allocation for north-of-Delta water service contractors.

7.9.3.21.2 CVP_RemainingWater

CVP_RemainingWater is no longer used in SacWAM.

7.9.3.21.3 LV_WR

LV_WR represents Contra Costa WD's annual water right. In SacWAM, it is set to a value of 95.85 TAF.

7.9.3.21.4 LV_WR_RemainingWater

LV_WR_RemainingWater maintains an account of Contra Costa WD's Los Vaqueros water right.

7.9.3.21.5 LVFill_CVPWater_Prev

LVFill_CVPWater_Prev is the previous month's use of CVP water to fill Los Vaqueros Reservoir.

7.9.3.21.6 LVFill_WRWater_Prev

LVFill_WRWater_Prev is the previous month's use of CVP water to fill Los Vaqueros Reservoir.

7.9.4 El Dorado ID

El Dorado ID was formed in 1925 to provide water to El Dorado County. Water supplies, which are described in the following sections, include water rights associated with Project 184, Sly Park Unit, and minor streams in the South Fork American River and North Cosumnes River watersheds, and CVP water delivered at Folsom Lake.

El Dorado ID is represented in SacWAM by two DUs: a lowland western section that represents the district's El Dorado Hills service area (U_EIDLo_NU); and an eastern section at higher elevation that represents the Western/Eastern service area (U_EIDUp_NU). Annual water demands are assumed to be 12 TAF and 24 TAF, respectively.

7.9.4.1 Project 184

The El Dorado Project (FERC Project No. 184) was purchased by El Dorado ID from PG&E in 1999. It is now operated by the district for water supply, hydropower, environmental flows, and recreation. A new FERC license was issued for the project in October 2006. The project includes four reservoirs (Aloha, Caples, Echo, and Silver), the El Dorado Canal, and El Dorado Powerhouse. The total combined usable storage capacity in Lake Aloha, Caples Lake, Echo Lake, and Silver Lake is approximately 36 TAF. However, only Silver Lake and Caples Lake are represented in SacWAM. Water is diverted from the South Fork American River, below the river's confluence with the Silver Fork, into the 22-mile long El Dorado Canal. The El Dorado Canal terminates at the El Dorado Forebay. Some of the water delivered to the forebay is subsequently diverted through district facilities for M&I water supply. The remaining canal flow is used to generate power at the El Dorado Powerhouse, before returning to the river. Storage withdrawals from Project 184 reservoirs are also rediverted by the district at Folsom Lake to supply the community of El Dorado Hills. Operation of Lake Aloha, Caples Lake, Echo Lake, and Silver Lake are constrained by lake-level requirements for recreation. The lakes are operated to maintain as high storage as possible during the summer until after Labor Day.

SacWAM assumes that the El Dorado Canal has a maximum hydraulic capacity of 163 cfs, but is closed for maintenance during October, November, and the first half of December. SacWAM does not represent the many minor diversions from small creeks into the canal. Neither does the model represent canal seepage losses.

Simulated diversions from Alder Creek in to the El Dorado Canal. Diversions are made under water right A6383 (License 2543) from December 1 through June 15 at a maximum rate of 15 cfs for power generation at the El Dorado Powerhouse.

7.9.4.1.1 El Dorado Forebay Diversions

El Dorado ID claims 15,080 acre-feet annually of pre-1914 consumptive water rights associated with Project 184. The water is made available at the Project's Forebay Reservoir, where it is conveyed into the district's internal conveyance system for treatment and delivery.[48] The district also holds: (1) a pre-1914 water right for direct diversion of up to 70 cfs; and (2) a pre-1914 water right for rediversion of storage withdrawals of 5,400 acre-feet. Additionally, the district holds a post-1914 water right for power generation for up to 86 cfs (License 2540).

El Doardo ID also diverts water from Alder Creek in to the El Dorado Canal. Diversions are made under water right A6383 (License 2543) from December 1 through June 15 at a maximum rate of 15 cfs for power generation at the El Dorado Powerhouse.

In SacWAM, simulated diversions at the El Dorado Forebay for water supply are restricted to a maximum of 9,000 acre-feet per year and a fixed monthly pattern based on 1994-2015 historical diversion data.[49] This water is delivered to demand unit U_EIDUp_NU and is the preferred source of supply. Supplemental water is delivered to U_EIDUp_NU from Jenkinson Lake.

7.9.4.1.2 Folsom Lake Diversions

El Dorado ID diverts water from Folsom Lake to its El Dorado Hills WTP under a CVP contract and its own water rights. The CVP contract (14-06-200-1375-LTR1) is for up to 7,550 acre-feet and is subject to Reclamation's CVP M&I water shortage policy. Water is also diverted under a Warren Act contract associated with water right permit 21112 (A5645B). The permit allows for a direct diversion of 156 cfs from November 1 through July 31 and a maximum annual amount of 15,000 acre-feet. The total direct diversion and rediversion of storage withdrawals of Project 184 reservoirs is limited to 17,000 acre-feet per year. El Dorado ID also holds a Warren Act contract for diversion of up to 4,560 acre-feet per year from Folsom Lake associated with its 'Ditch' and Weber water rights.[50] These supplies are not represented in SacWAM. In SacWAM, permit 21112 water is the preferred source of supply and is sufficient to meet all water demands.

El Dorado ID Project 184 diversions from Folsom Lake have been reduced to 8,500 acre-feet per year to reflect restrictions imposed under the district's 2016 Warren Act contract with Reclamation.

CVP RemainingSupply

SacWAM tracks El Dorado ID's use of its annual CVP allocation. The parameter *CVP RemainingSupply* is the amount of CVP water available at the beginning of the month.

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[48] Originally, this water was diverted under a 1919 agreement between Western State Gas and Electric Company and El Dorado Water Company.

[49] SacWAM assumes a 10-week maintenance period for the El Dorado Canal, beginning October 1. This restricets the maximum delivery from the El Dorado Forebay to 8.46 TAF per year.

[50] 'Ditch' water rights are associated with Summerfield Ditch, Gold Hill Ditch, and Farmers Free Ditch. Under a series of one-year Warren Act contracts, the district allowed the water formerly turned into these ditches to pass downstream to Folsom Lake, where the district withdrew it to supply service zones in the EI Dorado Hills area. Additionally, the district has water rights for both direct diversion and diversion to storage on Weber Creek. El Dorado ID and Reclamation are completing a long-term Warren Act contract for these supplies: Slab Creek water that was previously diverted into the Summerfield Ditch, Hangtown Creek water that were previously diverted into the Gold Hill Ditch, and Weber Creek water - both natural flows and stored releases from Weber Reservoir - that were previously diverted or re-diverted into the Farmers Free Ditch.

Permit21112 RemainingSupply

SacWAM tracks El Dorado ID's use of its water right water under Permit 21112. The parameter *Permit21112 RemainingSupply* is the amount of water available at the beginning of the month. Permit 21112 water is assigned first preference from October through March. Available Permit 21112 water is divided into direct diversion of the natural flow above the Kyburz diversion and rediversion of storage releases. Water imported through the Echo Lake conduit may not be rediverted at Folsom Lake. CVP is assigned first preference from April to September.

7.9.4.2 Sly Park Unit

Sly Park Dam, which impounds Jenkinson Lake on Sly Park Creek, was constructed by Reclamation in 1955 as part of the Sly Park Unit of the CVP. The reservoir has a storage capacity of approximately 41 TAF. The unit was transferred to El Dorado ID in 2003. Associated facilities include Camp Creek Diversion Dam and Tunnel connecting Camp Creek to Jenkinson Lake, and the Camino Conduit which delivers water from Jenkinson Lake to the El Dorado ID service area to supplement district supplies drawn from the El Dorado Forebay and Folsom Lake.[51]

El Dorado ID diverts water from Camp Creek via the Camp Creek Tunnel to Jenkinson Lake. This direct diversion was originally associated with EID's Crawford Ditch and dates from 1851. The maximum diversion rate is 12.5 cfs. Up to 500 cfs may be diverted under appropriative water rights from November 1 through June 30 (licenses 11835 and 11836). The total amount that may be diverted to storage is 36,700 acre-feet. The total amount of water that may be diverted under the two permits (direct diversion and diversion to storage) may not exceed 40,300 acre-feet per year. In SacWAM, flow restrictions are placed on the Camp Creek Tunnel diversion arc using the maximum diversion property.

El Dorado ID must meet a flow requirement below Camp Creek Diversion Dam of 2 cfs or the natural flow, whichever is less. Similarly, the district must meet a flow requirement below Jenkinson Lake of 1 cfs or the natural flow, whichever is less. These flow requirements are not represented in SacWAM.

Allocation logic associated with the operation of Jenkinson Lake is described in the following sections.

7.9.4.2.1 Cosumnes\AvailableInflow

The *AvailableInflow* state variable represents the combined flow of Sly Park Creek to Jenkinson Lake and Camp Creek above the Camp Creek Diversion Dam. It is equal to the sum of inflow time series data (I_JNKSN, I_CMP012) read from SACVAL_Headflows.csv.

7.9.4.2.2 *Cosumnes\ForecastWaterSupply*

The *ForecastWaterSupply* state variable is the sum of March through September inflows to Jenkinson Lake and Camp Creek Diversion Dam, i.e., the sum of *AvailableInflow*.

7.9.4.2.3 *Cosumnes\EIDAllocation*

The *EIDAllocation* state variable represents the annual allocation of water from Jenkinson Lake to El Dorado ID as a fraction of the annual water demand. Deliveries through the transmission link connecting the Camino Conduit to the district are constrained using the *Maximum Flow Percent of Demand*

[51] The Hazel Creek Tunnel, which connects the El Dorado Canal to Sly Park Creek is not represented in the model. The tunnel is used to send Project 184 water into Jenkinson Lake when lake levels are low.

property, which is set equal to *EIDAllocation*. The *EIDAllocation* varies from zero to one, depending on the storage in Jenkinson Lake, the forecasted inflow through the end of the water year, target carryover storage, and water demands. Under normal conditions, Jenkinson Lake is operated to maintain 14,000 to 18,000 acre-feet of carryover storage each year. The allocation is determined in March based on perfect foresight of future inflows. An adjustment to the allocation allows the reservoir to be drawndown under drought conditions to the historical 1977 end-of-September storage.

7.9.4.3 Water Supply Preferences and Constraints

In SacWAM, Jenkinson Lake is a supplemental supply for both El Dorado ID DUs (U_EIDUp_NU, U_EIDLo_NU). U_EIDUp_NU water demands are primarily met from the El Dorado Forebay. Water demands for U_EIDLo_NU are primarily met from Folsom Lake; first using permit 21112 water and second using CVP water. Water is taken on a fixed monthly pattern. Simulation of contract and water right constraints are further discussed in Section 8.14.

7.9.5 Freeport Water Supply Project (Freeport)

The Freeport Water Supply Project supplies Sacramento County WA and EBMUD from a point of diversion on the Sacramento River approximately 9 miles below the American River confluence. The project enables EBMUD to take delivery of CVP water to meet a portion of its drought year water demands. The CVP contract allows EBMUD to divert up to 133,000 acre-feet of American River water each year with a total not to exceed 165,000 acre-feet in three consecutive years. This diversion can only occur in drought years when EBMUD's total system storage is forecast to be less than 500,000 acre-feet. The maximum diversion rate is 100 million gallons per day (mgd). Water is conveyed through the Folsom South Canal to its Mokelumne Aqueduct. The UDC *Freeport Regional Water Project\NoSupplyFromAmerican* ensures that no American River water is diverted and delivered to EBMUD.

7.9.5.1 Combine_Store

This variable is the sum of previous month storage in Pardee and Camanche reservoirs.

7.9.5.2 Divert

This variable is a trigger for EBMUD diversions based on district storage conditions and the amount of water delivered in the previous 3 years.

7.9.5.3 FPT_Diversion

This variable is the dry year deficiency that is imposed on EBMUD customers based on forecasted carryover storage in district reservoirs.

7.9.6 Georgetown Divide PUD

This section has been added for the purposes of documentation. It does not correspond to a branch in the SacWAM data tree.

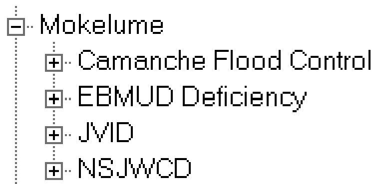
Georgetown Divide PUD is located on the western slope of the Sierra Nevada foothills, approximately 45 miles northeast of Sacramento, California. It straddles a ridge that separates the drainage basin of the Middle Fork American River and the Rubicon on the north from that of the South Fork American River on the south. The existing Service Area encompasses approximately 75,000 acres with approximately

30,000 acres currently having some form of water service available. GDPUD water supplies originate from the Pilot Creek Watershed above Stumpy Meadows Reservoir. Stumpy Meadows Reservoir is the district's sole source of supply. Water released from Stumpy Meadows Reservoir into Pilot Creek is diverted by the district at a downstream diversion dam into the Georgetown Divide Ditch. The district must also meet a minimum flow requirement below the diversion dam that varies between 2-4 cfs.

SacWAM contains no specific operation logic for Stump Meadows Reservoir. The reservoir provides a firm water supply for the district with the exception of extreme drought.

7.9.7 Mokelumne

In SacWAM, all state variables associated with Mokelumne River operations, other than IFRs, are located under *Ops\Mokelumne*.



7.9.7.1 Camanche Flood Control

Pardee and Camanche Reservoirs, located on the Mokelumne River, are owned and operated by EBMUD. The USACE flood-control agreement with EBMUD requires that a combined reservation of up to 200 TAF be maintained in Pardee and Camanche Reservoirs from September 15 to July 31. However, up to a maximum of 70 TAF of this flood-control reservation may be transferable to available space in PG&E's Salt Springs and Lower Bear Reservoirs. The following sections describe state variables relating to flood space requirements for Pardee and Camanche Reservoirs.

7.9.7.1.1 CamancheAprilStorage

The state variable *CamancheAprilStorage* is the previous April's storage in Camanche Reservoir. The variable is updated each April. The variable is used to determine releases from Pardee Reservoir to maintain thermal stratification in Camanche Reservoir. The variable is not related to flood control requirements but is described here for convenience.

7.9.7.1.2 FloodSpaceAdjustmentforPreRelease

The state variable *FloodSpaceAdjustmentforPreRelease* is the cumulative amount of water that must be released in July, August, and September to minimize reservoir spills in October. It is calculated as the cumulative value of *PreReleaseofOctFloodWater.* It is used to adjust the flood control diagram as a mechanism of forcing additional releases of water from storage.

7.9.7.1.3 FloodSpaceRequirement

The state variable *TransferableSnowFloodSpace* is the combined flood reservation in Pardee and Camanche Reservoirs. It is initially calculated as the *RainFloodSpaceRqment* plus *SnowFloodSpaceRqment* less *TransferableRainFloodSpaceRqment less TransferableSnowFloodSpace.* This volume is subsequently adjusted to force prerelease of water that would otherwise spill in later months (*FloodSpaceAdjustmentforPreRelease*).

7.9.7.1.4 MokFNFthrJuly

The state variable *MokFNFthruJuly* is the sum of the unimpaired monthly flows for the Mokelumne River at Mokelumne Hill from the current month (beginning in March) through July. This variable is used in the determination of flood space requirements during the snowmelt season.

7.9.7.1.5 NonTransferableFloodSpace

The state variable *NonTransferableRainFloodSpace* is the flood space that must be maintained in Pardee and/or Camanche Reservoirs and cannot be transferred to upstream PG&E reservoirs. The variable is used to calculate the transferable flood space.

7.9.7.1.6 PreReleaseofOctFloodWater

Flood space requirements for Pardee and Camanche reservoirs are zero from July 31 through September 15, but subsequently increase to 180 TAF by the end of October. In wetter years, this may result in excessive reservoir spills in SacWAM's simulation. The state variable *PreReleaseofOctFloodWater* is used to gradually release water from storage during the summer months and avoid water spills caused by drawdown in October for flood control. For the months of July, August, and September the value of *PreReleaseofOctFloodWater* is one quarter of the October *RainFloodSpaceRqment.* This value was determined from inspection of recent historical reservoir operations.

7.9.7.1.7 RainFloodSpaceRqment

The state variable *RainFloodSpaceRqment* is the rain-flood reservation for Pardee and Camanche Reservoirs, combined, including any transferable space. The monthly requirements are constant from year to year.

7.9.7.1.8 SnowFloodSpaceRqment

The state variable *SnowFloodSpaceRqment* is the snowmelt-flood reservation in Pardee and Camanche Reservoirs, including any transferable space. The requirements depend on the natural runoff into Camanche Reservoir from the current date through July 31.

7.9.7.1.9 *TransferableRainFloodSpaceRqment*

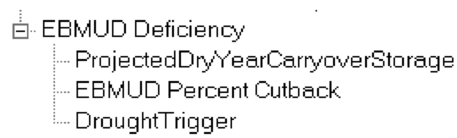
The state variable *TransferableRainFloodSpaceRqment* is the reduction in the rain-flood reservation in Pardee and Camanche Reservoirs because of available space in PG&E's upstream reservoirs: Lower Bear Reservoir and Salt Springs Reservoir.

7.9.7.1.10 *TransferableSnowFloodSpace*

The state variable *TransferableSnowFloodSpace* is the reduction in the snowmelt-flood reservation in Pardee and Camanche reservoirs because of available space in PG&E's upstream reservoirs: Lower Bear Reservoir and Salt Springs Reservoir.

7.9.7.2 EBMUD Deficiency

The following sections describe state variables relating to imposed deficiencies on EBMUD customer demands.



7.9.7.2.1 *DroughtTrigger*

The state variable *DroughtTrigger* is a flag used to indicate delivery deficiencies. It is determined in April based on *EBMUD Percent Cutback*.

7.9.7.2.2 *EBMUD Percent Cutback*

The state variable *EBMUD Percent Cutback* is the percent deficiency imposed on deliveries to EBMUD. If the *ProjectedDryYearCarryoverStorage* is greater than 500 TAF, there is no deficiency (*EBMUD Percent Cutback* = 0). Between 450 TAF and 500 TAF carryover storage, deficiencies increase linearly from zero to 15 percent. Between 300 TAF and 450 TAF carryover storage, deficiencies increase linearly from 15 to 25 percent. A larger deficiency is simulated in SacWAM, as the dry-year supply available as part of the Freeport Regional Water Project has currently not been implemented.

Deliveries through the transmission link connecting the Mokelumne Aqueduct to demand unit U_EBMUD are constrained using WEAP's *Maximum Flow Percent of Demand* property, which is set equal to (100- *EBMUD Percent Cutback*).

7.9.7.2.3 *FirstYear*

The parameter *FirstYear* indicates whether it is the first year of a multi-year drought.

7.9.7.2.4 *ProjectedDryYearCarryoverStorage*

EBMUD adopted its first Water Supply Availability and Deficiency Policy in 1985. Beginning in 1989, EBMUD revised this policy to limit deficiencies to a maximum of 25 percent of total customer demand. In 2010, with the adoption of Policy 9.03, the maximum deficiency was reduced to 15 percent, based on the development of new dry-year supplies. In April of each year, EBMUD forecasts its total carryover storage at the end of the water year. If total carryover storage is projected to be less than 500 TAF, customer deficiencies may be imposed.

In SacWAM, the state variable *ProjectedDryYearCarryoverStorage* is a forecast of total carryover storage based on the previous month storage in Pardee, Camanche, and EBMUD's terminal reservoirs; and on the forecasted unimpaired flow at Mokelumne Hill, less river diversions, less Mokelumne Aqueduct draft, less evaporative losses, less groundwater seepage losses, less the MFR at Woodbridge (USGS 11325500).

7.9.7.3 Jackson Valley ID (JVID)

Jackson Valley ID, located in southwest Amador County, provides water for irrigation and M&I use in Jackson Valley. District facilities include Jackson Dam, which impounds Lake Amador, an associated hydro-electric plant, and the Lake Amador Resort Area WTP. Jackson Valley ID has rights to store up to 36 TAF of Jackson Creek flows. The district may divert flows to Lake Amador between November and May at a maximum rate of 110 cfs. However, because of reservoir capacity constraints, the district typically uses about 10 TAF of this right. Additionally, Jackson Valley ID has rights to divert up to 3.85 TAF from the Mokelumne River at a diversion rate of 50 cfs. Under an agreement with EBMUD, Mokelumne River water is delivered to Jackson Valley ID by gravity from the north arm of Pardee Reservoir to Lake Amador. The district requests and usually receives 3.85 TAF annually from EBMUD. However, if the elevation in Pardee Reservoir falls below 550 feet, equivalent to approximately 161 TAF, deliveries to the district are no longer possible.

7.9.7.3.1 PardeeElevFlag

The state variable *PardeeElevFlag* is used to determine whether deliveries from Pardee Reservoir to Jackson Valley ID are possible. The variable is assigned a value of 0 when the beginning of month storage in Pardee Reservoir is below 161 TAF; otherwise, the variable is set equal to 1.

7.9.7.3.2 PrevDemand

The state variable *PrevDemand* is the previous month water demand based on Jackson Valley ID's annual water right of 3.85 TAF and recent historical monthly delivery patterns.

7.9.7.3.3 Shortage

The state variable *Shortage* tracks shortages in deliveries to Jackson Valley ID from Pardee Reservoir for the current water year based on cumulative monthly demand and cumulative deliveries.

In SacWAM, the *Maximum Diversion* property on the diversion arc from Pardee Reservoir to Lake Amador is set to the minimum of 50 cfs multiplied by *PardeeElevFlag* and the monthly demand plus any delivery shortage (*Shortage*) in the current water year.

7.9.7.4 North San Joaquin WCD (NSJWCD)

7.9.7.4.1 Cumulative Deliveries

North San Joaquin WCD (A_60N_NA3) includes approximately 157,000 acres east of the City of Lodi in eastern San Joaquin County. The service area covers land on both banks of the Mokelumne River, stretching from Dry Creek in the north to the Calaveras River and the boundary with Stockton East WD to the south.

In 1956, North San Joaquin WCD was issued a temporary water right (Permit 10477) as part of Decision 858 (D-858). Permit 10477 is for the temporary appropriation of up to 20 TAF of water from the lower Mokelumne River that is surplus to EBMUD's needs with a diversion season of December 1 to July 1. Through an agreement between both districts, EBMUD stores up to 20 TAF of water in the average to wettest years for delivery to North San Joaquin WCD during the irrigation season. The maximum diversion rate is 80 cfs. Historically, North San Joaquin WCD has used up to 9.5 TAF of water under Permit 10477. However, current demand for Mokelumne River water within the district service area is only approximately 3 TAF (Reclamation, 2014b).

In SacWAM, the state variable *CumulativeDeliveries* tracks annual water deliveries from February through September. Deliveries to the district are restricted using the *Maximum Flow Volume* property on the transmission link from the Mokelumne River to A_60N_NA3. The flow is restricted to the months of December through June and to 20 TAF less the previous month's deliveries (i.e., *CumulativeDeliveries*). The maximum flow rate is 80 cfs.

7.9.7.5 LowerMokelumneDiversionsCutback

The purpose of the parameter *LowerMokelumneDiversionsCutback* is to share the responsibility of meeting any new State Water Board flow requirements among water users of the lower Mokelumne River. The parameter has a value of 1 unless EBMUD deficiencies to its customers exceeds 25 percent. In this case, the parameter is reduced linearly below 1 as EBMUD deficiencies increase above 25 percent.

7.9.8 Nevada ID

Nevada ID's Yuba-Bear Project (FERC Project No. 2266) is located on the western slope of the Sierra Nevada Range in the Middle Yuba River, Canyon Creek, Fall Creek, Rucker Creek, and Bear River watersheds. The project consists of four developments - Bowman, Dutch Flat, Chicago Park, and Rollins. Project facilities include 13 dams with a combined gross storage capacity of approximately 208,000 acre-feet; four water conduits; five diversion dams; and four powerhouses with a combined authorized installed capacity of 79 megawatts (MW). Nevada ID coordinates project operations with PG&E's Drum-Spaulding Project.[52]

Water is stored and released from the district's upper reservoirs (Mountain Division) based on Nevada ID's consumptive demands and combined reservoir storage targets developed as part of the Consolidated Contract with PG&E. Discretionary releases are made from Jackson Meadows Reservoir located on the Middle Yuba during the spring runoff season through late fall. These releases are conveyed to Bowman Lake on Canyon Creek through the Milton-Bowman Tunnel. Inflows to Bowman Lake are augmented by releases from Jackson, French, Faucheria, and Sawmill reservoirs (these smaller reservoirs are not represented in SacWAM). This water is then stored and released from Bowman Reservoir through Bowman Powerhouse into the Bowman-Spaulding Conduit that leads to PG&E's Lake Spaulding located on the South Yuba River. From Lake Spaulding, PG&E delivers Nevada ID water to Deer Creek through the South Yuba Canal and Deer Creek Powerhouse and to the Bear River through the Drum Canal. Deer Creek flows are regulated by Scott Flat Reservoir. Bear River flows are regulated by Rollins Reservoir and to a lesser extent by Lake Combie.

Nevada ID service area consists of the Deer Creek system, which supplies the Scotts Flat and Nevada-Grass Valley areas, and the Bear River system, which covers southern Nevada County and Placer County. The district delivers water to its Deer Creek system from six diversion points on Deer Creek. Water is delivered to its customers in the Bear River system from PG&E's Wise Canal and from the district's Combie-Ophir Canal. The district's water supply is supplemented by purchased water from PG&E.

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[52] The 1963 Yuba-Bear Consolidated Contract describes the relationship and responsibilities of Nevada ID and PG&E in operating their respective projects. The document consists of the Yuba-Bear Project Power Purchase Contract, which is Part I, and the Yuba-Bear Water Operation Contract, which is Part II. The Water Operation Contract governs the coordinated operations of and water conveyance between the Yuba-Bear Project and PG&E's Drum-Spaulding Project.

Nevada ID operates its Yuba-Bear Project to meet the requirements of the FERC license issued in June 1963, including releases water to meet instream flow requirements. The 50-year license expired in 2013. The district filed a relicense application document in 2011. FERC issued a final EIS for the project in 2014. The project is awaiting 401 water quality certification by the State Water Board. SacWAM simulates the requirements of the 1963 FERC license.

SacWAM's simulation of the Yuba-Bear Project is based on the 1963 Consolidated Contract between Nevada ID and PG&E. The simulation separately tracks Nevada ID water and PG&E water. The simulation sequence is as follows:

- **Priority 6**: First, storage withdrawals are made, when required, to meet instream flow requirements below Jackson Meadows Dam (*REG Middle Yuba blw Jackson Meadows Dam*), below Milton Dam (*REG Middle Yuba blw Milton Dam*), below Bowman Dam (*REG Canyon Creek blw Bowman*), below Rollins Dam downstream from the Bear River Canal (*REG Bear River blw Bear River Canal*), and below Combie Dam (*REG Bear River blw Combie Dam*). Flow requirements are from the existing FERC P-2266 license issued in 1963, except for Deer Creek near Smartville, which is outside of the FERC project area.

- **Priority 12**: Top of conservation storage in Lake Combie is set equal to the average monthly observed storage. A relatively high priority is assigned to conservation storage so that simulated storage follows the average observed values in all but the driest years. Lake Combie, owned and operated by Nevada ID, is not part of FERC P-2266. It is a relatively small reservoir (5,560 acre-feet capacity) with a regular fill and drawdown pattern.

- **Priority 15:** Top of buffer storage in Rollins Reservoir is set equal to the average monthly observed storage. The model will maintain this storage using a mix of natural flows and storage withdrawals from Jackson Meadows and Bowman reservoirs. Under the 1963 Consolidated Contract, PG&E can store up to 30,000 acre-feet of PG&E water in Rollins Reservoir. This provision is not included in SacWAM.

- **Priority 18**: Nevada ID water is delivered by PG&E at the Deer Creek Powerhouse to meet Nevada ID consumptive uses in the Deer Creek watershed. Deliveries during the nine-month power period (described below) are limited to 47,700 acre-feet in normal years and to 37,100 acre-feet in dry years. Deliveries during the non-power-period (described below) are limited to 17,300 acre-feet in normal years and to 10,900 acre-feet in dry years. These limitations are imposed using the maximum diversion property of the Chalk Bluff Canal that leads to the Deer Creek Powerhouse. Additional constraints are imposed to limit flows through the Deer Creek Powerhouse to Nevada ID deliveries to Lake Spaulding less a 12.5 percent conveyance loss along the Chalk Bluff Canal (see Section 8.23). The model assumes that Nevada ID relies on district water for the Deer Creek system and does not purchase PG&E water to supplement supplies.

- **Priority 18**: Nevada ID water is wheeled by PG&E through the Drum Canal and South Yuba Canal wasteway to be delivered from Lake Combie to agricultural water users on the right bank (A_NIDBR_NA) and left bank (A_24_NA1) of the Bear River and from the Bear River Canal and Wise Canal to both agricultural (A_24_NA1) and urban (U_24_NU1) water users. Wheeling of Nevada ID water through PG&E's Bear River Canal is limited to 120 cfs (*UDC\NevadaID\BRC_NID_Max*). The model also imposes minimum diversion of Nevada ID water to the Bear

River Canal (*UDC\NevadaID\BRC_NID_Min*), known as 'Required Nevada Aqueduct Diversions' and as specified in the 1963 Consolidated Contract.

- **Priority 18**: PG&E water is delivered/sold to Nevada ID from Rock Reservoir on the Bear River Canal (to supply *A_24_NA1* and *U_24_NU1*) and from the Wise Canal via Auburn Ravine (to supply *A_24_NA1).*
- **Priority 19**: Water is stored in Jackson Meadows Reservoir, Lake Bowman, and Scott Flat Reservoir up to the top of buffer storage. Buffer storage in Nevada ID's Mountain Division is given higher priority than PG&E's Lake Fordyce and Lake Spaulding to encourage purchase of PG&E water by Nevada ID.
- **Priority 20**: Operational IFRs are placed on the Milton-Bowman Tunnel (*OPS NID Spill Prevention Milton Bowman*) and the Bowman-Spaulding Tunnel (*OPS NID Spill Prevention Bowman Spaulding*) to force the prelease of water from storage beginning in February to avoid future forecasted spills in the refill period.
- **Priority 20**: An operational IFR that varies between 290 and 300 cfs is placed on the Bowman-Spaulding Conduit to encourage Nevada ID to convey all available water up to these limits to Lake Spaulding. Particular conveyance limits, described in the 1963 Power Contract, are imposed using the maximum diversion property of the diversion arc.
- **Priority 21**: Water is stored in Jackson Meadows, Bowman, Fordyce, and Spaulding reservoirs up to the top of conservation.
- **Priority 22**: Water is stored in Scotts Flat and Rollins reservoirs up to the top of conservation.
- **Priority 24**: Water that cannot be stored in upstream storage and is surplus to consumptive use needs is routed through the Newcastle Powerhouse (*OPS Newcastle Powerhouse*).
- Nevada ID will not make discretionary releases for power generation if the resulting releases exceed downstream consumptive use demands and flows in Deer Creek near Smartville and flows in the Bear River below Combie Dam above the minimum flow requirements.
- Nevada ID water may not be stored in Lake Spaulding. Therefore, district deliveries to Lake Spaulding less 114.3 percent of flow through the Deer Creek Powerhouse (*NevadaWaterSupply*) augmented by natural accretions to the Bear River upstream from Combie Dam[53] are constrained to be greater than district's consumptive water use and storage gain in Rollins Reservoir and Lake Combie (*NevadaWaterUse*) supplemented by purchases from PG&E (see Section 8.23). Any excess Nevada ID water is spilled from Lake Combie to the Bear River.
- Nevada ID may buy water from PG&E. Buying points include Rock Creek on the Wise Canal to North Auburn (U_24_NU1) and Wise Powerhouse releases to Auburn Ravine for irrigation purposes (A_24_NA1). PG&E sales to Nevada ID are limited to a set of maximum monthly amounts for normal year and dry year conditions. In a normal year, the maximum annual

[53] PG&E is entitled to the first 350 cfs of natural flow in the Bear River upstream from Rollins Dam.

amount is 13,020 acre-feet; dry year supplies depend on the preceding October 1 – June 30 inflow to Lake Spaulding. These maximum amounts are subject to a PG&E allocation.

- Nevada ID draws down Jackson Meadows Reservoir and Lake Bowman to make deliveries to Lake Spaulding up to the maximum allowable volume described in the Consolidated Contract, but limited to Nevada ID downstream consumptive use demands and available storage in Rollins Reservoir.

- Nevada ID simulated demands on Deer Creek are 100 TAF/year. In normal years, local runoff to Deer Creek may meet approximately 40 TAF/year of this demand, but significantly less in drier years. In SacWAM, annual imports through Deer Creek Powerhouse are capped at 65 TAF/year in normal years and 48 TAF/year in dry years.

The following sections describe parameters for the Yuba-Bear Project defined under Other Assumptions.

7.9.8.1 PowerPeriod

The ‘Power Period’, as defined in the 1963 Consolidated Contract between Nevada ID and PG&E, is the 9-month period from July 1 through March 31 of the following year. The parameter *PowerPeriod* is assigned a value of 1 during this period and 0 outside of the period.

7.9.8.2 NonPowerPeriod

The ‘Non-Power Period’, as defined in the 1963 Consolidated Contract between Nevada ID and PG&E, is the three months of April, May, and June. The parameter *NonPowerPeriod* is assigned a value of 1 during this period and 0 outside of the period.

7.9.8.3 BowmanSpauldingMaxFlow

The 1963 Consolidated Contract between Nevada ID and PG&E defines an upper limit on Nevada ID water entering Lake Spaulding through the Bowman-Spaulding Tunnel. During the power period these flows are limited to approximately 290 cfs when the Mountain Division Storage is greater than the storage index and to 216 cfs when less than the Storage Index. During the non-power period flows are limited to 300 cfs when the Mountain Division Storage is greater than the storage index and to the amount that would not cause the Mountain Division Storage to fall below the storage index. The upper limits on Bowman-Spaulding flows are assigned to the parameter *BowmanSpauldingMaxFlows*.

The Drum-Spaulding Conduit is typically closed for several weeks each summer for maintenance. Initially, this maintenance period was simulated as a fixed two-week closure in June. However, the fixed closure period distorted operations in some years, so it was removed. It is assumed that maintenance is scheduled around operational needs and the timing varies from year to year.

7.9.8.4 DeerCreekPHMaxFlows

The 1963 Consolidated Contract defines the maximum monthly amount that Nevada ID can request, and PG&E deliver at the Deer Creek Powerhouse depending on the water conditions (normal or dry). These limits are assigned to the parameter *DeerCreekPHMaxFlows*.

7.9.8.5 MinReleaseAvoidSpills BS

Initial SacWAM simulation runs showed excessive amounts of water spilled to the Middle and South Yuba rivers, and Canyon Creek when compared to historical streamflow data. Therefore, a routine was developed to forecast spills during the refill period (February – June) and to prelease this volume of water at a steady rate to minimize spilled water. *MinReleaseAvoidSpills BS* is this steady release volume, over and above instream flow requirements, based on current storage and perfect insight of future inflows. A calibration factor was introduced based on observed data, to implement a more conservative approach to reservoir releases, acknowledging uncertainty in forecast information.

7.9.8.6 MinReleaseAvoidSPills MB

Similar to *MinReleaseAvoidSpills BS, MinReleaseAvoidSpills MB* is the required flow through the Milton-Bowman Tunnel to minimize future spills from Jackson Meadows Reservoir to the Middle Yuba River.

7.9.8.7 MountainDivisionStorage

'Mountain Division Storage', as defined in the 1963 Consolidated Contract between Nevada ID and PG&E, is the active storage in Jackson Meadows, Milton, French Lake, Faucherie Lake, Sawmill Lake, Jackson Lake, and Bowman reservoirs. The parameter *MountainDivisionStorage* is the previous end-of-month storage in Jackson Meadows and Bowman reservoirs plus historical average monthly flows for French, Faucherie, and Sawmill reservoirs, plus 90% of the storage capacity of Milton Dam and Jackson Dam (SacWAM does not represent the other smaller reservoirs in the system).

7.9.8.8 NIDAllocationFraction

SacWAM uses information from the Nevada ID Drought Contingency Plan (NID, 2012) to determine the annual water allocation to Nevada ID customers based on the water supply forecast (*NIDWaterSupplyForecast*). The *NIDAllocationFraction* may vary between 0 and 1.

7.9.8.9 NIDCarryoverTarget

For the determination of annual allocation of water supplies to Nevada ID customers, *NIDCarryoverTarget* is the carryover storage target. It includes both active and inactive storage. For modeling purposes, a fixed value of 78,000 acre-feet is adopted (NID, 2012). However, Nevada ID may vary this amount during multiple consecutive dry years.

7.9.8.10 NIDEnvironmentalFlowRequirement

In the estimate of water supply, *NIDEnviornmentalFlowRequirement* is an estimate of instream flow requirements below Milton Dam on the Middle Yuba, below Bowman Dam on Canyon Creek, and below Combie Dam on the Bear River. This water leaves the Nevada ID service area and is not available to the district for water supply purposes.

7.9.8.11 NIDReuse

In the estimate of water supply, *NIDReuse* is an estimate of urban wastewater return flows or agricultural tailwater that is available for reuse within the Nevada ID service area.

7.9.8.12 NIDWaterSupplyForecast

The water supply forecast is made in April and fixed until March of the following year. In SacWAM, the parameter *NIDWaterSupplyForecast* is the sum of end-of-March storage in Jackson Meadows, Bowman, Rollins, Scott Flat, and Combie reservoirs, forecasted inflows from April through September, less the carryover storage target, (*NIDCarryoverTarget*) less instream flow requirements (*NIDEnvironmentalFlowRequirement*), plus water available for reuse (*NIDReuse*). The calculation assumes that up to 30,000 acre-feet of water stored in Rollins Reservoir is PG&E water.

7.9.8.13 PGETargetPurchase
The parameter *PGETargetPurchase* is the estimated amount of water Nevada ID will buy from PG&E. If the *WaterSupplyForecast* is above 235,700 acre-feet, the target amount is the minimum of 7,500 acre-feet or the full contract amount multiplied by the PG&E allocation to Nevada ID and Placer County WA. For a *WaterSupplyForecast* less than 235,700 acre-feet, the target purchase equals the allocation from PG&E. Currently, this parameter is not used in SacWAM.

7.9.8.14 ShareofRollinsInflow
The 1963 Consolidated Contract between Nevada ID and PG&E assigns the first 350 cfs of natural flow in the Bear River above Rollins Dam as PG&E water. The remaining flow, if any, is Nevada ID water. In SacWAM, this remaining flow is assigned to the parameter *ShareofRollinsInflow*.

7.9.8.15 StorageIndex
The 'Storage Index', as defined in the 1963 Consolidated Contract between Nevada ID and PG&E, consists of 12 monthly critical threshold values for Mountain Division Storage that vary from 68,000 acre-feet in February to 156,000 acre-feet in June. In SacWAM, these parameters are assigned to the parameter *StorageIndex*.

7.9.9 Stockton East WD (NewHoganOps)

New Hogan Reservoir was built by USACE in 1964 for flood control, water supply, and recreational purposes. The reservoir has a capacity of 317 TAF, with approximately 165 TAF reserved for flood control during the flood season. Inflows, derived primarily from precipitation, average approximately 150 TAF per year. The Corps operates New Hogan Reservoir when flood releases are required; otherwise, the reservoir is operated by Stockton East WD, which schedules releases from conservation storage. Calaveras County WD diverts water for its Jenny Lind WTP below New Hogan Reservoir. Stockton East WD diverts water downstream of New Hogan Reservoir at Bellota Weir for both agricultural and M&I purposes.

7.9.9.1 Allocation_Ag
The variable *Allocation_Ag* is the allocation of Calaveras River water for agricultural purposes.

7.9.9.2 Allocation_MI
The variable *Allocation_MI* is the final allocation of Calaveras River water for use at Stockton East WD's water treatment plant. It is equal to the sum of *Allocation_MI_1 and Allocation_MI_2.*

7.9.9.3 Allocation_MI_1
The variable *Allocation_MI_1* is the initial allocation of Calaveras River water for use at Stockton East WD's water treatment plant.

7.9.9.4 Allocation_MI_2
The variable *Allocation_MI_2* is an additional allocation of Calaveras River water for use at Stockton East WD's water treatment plant after agricultural allocations have been determined.

7.9.9.5 New Hogan Carryover Target
The *New Hogan Carryover Storage Target* defines the carryover storage objective for the current water year based on end-of-March storage.

7.9.9.6 New Hogan Water Supply Index

The *New Hogan Water Supply Index* is a measure of the April through September available water supply in New Hogan Reservoir. It is calculated, based on perfect foresight, as the sum of end-of-March storage, April through September reservoir inflows, less the carryover storage target, less diversions to the Jenny Lind WTP and to riparian water holders, less estimates for reservoir evaporation and river seepage losses.

7.9.10 Placer County WA Middle Fork Project (PCWA MFP)

This section describes Placer County WA's Middle Fork Project (MFP), which is located in the watershed of the Middle Fork of the American River. This section also describes operation of the agency's American River Pump Station located on the North Fork of the American River, approximately 3.5 miles below the confluence with the Middle Fork. Placer County WA's water supply from PG&E's Drum-Spaulding Project is discussed in Section 7.9.11.

The MFP located on the South Fork American River and Rubicon River is owned and operated by Placer County WA for both hydropower and water supply purposes. The project was completed in 1967. Project facilities include two dams (French Meadows and Hell Hole), five diversion dams, five tunnels, and five power plants (French Meadows, Hell Hole, Middle Fork, Ralston, and Oxbow and related electrical transmission facilities. The two storage reservoirs, French Meadows and Hell Hole, have a combined capacity of approximately 340,000 acre-feet.

At the Duncan Creek Diversion Dam, creek flows are diverted through the Duncan Creek Diversion Tunnel to French Meadows Reservoir. From French Meadows Reservoir water is conveyed through the French Meadows Tunnel and Powerhouse into Hell Hole Reservoir. Subsequently, water is diverted through the Hell Hole Tunnel to the Middle Fork Powerhouse. Tunnel flows are augmented by diversions from the North and South Fork of Long Canyon Creek. Tailwater from the powerhouse are impounded at the Interbay Dam on the Middle Fork American River. Water is diverted at the Interbay Dam through the Ralston Tunnel to the Ralston Powerhouse. Ralston Afterbay is located immediately downstream from the Rubicon River-Middle Fork confluence. The Oxbow Powerhouse at the Afterbay is lowest elevation of the five generating plants.

In addition to water supply and hydropower demands, the MFP must, at times, release water to the lower American River in mitigation water for lower basin diversions in accordance with the American River Water Forum Agreement. Storage releases for mitigation of Folsom Lake diversions are triggered when the forecasted March through November unimpaired inflow to Folsom Lake is less than 400,000 acre-feet. Currently, release of mitigation water in dry years is not simulated in SacWAM.

In 2015, Placer County WA signed a water transfer agreement with EBMUD. Under this agreement, mitigation water is diverted at the Freeport Regional Water Project and conveyed to EBMUD's Mokelumne Aqueduct. The Placer County WA-EBMUD water transfer agreement is not modeled in SacWAM.

Placer County WA operates the MFP (FERC Project No. 2079) under a 50-year-old license issued in 1963. By the Federal Power Commission (predecessor of the Current FEWRC). Placer County WA applied for a new license in 2010 and is now waiting for the State Water Board to complete the water quality certification to finalize the relicensing. SacWAM has been designed so that the user may switch between the old and new license instream flow requirements.

Placer County WA's operation of the MFP is guided by several factors, including water supply needs, power demand; FERC license requirements; and dam safety requirements. SacWAM simulation logic for Placer County WA's facilities is as follows:

Duncan Creek Diversion Dam diversions are limited to a physical capacity of 400 cfs. From November through June all flows in Duncan Creek over and above those required to meet the flow requirement below the diversion dam, are diverted through the Duncan Creek Diversion Tunnel to French Meadows Reservoir. In practice, diversions are shut-off when French Meadows Reservoir is spilling. This is not modeled in SacWAM.

French Meadows Reservoir has a fixed top of conservation level. However, SacWAM uses this level to impose water right constraints on the period of diversion to storage (November 1 – July 1). Water is released to the French Meadows Tunnel and to the South Fork American River to meet instream flow requirements below the dam. Any excess water is spilled to the South Fork. A monthly rule curve, which is implemented using buffer storage, controls the transfer of water to Hell Hole Reservoir and subsequently to Hell Hole Tunnel fort power generation. The rule curve depends on the April-to-July unimpaired flow at Fair Oaks.

French Meadows Tunnel and Powerhouse flows are limited to the 400 cfs physical capacity.

Hell Hole Reservoir has a fixed top of conservation level. However, SacWAM uses this level to impose water right constraints on the period of diversion to storage (November 1 – July 1). Water is released to the Hell Hole Tunnel and to the Rubicon River to meet instream flow requirements below the dam. Any excess water is spilled to the Rubicon River. SacWAM does not represent the 36 cfs capacity Hell Hole Powerhouse at the dam outlet. Additionally, SacWAM does not represent operational restrictions that limit releases through the Howell-Bunger valve to approximately 80 cfs. A monthly rule curve that is implemented using buffer storage controls the release of water for power generation. The rule curve depends on the April-to-July unimpaired flow at Fair Oaks.

Hell Hole Tunnel flows are restricted to by its hydraulic capacity and capacity of the powerhouse, which is approximately 940 cfs. The model assumes a one-month closure period in October for maintenance of the Middle Fork Powerhouse. Flows through the tunnel are driven by an IFR object (*OPS Hell Hole Tunnel*) placed on the tunnel with an associated flow requirement of 940 cfs.

Middle Fork Powerplant is located at the downstream end of Hell Hole Tunnel. Model logic is applied to Tunnel flows and not the powerhouse.

Long Canyon Creek Diversion Dams, located on the North Fork and South Fork Canyon Creek, supplement flows in the Hell Hole Tunnel. Simulated diversions are limited to an assumed physical capacity of 300 cfs and to the November through June period. SacWAM includes an instream flow requirement below the dams. Priorities on Hell Hole storage ensure that Long Canyon Creek water is taken before storage withdrawals from Hell Hole Reservoir. In practice, Placer County WA limits diversions to the snowmelt season to avoid inflow of sediment during heavy runoff. Additionally, diversions are shut-off when Hell Hole Reservoir is spilling. These operations are not simulated in SacWAM.

Ralston Tunnel flows are limited to an assumed 925 cfs capacity. The model assumes a one-month closure period in October for maintenance of Ralston Powerhouse. Flows through the tunnel are driven by an IFR object (*OPS Ralston Tunnel*) placed on the tunnel with an associated flow requirement of 925 cfs.

Ralston Powerplant, located at the downstream end of Ralston Tunnel. Model logic is applied to Tunnel flows and not the powerhouse.

Ralston Afterbay/Oxbow Reservoir is not modeled as a storage facility.

Oxbow Powerplant is simulated as a run-of-the river facility. Flow through the powerhouse is limited to an assumed 1,025 cfs capacity. Additionally, the plant is assumed to be off-line for the month of October for maintenance. Placer County WA releases 5 cfs from the Afterbay Dam to maintain water quality between the dam and powerhouse. This requirement is not represnted in SacWAM.

Middle Fork American River near Foresthill is the location of USGS gauge No. 11433300, which is a compliance point under both the existing and new license. The new license refers to this location as the Middle Fork American River below Oxbow Powerhouse. However, inflows from the North Fork of the Middle Fork American River are available to help meet the flow requirements.

American River Pump Station, located on the North Fork American River below the conference with the Middle Fork, provides water for Placer County WA's Zone 1 and Zone 5 for agricultural and M&I purposes. The pump station, completed in 2008 with a design capacity of 100 cfs, supplements water purchased from PG&E and delivered through the Bear River, Wise, and South canals. As part of the American River Water Forum Agreement, Placer County WA agreed to limit diversions at the pump station to 35.5 TAF per year.

Generally, all of the water pumped between April 15 and October 15 is discharged to the Auburn Ravine for delivery to Zone 5 growers. During the annual PG&E outage on the Bear River Canal, usually after October 15, the outlet valve of the tunnel is closed, and water is pumped out of the tunnel at the Auburn Tunnel Pump Station, near the Auburn Wastewater Treatment Plant into the PG&E South Canal for use at Placer County WA's Foothill WTP. Water pumped after October 15 is used in Zone 1. Currently, discharge to Auburn Ravine is limited to a rate of 50 cfs until completion of the Auburn Ravine mitigation studies.

From 2008 to 2017, the annual volume of water delivered form the pump station has varied from 3.1 TAF (2017) to 24.2 TAF (2015) and has averaged 11.7 TAF. SacWAM limits diversions to a base amount of 12 TAF per year on a predefined monthly diversion pattern based on historical deliveries from 2006 through 2015, plus an incremental amount equal to the PG&E contract deficiency. SacWAM models a 75 cfs flow requirement below the pump station. Diversions at the pump station are driven by priorities on deliveries to Placer County WA Zones 1 and 3. The priority assigned to MFP storage (27 and 21 for buffer storage) are lower than priorities assigned to Nevada ID and PG&E storage in the Yuba River watershed (21 and 19 for Nevada ID buffer storage). Therefore, SacWAM meets Zone 1 and Zone 5 demands first from the American River up to the maximum diversion amount and second from the Yuba/Bear River. Deliveries to Zone 1 are restricted to 50 cfs in April and October and to 0 cfs May through September.

Folsom Lake is the point of diversion for MFP water supplied to the City of Roseville, San Juan WD, and Sacramento Suburban WD.

- The City of Roseville has signed a water supply contract with Placer County WA for up to 30,000 acre-feet of MFP water. The City also holds a CVP contract for up to 32,000 acre-feet. The City is signatory to the 2000 Water Forum Agreement and has agreed to limit its surface water diversions based on hydrologic conditions and the unimpaired inflow to Folsom Lake. The 2000 Water Forum Agreement, including the Purveyor Specific Agreements, is not currently represented in SacWAM.
- San Juan WD has signed a water supply contract with Placer County WA for up to 25,000 acre-feet per year of MFP water. The district has an agreement with the City of Roseville to sell up to 4,000 acre-feet of this water during normal years if required by the City of Roseville. In addition to MFP water, San Juan WD holds pre-1914 water rights for 33,000 acre-feet per year from the American River. The district also holds a Reclamation contract for 24,200 acre-feet per year.
- Sacramento Suburban WD has an agreement with Placer County WA for delivery of up to 29,000 acre-feet per year of the agency's MFP water. The conditions of the contract were amended in 2008 to an annual entitlement of 12,000 acre-feet per year, and an additional 17,000 acre-feet supplemental amount, delivered with the approval of Placer County WA, for a maximum total of 29,000 acre-feet per year. Starting in 2010, the supply became available only during Water Forum wet years, when the March-through-November unimpaired inflow into Folsom Lake is greater than 1.6 MAF. Delivery of this water also may be limited by available capacity at San Juan WD's Peterson WTP.

Operation of MFP reservoirs to meet water supply commitments at Folsom Lake are imposed using UDCs (see Section 8.27).

7.9.10.1 PeriodofDirectDiversion

The variable *PeriodofDirectDiversion* is used to impose Placer County WA's water right for direct diversion at the American River Pump Station. The variable has a value of 1 for the months of November through June and a value of zero for the remaining months of the year. It is references by *UDC\PCWA MFP\FolsomDiversion* (see Section 8.27.2).

7.9.10.2 PeriodofStorageRelease

The variable *PeriodofStorageRelease* is used to model Placer County WA's water right for diversion at the American River Pump Station. The variable has a value of 1 for the months of July through October and a value of zero for the remaining months of the year. It represents the period when Placer County WA diversions are met by storage withdrawals from MFP reservoirs. It is references by *UDC\PCWA MFP\FolsomDiversion* (see Section 8.27.2).

7.9.11 PG&E Chili Bar Project

This section has been added for the purposes of documentation. It does not correspond to a branch in the SacWAM data tree.

PG&E's Chili Bar Project (FERC Project No. 2155) is located on the South Fork American River immediately downstream from the SMUD UARP White Rock powerhouse. The Chili Bar Project consists of a dam, reservoir, intake, penstock, and powerhouse. The Chili Bar project is a run-of-the-river facility.

Downstream flow requirements specified in the FERC license are met through operational agreements between PG&E and SMUD and releases from SMUD reservoirs when required.

SacWAM contains no specific operation logic for the Chili Bar Project. The facility is represented using a storage object, but storage is held constant at 3,000 acre-feet. SacWAM uses an IFR object (*REG SF American nr Placerville*) to represent the downstream flow requirements in the FERC license.

7.9.12 PG&E Drum-Spaulding Project

The Drum-Spaulding Project (FERC Project No. 2310), owned and operated by PG&E, spans the Yuba, Bear, and American River watersheds. Storage facilities include Lake Spaulding (75,912 acre-feet) on the South Yuba River, Fordyce Lake (49,525 acre-feet) on Fordyce Creek above Lake Spaulding, Lake Valley Reservoir (7,902 acre-feet) on the North Fork of the North Fork American River, and several smaller reservoirs in the South Yuba River watershed.[54] The combined gross storage capacity of the project is approximately 154,000 acre-feet. The project also includes 12 powerhouses (Spaulding 1, 2, and 3, Deer Creek, Drum 1 and 2, Alta, Dutch Flat 1, Halsey, Wise 1 and 2, and Newcastle) that have a combined normal operating capacity of 190 MW.

PG&E relies upon pre-1914 and appropriative water rights to store water, generate power, and deliver water for irrigation and M&I purposes. In addition, some of the water used by PG&E for power generation is furnished by Nevada ID (i.e., Nevada water) for subsequent delivery to Nevada ID at downstream diversion points. PG&E and Nevada ID have entered into several agreements coordinating water operations. These agreements include the 1963 Consolidated Contract for Water Diversion and Power Purchase and subsequent amendments. PG&E also delivers water to Placer County WA.

PG&E facilities represented in SacWAM include Lake Fordyce, Lake Spaulding, Lake Valley Reservoir, and the Drum and South Yuba canals. SacWAM also simulates flows through PG&E's Bear River Canal, Wise Canal, and South Canal and associated deliveries to Nevada ID and Placer County WA. Outflow from the South Canal passes through the Newcastle Powerhouse to discharge into the northern arm of Folsom Lake.

The Bear River Canal has a capacity of 420 cfs. In SacWAM, this capacity is reduced in October and November to represent a 3-week canal outage for maintenance from October 18 to November 7. Canal seepage losses are assumed to be 7 percent of the canal headflow, modeled as a diversion arc leaving the model domain. Downstream from the Halsey Powerhouse, the canal becomes the Wise Canal with a capacity of 488 cfs. No separate maintenance period is simulated. The Wise Powerhouse Afterbay marks the beginning of the South Canal with a simulated capacity of 375 cfs. As with the Wise Canal, no maintenance period is simulated.

PG&E operates its Drum-Spaulding Project to meet the requirements of the FERC license issued in June 1963, including releases water to meet instream flow requirements. The 50-year license expired in 2013. PG&E filed a relicense application document in 2011. FERC issued a final EIS for the project in 2014. The project is awaiting 401 water quality certification by the State Water Board.

[54] Gross storage volumes are from PG&E FERC license application for Drum-Spaulding Project, P-2310.

7.9.12.1 PG&E Deliveries to Placer County Water Agency

Placer County WA holds two water sale agreements with PG&E to purchase water from PG&E's Drum-Spaulding Project. Under a 1982 agreement, Placer County WA may purchase up to 25,000 acre-feet per year to serve its Zone 3 area. The majority of this water is delivered from the upper reaches of the lower Boardman Canal – a Placer County WA facility. Under a 2015 agreement, Placer County WA may purchase up to an additional 100,400 acre-feet to serve its Zone 1 and Zone 5 service areas. Water is delivered at buying points along PG&E's Bear River Canal, Wise Canal, and South Canal. PG&E may curtail these supplies based on Drum-Spaulding storage and forecasted inflows.

7.9.12.1.1 Zone 3 Deliveries

In SacWAM, Zone 3 deliveries are represented by a single transmission link from the lower Boardman Canal to demand unit U_PCWA_NU. The annual demand is 10 TAF. PG&E water is diverted in to the lower Boardman Canal from the Drum Canal.[55] The simulated capacity of the canal in its head reaches is 29 cfs (the capacity of the Cedar Creek Canal that links Lake Alta to the lower Boardman Canal). Seepage losses from the lower Boardman Canal are assumed equal to 12 percent of the canal headflow, modeled as a diversion arc leaving the model domain. No reductions of the Zone 3 supply are modeled in SacWAM. Zone 3 demands are approximately 10 TAF per year, significantly lower than the full contract amount.

Typically, canal outflows from Placer County WA Zone 3 to Zone 1 are less than 1 cfs. However, during PG&E maintenance of the Bear River Canal, the lower Boardman Canal is used to supply Placer County WA upper Zone 1 demands, represented by demand unit U_24_NU. This is further discussed in Section 8.28.

7.9.12.1.2 Zone 5 Deliveries

Placer County WA delivers raw water to Zone 5 for agricultural purposes. In SacWAM, Zone 5 is represented by demand unit A_24_NA2. PG&E water for Placer County WA Zone 5 is conveyed from the Bear River through the Bear River and Wise canals to the South Canal to buying point YB-136.[56] From here, water is discharged into a short ravine that leads to the Mormon Ravine below the American River Pump Station Tunnel/Auburn Ravine Tunnel outlet. The PG&E supply is supplemented by deliveries from Placer County WA's American River Pump Station. In SacWAM, a UDC constrains Auburn Ravine deliveries to the sum of South Canal outflow at YB-136 and American River Pump Station deliveries less a 6.25 percent seepage loss (see Section 8.28).[57]

[55] SacWAM does not represent PCWA pre-1914 water rights for diversion from Canyon Creek or explicitly represent conveyance from the Drum Canal via Canyon Creek, Towle Canal, and Pulp Mill Canal to Lake Alta and from here through the Cedar Creek Canal to the lower Boardman Canal.

[56] Additional water is delivered to PCWA for Zone 5 at YB-76A. For modeling purposes, YB-76A deliveries are combined with YB-136.

[57] Nevada ID is the watermaster for the Auburn Ravine upstream from the Lincoln Gauge. For water accounting purposes, the Nevada ID and PCWA agree on a 6.25 percent transmission loss along this reach of the ravine. This is implemented in SacWAM using the groundwater outflow property of a river object. PCWA also assumes a 10 percent loss in conveying water from the Lincoln Gauge to its customers in Zone 5. In SacWAM, this conveyance loss is incorporated in the loss to groundwater property of the transmission link from Auburn Ravine to A_24_NA2.

North Fork American River water is a supplemental supply given the high pumping cost associated with the pump station. This pumped water is mainly used to supply the Foothill Water Treatment Plant with raw water during the annual PG&E Bear River canal maintenance. Discharge from the Auburn Tunnel to the Auburn Ravine is currently limited to 50 cfs. The capacity of the pump station is 100 cfs.

7.9.12.1.3 Zone 1 Deliveries

In SacWAM, PG&E water for Placer County WA Zone 1 is conveyed from the Bear River Canal, Wise Canal, South Canal, and lower Boardman Canal as follows:

- Conveyance of PG&E water to the lower Boardman Canal (*Wise Lower Boardman Intertie*).[58]
- To demand unit U_24_NU1, representing deliveries to the agency's Bowman and Auburn water treatment plants (Demand Unit U_24_NU1 also represents the North Auburn water treatment plant supplied by Nevada ID from Rock Creek Reservoir).
- To demand unit U_24_NU2, representing deliveries to the agency's Foothill and Sunset water treatment plants. The PG&E supply may be supplemented by deliveries from Placer County WA's American River Pump Station.
- To demand unit A_24_NA3, representing deliveries for agricultural purposes. Simulated deliveries are made from the South Canal and lower Boardman Canal. The PG&E supply may be supplemented by deliveries from Placer County WA's American River Pump Station.

The following sections describe SacWAM logic for simulating PG&E's Drum Spaulding Project.

7.9.12.2 WaterSupplyForecast

The variable *WaterSupplyForecast* is a measure of the total water available to both projects through the end of the water year. It is determined in February using perfect insight of reservoir inflows through the end of September. The *WaterSupplyForecast* is subsequently used in the definition of 'operational' flow requirements on the Drum Canal and Newcastle Powerhouse. The relationship between the flow requirements and the *WaterSupplyForecast* was derived from historical data and is a device to approximate a much more complex set of operational rules that govern actual operations of the two projects.

7.9.12.3 NIDMonthlyMaxContractAmount

In 1963, PG&E and Nevada ID signed a Consolidated Contract for collectively managing their respective projects in the Yuba and Bear watersheds. The amount of PG&E water available for purchase by Nevada ID depends on hydrologic conditions. Under normal conditions, 13,020 acre-feet are available for purchase at points along the Wise Canal. Dry year purchases are determined by the October through June unimpaired inflow to Lake Spaulding. The maximum delivery rate is 40 cfs. The Consolidated Contact was modified by the 1972 agreement to provide regular purchases of PG&E water at Rock Creek Reservoir to meet the demand of Nevada ID's Auburn Water Treatment Plant. This is the only water that the district is obligated to purchase.

[58] The 'intertie' represents flows through PCWA's Ragsdale Random, Fiddler Green Canal, and direct diversion from the South Canal into the lower Boardman Canal.

The parameter *NIDMonthlyMaxContractAmount* is the monthly amount of PG&E water available to Nevada ID for Zones 1 and 5.

7.9.12.4 NIDAnnualMaxContractAmount

The parameter *NIDAnnualMaxContractAmount* is the maximum annual amount of PG&E water available to Nevada ID for Zones 1 and 5. It is the sum of monthly volumes described above.

7.9.12.5 SpauldingPrecipitation

The parameter *SpauldingPrecipitation*, which is read from the input data file Data\WYT\ SpauldingPrecipitation.csv, is the historical monthly precipitation at Lake Spaulding Dam.

7.9.12.6 AccumulatedPrecipitation

The parameter *AccumulatedPrecipitation* is the accumulated monthly precipitation at Lake Spaulding Dam from the previous July 1st through to the start of the current month.

7.9.12.7 WaterConditions

Water conditions for the Drum-Spaulding Project are designated 'normal' or 'dry' based on the *AccumulatedPrecipitation*. The parameter *WaterConditions* is set equal to 1 to indicate normal water conditions or 0 to indicate dry year conditions. The *WaterConditions* parameter is used in calculating the amount of PG&E water available to Nevada ID. It varies monthly from January through June and is fixed for the remainder of the year based on the June value of the *AccumulatedPrecipitation.*

7.9.12.8 WaterConditionsJuly

The *WaterConditionsJuly* parameter determines whether conditions are normal or dry based on the accumulated precipitation July 1 through May 31. These conditions are subsequently fixed through the end of the year.

7.9.12.9 SpauldingUnimpInflowOctJun

The amount of water to be made available by PG&E to Nevada ID depends on hydrologic conditions (normal or dry). Under normal water conditions, up to 13,020 acre-feet are available. When dry year water conditions exist: no water is available January through March; 4,240 acre-feet are available April through June; and up to 7,650 acre-feet are available July through December depending on the October through June unimpaired inflow to Lake Spaulding. For modeling purposes, the parameter *SpauldingUnimpInflowOctJun* is determined in February using perfect foresight to facilitate determination of an annual water allocation.

7.9.12.10 PCWAAnnualMaxContractAmount

Under a 1968 agreement, which was renewed in 2015, PG&E agrees to sell to Placer County WA water requested by that agency, up to a maximum annual amount of 100,400 acre-feet over the water year. Under this agreement, Placer County WA may also purchase additional surplus water, when it is available. The maximum delivery rate is 244.8 cfs. Sales are further limited to a maximum of 25,000 acre-feet per year upstream from PG&E's Halsey Powerhouse, and to a maximum of 55,000 acre-feet per year upstream from PG&E's Wise Powerhouse.

The parameter *PCWAMaxContractAmount* represents Placer County WA full contract amount with PG&E to serve Zones 1 and 5. It is set equal to 110.4 TAF.

7.9.12.11 FebJulyRunoffForecast

The parameter *FebJulyRunoffForecast* is the sum of forecasted February through September unimpaired inflow to Lake Fordyce, Lake Spaulding, and Lake Valley Reservoir, plus the inflow to Rollins Reservoir that exceeds 350 cfs. The parameter is determined in February using perfect foresight and is subsequently fixed for a 12-month period. The parameter is used in the calculation of *PCWA WaterAllocation*, described below.

7.9.12.12 MinimumFlowFebSep

The parameter *MinimumFlowFebSep* is the February through September flow requirement below Lake Spaulding, expressed as a volume. *MinimumFlowFebSep* is determined in the month of February. The parameter is used in the calculation of *PCWA WaterAllocation*, described below.

7.9.12.13 PGECarryoverStorageTarget

The parameter *PGECarryoverStorageTarget* represents PG&E's carryover target for the end of the water year. It is the sum of individual targets for Lake Fordyce (10,000 acre-feet), Lake Spaulding (25,000 acre-feet), and Lake Valley Reservoir (2,500 acre-feet). The total carryover target is 37,500 acre-feet.

7.9.12.14 SWRCBSouthYubaIFR

The parameter *SWRCBSouthYubaIFR* represents the additional amount of water that must be released from Lake Spaulding to meet a potential new instream flow requirement established by the State Water Board on the South Yuba at Jones Bar.

7.9.12.15 PCWA WaterAllocation

The 2015 water supply contract between PG&E and Placer County WA does not specify when and by how much Placer County WA sales may be cut in dry hydrologic conditions. In 2015, Placer County WA were accorded only 68.9 percent of the maximum 100,400 acre-feet amount for Zones 1 and 5 (PG&E 2015). For modeling purposes, a water allocation procedure was developed based on the metric *WaterSupplyForecast*, described above, and a threshold of 175 TAF. For water year 2015, the historical value of this metric was 152 TAF. For each acre-foot below the threshold, the allocation to Placer County WA is reduced by one acre-foot. The parameter *PCWA WaterAllocation* is the resulting allocation, expressed as a fraction of the full contract amount.

The calculation of *PCWA WaterAllocation* is determined in February based on beginning of month storage in PG&E reservoirs and references to the following parameters that are described above:

- *FebJulyRunoffForecast*
- *MinimumFlowFebSep* (which references *SWRCBSouthYubaIFR*)
- *PGECarryoverStorageTarget*
- *NIDAnnualMaxContractAmount*
- *PCWAAnnualMaxContractAmount*

The parameter *NIDAnnualMaxContractAmount* depends on the following parameters that are described above:

- *WaterConditions*

- *SpauldingUnimpInflowOctJun*

The parameter *WaterConditions* depends on the following parameters that are described above:

- *SpauldingPrecipitation*
- *AccumulatedPrecipitation*

PCWA WaterAllocation is referenced in two places. Firstly, to limit delivery of PG&E water from the Wise and South canals to Zone 1 and Zone 5 (*UDC\PGE Drum Spaulding\PGE saletoPCWA*). This is fully described in Section 8.28. Secondly, *PCWA WaterAllocation* is used to regulate supplemental delivery of Placer County WA water from the American River Pumping Station to Placer County WA Zone 1 and Zone 5 using the maximum delivery property on the Auburn Tunnel diversion arc. Delivery of Placer County WA water increases to offset reductions in PG&E sales up to a maximum of 35,500 acre-feet per year, corresponding to Placer County WA's water right.

7.9.12.16 NID WaterAllocation

Nevada ID and Placer County WA both receive the same annual allocation (as a percentage of full contract amount) from PG&E. The parameter *NID WaterAllocation* is set equal to *PCWA WaterAllocation*.

7.9.12.17 MinReleaseAvoidSpills Drum

Initial SacWAM simulation runs showed excessive amounts of water spilled to the South Yuba River when compared to historical streamflow data. Therefore, a routine was developed to forecast spills during the refill period (February – June) and to prelease this volume of water at a steady rate to minimize spilled water. *MinReleaseAvoidSpills Drum* is this steady release volume, over and above instream flow requirements, based on current storage and perfect insight of future inflows. A calibration factor was introduced based on observed data, to implement a more conservative approach to reservoir releases, acknowledging uncertainty in forecast information.

7.9.12.18 MinReleaseAvoidSpills SY

The parameter *MinReleaseAvoidSpills SY* is similar to *MinReleaseAvoidSpills Drum* and represents the additional water that must be released through the South Yuba Canal and wasteway over and above releases to the Drum Canal to avoid reservoir spills during the refill period.

7.9.13 PG&E Feather River Project

PG&E has extensively developed the North Fork of the Feather River for hydropower purposes. Facilities are licensed under several projects as follows:

- FERC P-2105: The Upper North Fork Feather River Project consists of two reservoirs and five powerhouses. Water in Lake Almanor is diverted through the Prattville Tunnel and Butt Valley Powerhouse into Butt Valley Reservoir on Butt Creek. From Butt Valley Reservoir, water flows though Caribou 1 and Caribou 2 powerhouses into Belden Forebay on the North Fork Feather River. From the forebay, water is diverted to the Belden Powerhouse that discharges into Rock Creek Reservoir. Water released from Belden Reservoir to meet downstream flow requirements pass through Oak Flat Powerhouse.

- FERC P-619: The Bucks Creek Project is situated on three tributaries of the North Fork Feather River: Bucks, Grizzly, and Milk Ranch creeks.[59] Key facilities include Bucks Lake, Lower Bucks Lake, Three Lakes Reservoir, and Grizzly Forebay. Power is generated at the Bucks and Grizzly powerhouses. The City of Santa Clara is a joint licensee and owns and operates the Grizzly Powerhouse. Released water from Bucks Lake immediately enters Lower Bucks Lake. Water also enters Lower Buck Lake from Three Lakes Reservoir and the Milk Ranch Conduit. Water from Lower Bucks Lake is diverted through the Grizzly Powerhouse Tunnel to Grizzly Powerhouse, from where it discharges into Grizzly Forebay. Water from Grizzly Forebay is conveyed through Grizzly Forebay Tunnel to the Bucks Creek Powerhouse and thence discharges into the North Fork Feather River upstream from Cresta Reservoir. Releases also are made from Lower Bucks Lake into Bucks Creek and from Grizzly Forebay into Grizzly Creek to meet instream flow requirements.

- FERC P-1962: The Rock Creek-Cresta Project consists of two small reservoirs and powerhouses on the North Fork Feather River. Rock Creek Reservoir regulates flows to the Rock Creek Powerhouse. Cresta Reservoir regulates flows to the Cresta Powerhouse.

- FERC P-2107: The Poe Project consists of Poe Reservoir, Penstock, and Powerhouse, and Big Dam Reservoir[60] – all located on the North Fork Feather River. The project is operated in conjunction with upstream PG&E facilities to maximize power generation. With the exception of the current minimum flow of 50 cfs released from Poe Dam, flows up to 3,700 cfs are diverted through the Poe Penstock and Powerhouse. Big Bend Reservoir was originally built to divert water to Big Bend Powerhouse, but now acts as an afterbay for Poe Powerhouse.

Additional to the above FERC-licensed projects, PG&E owns and operates Mountain Meadows Reservoir that is located upstream from Lake Almanor.

SacWAM represents PG&E storage facilities, penstocks, and powerhouses. However, storage in the smaller reservoirs (Belden, Rock Creek, Cresta, and Poe) are held constant. PG&E operations are simulated using a combination of WEAP's IFR objects and priorities assigned to conservation storage and buffer storage in Mountain Meadows Reservoir, Lake Almanor, Butt Valley Reservoir, and Bucks Lake. Instream flow requirements below PG&E dams are taken from FERC license requirements.[61] IFR objects placed on powerhouse penstocks with an associated priority of 99 preferentially route any excess stream flows (i.e., above the stream requirement) through the powerhouses. A relative high priority assigned to the Belden Powerhouse drives releases from Mountain Meadows, Almanor, and Butt Valley reservoirs. Similarly, a relatively high priority assigned to Bucks Powerhouse drives releases from Bucks Lake. Discretionary releases are made for hydropower generation when reservoir storage is above top of buffer. Once storage is at or falls below top of buffer, only non-discretionary releases from storage are made. The top of buffer varies by month and by water year index, which is based on the annual

[59] SacWAM does not represent Three Lakes Reservoir and other PG&E facilities on Milk Ranch Creek.

[60] Big Bend Dam was built in 1910 to divert water to Big Bend Powerhouse. This facility was inundated with the construction of Oroville Dam. Big Bend Reservoir now serves as an afterbay for the Poe powerhouse.

[61] A new license for P-1962 was issued in 2001. Relicensing for P-619, P-2105, and P-2107 is incomplete and licenses are pending. SacWAM instream flow requirements are from the original licenses issued in 1974, 1955, and 1953, respectively.

unimpaired inflow to Lake Oroville. Top of buffer values were developed from an analysis of historical storage conditions.

SacWAM contains no user-defined constraints for the simulation of PG&E facilities on the North Fork Feather River.

7.9.13.1 P-1962 WaterYearType

Instream flow requirements associated with FERC P-1962 vary by water year type (*P-1962 WaterYearType*). In SacWAM, the water year type is defined in March from the forecasted runoff at Oroville for the current water year.

7.9.14 Sacramento County WA

Sacramento County WA provides retail water supply to portions of unincorporated Sacramento County, the City of Rancho Cordova, and the City of Elk Grove. The agency also provides wholesale water supply to a portion of the service area of Elk Grove WD. The combined Mather Sunrise and Laguna Vineyard public water systems are known as Zone 40. SacWAM represents both the retail and wholesale service area by demand unit 26_PU4. Sacramento County WA has two sources of surface water. Agency water is treated at the City of Sacramento WTP and wheeled through the city's conveyance system. Additionally, Sacramento County WA diverts Sacramento River water as part of the Freeport Regional Water Project. Diverted water is treated at the Vineyard WTP.

SacWAM limits Sacramento County WA water wheeled through the City of Sacramento facilities to a maximum of 12.3 TAF/year, taken on a fixed monthly pattern. Wheeled water is part of the agency's CVP contract water. Agency water diverted at Freeport consists of a mix of water right water and CVP contract water. These are conveyed to DU 26_PU4 using separate transmission links. SacWAM assumes Sacramento County WA takes between 25 to 45 TAF/year depending on the CVP M&I allocation. The availability of water right water is estimated based on the month and Sacramento Valley Index. No water right water is available from July through November.

7.9.15 Sacramento Suburban Water District

Sacramento Suburban WD provides retail water services to four service areas within Sacramento County using a mix of surface water and groundwater. The district does not have any water rights, nor does it hold contracts with Reclamation for the delivery of CVP water. Surface water is provided under a contract with Placer County WA for supply of MFP water (see Section 7.9.10).

Model operational logic for Sacramento Suburban WD is imposed using the maximum diversion property on transmission links and associated supply preferences. The maximum annual availability of MFP water is restricted to 14,000 acre-feet taken on a fixed monthly pattern and is only available when the forecasted unimpaired inflow to Folsom Lake is greater than 1.6 MAF[62].

[62] The annual entitlement is 12 TAF. Additionally, the district may request up to a total water supply of 29 TAF. Recent deliveries are approximately 14 TAF/year.

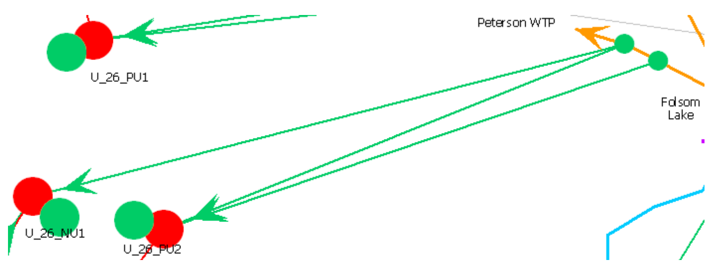
7.9.16 San Juan Water District

San Juan WD is both a wholesale and retail water agency, providing water to urban areas north of the American River in northeastern Sacramento and southern Placer counties. Wholesale services are provided to a group of retail water agencies, which include Citrus Heights WD, Fair Oaks WD, and Orange Vale WC and the Ashland area of the City of Folsom lying to the north of the river. San Juan WD receives water from Folsom Lake, which is treated at its Sidney N. Peterson WTP. SacWAM represents both the retail and wholesale service area by demand unit 26_PU2.

San Juan WD holds pre-1914 and post-1914 water rights for 33,000 acre-feet per year from the American River. The district has agreed with Reclamation to limit diversions to 60 cfs (pre-1914) and 15 cfs (post-1914). The pre-1914 right is for a year-round diversion. The season for diversion for the post-1914 right is from June 1 to November 1. San Juan Water District also has signed a water supply contract with Placer County WA for up to 25,000 acre-feet per year of MFP water. The district has an agreement with the City of Roseville to sell up to 4,000 acre-feet of this water during normal wet and years, if required by the City of Roseville. In addition to MFP water, the district also holds a Reclamation contract for 24,200 acre-feet per year of CVP water (Contract No. 6-07-20-W1373-LTR1). Under the CVP contract, the first 149 acre-feet per day (75 cfs) of water delivered is considered to be the district's senior water rights water. San Juan WD wheels MFP water through its facilities for Sacramento Suburban WD (demand unit U_26_NU1). This supply of MFP water only is available in Water Forum wet years.

San Juan WD is signatory to the 2000 Water Forum Agreement. Under its Purveyor Specific Agreement, the district agrees to limit diversions to a total ranging from 54,200 acre-feet to 82,200 acre-feet, depending on hydrologic conditions. The Water Forum Agreement is not represented in SacWAM.

Model operational logic for San Juan WD is imposed using the maximum diversion property on transmission links and associated supply preferences. The multiple sources of supply are represented in the model using two transmission links from the water treatment plant to the demand unit; one transmission link conveys CVP water, the other transmission link conveys a mix of MFP water and water right water. It is assumed that San Juan WD buys CVP water on a fixed monthly schedule (expressed as a percentage of the annual allocation). CVP water is accorded the first supply preference.



7.9.16.1 CVPRemainingSupply

The parameter *CVPRemainingSupply* is the remaining volume of CVP water that is available to San Juan WD at the beginning of each month. In March, the parameter value equals the product of 32,000 AF and the CVP North-of-Delta M&I allocation. The initial value for the current account year is based on a 100% allocation less annual demand March-October.

7.9.16.2 MFPRemainingSupply

The parameter *MFPRemainingSupply* is the remaining volume of Middle Fork Project water that is available to San Juan WD at the beginning of each month. In January, the parameter value equals 29,000 AF.

7.9.16.3 CVPFlag

The parameter *CVPFlag* indicates whether th remaining volume of CVP water, *CVPRemainingSupply,* is sufficient to meet the current month's district water demand. It is no longer used in SacWAM.

7.9.17 SMUD – Middle Fork Project

Since 1946, SMUD, a publicly owned utility district, has served electricity to the greater Sacramento region. It now supplies most of Sacramento County and part of Placer County. The UARP (FERC Project No. 2101), completed in 1963, is owned and operated by SMUD primarily for hydropower production. Other project purposes include recreation and fish and wildlife enhancement and mitigation. Currently, there are no consumptive uses associated with the UARP.[63] Major UARP storage facilities include Loon Lake, Union Valley Reservoir, and Ice House Reservoir.

Flows are diverted from Rubicon Reservoir on the upper Rubicon River and Buck Island Reservoir on the Little Rubicon River through Buck-Loon Tunnel to Loon Lake on Gerle Creek. Releases from Loon Lake pass through the Loon Lake Tunnel and Powerhouse to Gerle Reservoir, where the flows are rediverted through the Gerle Canal to the South Fork Rubicon River. At the Robbs Peak Diversion Dam, water is exported from the Rubicon River watershed to the Silver Creek watershed, tributary to the South Fork American River. Exported water passes through Robbs Peak Powerhouse to Union Valley Reservoir on Silver Creek. Inflows to Union Valley Reservoir are supplemented by water conveyed from Ice House Reservoir on the South Fork Silver Creek through the Jones Fork Powerhouse. Controlled releases from Union Valley Reservoir flow through the Union Valley Powerhouse, and subsequently through the Jaybird and Camino powerhouses before discharging into the South Fork American River. At Slab Creek Reservoir and Dam on the South Fork American River water is diverted into the White Rock Tunnel and Powerhouse, which discharges water immediately upstream from PG&E's Chili Bar Reservoir.

SMUD's operation of the UARP is guided by several factors, including power demand; FERC license requirements; and dam safety requirements. SacWAM simulation logic for SMUD facilities is as follows:

- **Rubicon Reservoir** storage is held constant in the model. All flows in the Rubicon River over and above those required to meet the flow requirement below the diversion dam, are diverted through the **Rockbound Tunnel**. Head-dependent diversion capacity is not modeled. The physical capacity at maximum head is approximately 910 cfs (SMUD, 2005). Tunnel gate closure in the late summer through fall to conserve water for instream flow requirements is not modeled.[64]
- **Buck Island Reservoir** storage is held constant in the model. Inflows from the Rockbound Tunnel and natural flows in the Little Rubicon River over and above those required to meet the flow requirement below the diversion dam, are diverted through the **Buck-Loon Tunnel**. Flows through the tunnel are constrained to the monthly maximum observed values for WYs 1970-

[63] SMUD and El Dorado ID have signed a 2005 agreement for the irrigation district to receive water from a turnout on the White Rock Penstock.

[64] Gates are manually installed at the entrance to Rockbound Tunnel in July, after the snowmelt peak, to store water that supports the environmental flow release in late summer. The gates are removed before the next water year on approximately October 1.

2009. Head-dependent diversion capacity is not modeled. The maximum physical capacity is approximately 1,260 cfs (SMUD, 2005). Similar to Rockbound Tunnel, Buck-Loon Tunnel gate closure in the late summer through fall to conserve water for instream flow requirements is not modeled.

- **Loon Lake** storage typically follows an annual cycle. Water elevation slowly rises during the spring and early summer as runoff refills the reservoir, reaching its highest level during early summer. The reservoir level gradually falls throughout the summer and fall months as the water is passed through **Loon Lake Powerhouse**. Storage is simulated using 5 rule curves implemented in SacWAM using buffer storage. The rule curves depend on the April-to-July American River unimpaired runoff forecast at Fair Oaks. Any excess water is spilled from Loon Lake to Gerle Creek. Additionally, water is released to Gerle Creek to meet instream flow requirements below the dam. Flows through the Loon Lake Powerhouse are limited to 1,178 cfs.

- **Gerle Reservoir** storage is held constant in the model. Water is released to Gerle Creek to meet instream flow requirements below the dam. All remaining water is diverted through the **Gerle Canal**, up to its physical capacity. Head-dependent diversion capacity is not modeled. The maximum physical capacity is approximately 1,120 cfs (SMUD, 2005). This is not imposed in SacWAM.

- **Robbs Peak Tunnel** diverts natural flow in the South Fork Rubicon River and imports through the Gerle Canal. Flow requirements are specified below the Robbs Peak Diversion Dam. Flows through the tunnel are restricted by the 1,250 cfs physical capacity. A WEAP IFR object placed on the tunnel (*OPS Robbs Peak Tunnel*), set equal to the tunnel physical capacity, draws all available water from the Rubicon and Little Rubicon River, and storage withdrawals from Loon Lake above the Loon Lake rule curve (represented as top of buffer storage)[65]. No water right restrictions are placed on SMUD imports from the Middle Fork American River watershed.[66]

- **Ice House Reservoir** top of conservation storage varies with gated spill operations. Gates are assumed to be open November through March. Excess water is spilled to the South Fork Silver Creek. Water also is released to meet instream flow requirements below the dam. A monthly rule curve, which is implemented using buffer storage, controls the transfer of water from Ice House to Union Valley Reservoir. The rule curve depends on the April-to-July American River unimpaired flow at Fair Oaks.

- **Jones Fork Tunnel and Powerhouse** flows are constrained to an assumed capacity of 287 cfs. An IFR object placed on the tunnel (*OPS Jones Fork Tunnel*), set equal to the tunnel physical capacity, sends available water from Ice House to Union Valley Reservoir. Priorities are set so that water in Ice House Reservoir above buffer storage is transferred from this reservoir to Union Valley Reservoir.

[65] SMUD typically operated Robbs Peak Powerhouse in a run-of-the-river mode, i.e., its operation is subordinate to the operation of Loon Lake Powerhouse (SMUD, 2005).

[66] SMUD financially compensates Placer County WA for any loss in power production associated with imports over and above its water rights.

- **Union Valley Reservoir** top of conservation storage varies with gated spill operations. Gates are assumed to be open November 1 through March 31.[67] Controlled releases are made through the **Union Valley Powerhouse** to Silver Creek. A monthly rule curve, which is implemented using buffer storage, controls the transfer of water from Ice House to Union Valley Reservoir and the release of water for power generation. The rule curve depends on the April-to-July American River unimpaired flow at Fair Oaks. Flows through the Union Valley Powerhouse are limited to an assumed physical capacity of 1,634 cfs. Water is routed through the powerhouse, rather than directly released to the river, using an IFR object placed on the penstock (*OPS Union Valley Powerhouse*) with an associated priority of 99.

- **Junction Reservoir** storage is held constant in the model. Water over and above the downstream flow requirement (*REG Silver Creek blw Junction Dam*) is routed through the **Jaybird Powerhouse**, up to the assumed physical capacity of 1,477 cfs. This is implemented using an IFR object placed on the penstock (*OPS Jaybird Conduit*) with an associated priority of 99.

- **Camino Reservoir** storage is held constant in the model. Water over and above the downstream flow requirement (*REG Silver Creek blw Camino Dam*) is routed through the **Camino Powerhouse**, up to the assumed physical capacity of 2,200 cfs. An IFR object placed on the penstock (*OPS Camino Conduit*) with an associated priority of 12 is used to represent SMUD's power generation goals. The operational 'instream flow requirement' is set to a constant 1,500 cfs based on a review of historical data.

- **Brush Creek Tunnel** flows supplement flows in the Camino penstock. Simulated flows are not capped by the physical capacity. However, an instream flow requirement is modeled below the Brush Creek Diversion Dam. **Brush Creek Reservoir** is not represented.

- **Slab Creek Reservoir** storage is held constant in the model. Water over and above the downstream flow requirement (*REG SF American blw Slab Creek Dam*) is routed through the **White Rock Powerhouse**, up to the assumed physical capacity of 3,950 cfs. This is implemented using an IFR object placed on the penstock (*OPS White Rock Tunnel*) with an associated priority of 99. **Slab Creek Powerhouse** is located on the downstream face of Slab Creek Dam. It is not explicitly represented in the model.

- **Chili Bar Reservoir** storage is held constant in the model. Instream flow requirements below the facility (*REG SF American nr Placerville*) are met, when necessary, from storage withdrawals or bypass flows from SMUD's upstream storage facilities.

7.9.17.1 FolsomFNF

The unimpaired American River inflow to Folsom Lake is used to define minimum instream flow requirements specified in the UARP FERC license and to define UARP reservoir rule curves. Monthly unimpaired flows are read from the csv file Data\Streamflow\SACVAL_StreamflowFullNaturalFlow. The source of the data is CDEC station AMF, sensor 65.

[67] In a monthly model, the November 1 requirement is represented as a requirement for September 30.

7.9.17.2 FolsomFNFAprJul

FolsomFNFAprJul is the seasonal unimpaired American River inflow to Folsom Lake from April through July. It is calculated by summing the monthly values of *FolsomFNF* based on perfect foresight of future flows. This seasonal unimpaired flow is used to define a storage index described below.

7.9.17.3 ReservoirStorageIndex

The *ReservoirStorageIndex*, ranging from 1 to 5, is determined based on the April to July unimpaired inflow to Folsom Lake. A value of 1 indicates wet conditions with an unimpaired flow forecast in excess of 2.0 MAF. A value of 5 indicates drought conditions with an unimpaired flow forecast of less than 0.5 MAF. The *ReservoirStorageIndex* is used to define rule curves for Loon Lake, as described below.

7.9.17.4 LoonLakeTargetStorage

Rule curves for Loon Lake (*LoonLakeTargetStorage*) define the monthly target storage using the *ReservoirStorageIndex*. The rule curves were defined based on an analysis of end-of-month historical storage sorted by the *ReservoirStorageIndex*. Use of the *LoonLakeTargetStorage* parameter has since been abandoned and target storage levels are defined directly under Loon Lake Top of Buffer.

7.9.18 SMUD – Rancho Seco

SMUD owns and operates the Rancho Seco facility (U_60N_PU). It consists of a decommissioned nuclear power plant, a 160-acre lake, and recreational area. Water demands are met by deliveries from Folsom South Canal. SMUD holds a water right for a year-round diversion of 20 cfs. The utility also holds contracts for 30,000 acre-feet of CVP water. SacWAM uses two transmission links to deliver water from Folsom South Canal to the facility in order to distinguish water right water from CVP water. Water right water is assigned the higher preference.

7.9.19 South Sutter Water District

South Sutter WD, formed in 1954, provides irrigation water within a service area of approximately 64,000 acres located in Sutter and Placer counties. Over 80 percent of the irrigated land within the district's service area is dedicated to rice production.[68] Bear River water is stored in the district's Camp Far West Reservoir[69] and rediverted 1.2 miles below Camp Far West Dam in to the district's main canal and in to the North and South canals owned by Camp Far West ID.[70] South Sutter WD also owns and operates a hydroelectric facility at the base of Camp Far West Dam (FERC Project No. 2997). Camp Far West Reservoir and Dam are primarily operated for agricultural water supply, but also to meet instream flow requirements and power generation. Camp Far West Reservoir is not operated for flood control. In the winter and spring, the reservoir fills from a mix of rainfall-runoff and upstream spills from Nevada ID Yuba-Bear Project and PG&E's Drum-Spaulding Project. South Sutter WD tries to keep the reservoir full until the start of the irrigation season, releasing water only for downstream flow requirements. Power is

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[68] Between 2011 and 2015, South Sutter WD reports an average irrigated area of approximately 42,000 acres (SSWD, 2016a).

[69] Camp Far West Dam was constructed between 1924-1925 and subsequently enlarged in 1963-1964 to a gross storage of 93,740 (SSWD, 2016b).

[70] In 1957, South Sutter WD signed an agreement with Camp Far West ID to provide 13,000 acre-feet of water to Camp Far West ID to satisfy their senior water rights to Bear River water. A supplemental agreement was signed in 1973.

produced at Camp Far West Powerhouse during the winter and early spring months when the reservoir is spilling and during the spring and summer months when releases are being made for irrigation and to meet instream flow requirements.

The district holds two post-1914 appropriative water rights for diversion from the Bear River for irrigation purposes. License 11120 (A10221) is for 250 cfs direct diversion from March 1-June 30 and September 1-October 31, and for 40,000 acre-feet diversion to storage from October 1-June 30. License 11118 (A14804) is for 330 cfs direct diversion from May 1- September 1, and for 58,370 acre-feet diversion to storage from October 1-June 30. The district also holds water rights for diversion from the East Side Canal, Coon Creek, Markham Ravine, Auburn Ravine, and Yankee Slough. Diversions from the East Side Canal, Coon Creek, Markham Ravine, and Yankee Slough are not represented in SacWAM. Diversions from Auburn Ravine are included in SacWAM but are limited to runoff from adjacent lands and exclude discharge to the ravine from PG&E Wise and South canals.

The district also holds an appropriative water right (A26162, P18360) for power purposes. The permit is for up to a maximum of 725 cfs, the capacity of the powerplant, by direct diversion year-round and up to 103,100 acre-feet diversion to storage from October 1 through June 30. For the protection of fish and wildlife, Permit 18360 identifies a minimum required release of 25 cfs from April 1 through June 30 and 10 cfs from July 1 through March 31.

In February 2000, DWR, South Sutter WD, and the Camp Far West ID entered into the Bear Agreement (DWR, 2000b) to settle the responsibilities of the districts and other Bear River water right holders to implement the objectives of the 1995 Bay-Delta Plan. Under the agreement, South Sutter WD must release an additional 37 cfs from July through September, up to a maximum of 4,400 acre-feet, in dry and critical years, except when Camp Far West Reservoir storage is below 33,255 acre-feet on April 1 (see Section 7.7.1.3).

Logic to simulate annual water allocations to South Sutter WD is described in the following sections.

7.9.19.1 CampFarWest April 1 Storage
The parameter *Camp Far West Apr1 Storage* is Camp Far West Reservoir storage at the beginning of April.

7.9.19.2 ForecastedInflow AprtoSep
The parameter *ForecastedInflow AprtoSep* is the sum of the six monthly values of *ForecastedInflow* from April through September. It is based on a regression equation with the independent variable being the unimpaired flow for the Yuba River at Smartville.

7.9.19.3 Reg IFR
The parameter *Reg IFR* equals the instream flow requirement below the Camp Far West Diversion Dam (*REG Bear River blw CFW Diversion Dam*).

7.9.19.4 Reg IFR inc BDSA AprtoSep
The parameter *Reg IFR Inc BDSA AprtoSep* is the sum of the six monthly values of *Reg IFR* from April through September, including additional releases in Dry and Critical years as specified in the Bay-Delta Settlement Agreement.

7.9.19.5 StreamSeepageFactor

The parameter *StreamSeepageFactor* equals the stream seepage expressed as a fraction of stream flow for the lower Bear River.

7.9.19.6 SWRCB IFR Inc Loss

The parameter *SWRCB IFR Inc Loss* equals the proposed State Water Board instream flow requirement at the mouth of the lower Bear River (*SWRCB Bear River*) increased by the groundwater loss along the lower Bear River.

7.9.19.7 SWRCB IFR Inc Loss AprtoSep

The parameter *Reg IFR Inc Loss AprtoSep* is the sum of the six monthly values of *Reg IFR Inc Loss* from April through September.

7.9.19.8 TargetDelivery

The *TargetDelivery* is the agricultural delivery by South Sutter WD to its member agencies and to Camp Far West ID in dry years in the absence of any deficiency. This target delivery is assumed equal to 210,000 acre-feet.

7.9.19.9 CampFarWest Carryover Target

The parameter *CampFarWest Carryover Target* is South Sutter WD's storage target for September 30 in dry years when the agency's contractors are faced with water deficiencies. A fixed value of 5,200 acre-feet is used.

7.9.19.10 WaterSupplyIndex

The parameter *WaterSupplyIndex* is an estimate of the amount of water available for delivery to South Sutter WD and Camp Far West ID service areas. It is the sum of the following components:

- *ForecastedInflow AprtoSep*
- *AccretionsbelowDam AprtoSep*
- *Less CampFarWest Evaporation AprtoSep*
- *Less CampFarWest Carryover Target*
- Less the maximum of *Reg IFR Inc Loss AprtoSep* and *SWRCB IFR Inc Loss AprtoSep*

The *WaterSupplyIndex* is calculated in April and is subsequently fixed for the next 12 months.

7.9.19.11 YubaFNF

The parameter *YubaFNF* is the full natural flow or unimpaired flow for the Yuba River at Smartville.

7.9.19.12 YubaFNF AprtoSep

The parameter *YubaFNF AprtoSep* is the sum of *YubaFNF* for the months April through September using perfect foresight.

7.9.19.13 CampFarWest Evaporation AprtoSep

The parameter *CampFarWest Evaporation AprtoSep* is an estimate of the total reservoir evaporation from April through September. It is calculated as the product of the evaporation rate and an estimated reservoir surface area.

7.9.19.14 SSWDAllocation
The parameter *SSWD Allocation* is the annual allocation by South Sutter WD. Expressed as a fraction, it is calculated each April as the ratio of the Water Supply Index to the Target Delivery.

7.9.20 Solano Project

The Solano Project was constructed from 1953 to 1959 by Reclamation to provide irrigation water to approximately 96,000 acres of land located in Solano County. The project also furnishes M&I water to the major cities of Solano County. Project facilities include Lake Berryessa and Monticello Dam, Putah Diversion Dam, Putah South Canal and canal distribution system, and a small terminal reservoir. Water released from Monticello Dam is diverted at the Putah Diversion Dam located approximately 6 miles downstream. Water is subsequently conveyed to its end users via the Putah South Canal. Solano County WA holds contracts with Reclamation for water supply from the Solano Project. Solano County WA has entered into agreements with cities, districts, and State agencies to provide water from the Solano Project.

The subbranches under the branch *Solano Project* are associated with an annual water allocation to Solano Project contractors.

7.9.20.1 Allocation
The parameter *Allocation* is the annual allocation to Solano Contractors expressed as a fraction of the full contract amount. It is calculated as the ratio of the *WaterSupplyIndex* to *TargetDelivery*, allowing for a 15,000 acre-foot canal conveyance loss.

7.9.20.2 WaterSupplyIndex
The parameter *WaterSupplyIndex* is a measure of the water available for delivery to Solano contractors. It accounts for April 1 storage in Lake Berryessa, forecasted inflows from April to September, reservoir evaporation, stream losses to groundwater, instream flow requirements, and the carryover storage target for Lake Berryessa.

7.9.20.3 Berryessa Apr1 Storage
The parameter *Berryessa Apr1 Storage* is the storage in Lake Berryessa on March 31.

7.9.20.4 Berryessa Carryover Target
The parameter *Berryessa Carryover Target* equals the end-of-September target storage in Lake Berryessa. Its value is equal to half of the previous end-of-month storage above a threshold of 440 TAF. It has a maximum value of 660 TAF.

7.9.20.5 Berryessa Evaporation AprtoSep
The parameter *Berryessa Evaporation AprtoSep* is an estimate of the total reservoir evaporation from April through September.

7.9.20.6 ForecastedInflow
The parameter *ForecastedInflow* equals the monthly inflow to Lake Berryessa.

7.9.20.7 ForecastedInflow AprtoSep
The parameter *ForecastedInflow AprtoSep* is the forecasted inflow to Lake Berryessa from April through September, determined using perfect foresight.

7.9.20.8 SP_Allocation

The parameter *SP_Allocation* is set equal to the parameter *Allocation*. This duplication is a result of the model legacy.

7.9.20.9 StreamSeepageFactor abv DivDam

The parameter *StreamSeepageFactor abv DivDam* represents the stream losses between Black Butte Dam and the Northside Diversion Dam, expressed as a fraction of streamflow.

7.9.20.10 StreamSeepageFactor blw DivDam

The parameter *StreamSeepageFactor blw DivDam* represents the stream losses between the Northside Diversion Dam and the mouth of the creek, expressed as a fraction of streamflow.

7.9.20.11 Target Delivery

The parameter *TargetDelivery* is equal to the full contract amount of 207,350 acre-feet. It includes a 15,000 acre-foot conveyance loss.

7.9.20.12 REG IFR Inc Loss

The parameter *REG IFR Inc Loss* is the required release from Black Butte Dam to meet the flow requirements below Black Butte Dam and below the Northside Diversion Dam. It accounts for stream losses between Black Butte Dam and the diversion dam.

7.9.20.13 REG IFR Inc Loss AprtoSep

The parameter *REG IFR Inc Loss AprtoSep* is the required release from Black Butte Dam to meet the flow requirement below the Northside Diversion Dam over the irrigation season.

7.9.20.14 SWRCB IFR Inc Loss

The parameter *SWRCBIFR Inc Loss* is the required release from Black Butte Dam to meet proposed State Water Board flow requirements at the mouth of the creek. It accounts for stream losses along Stony Creek.

7.9.20.15 SWRCB IFR Inc Loss AprtoSep

The parameter *SWRCBIFR Inc Loss* is the required release from Black Butte Dam to meet proposed State Water Board flow requirements at the mouth of the creek over the irrigation season.

7.9.21 Orland Project (StonyCreek)

The Orland Project, centered on Stony Creek, is one of the oldest Federal reclamation projects in the United States. Water was delivered to the first farm units at the beginning of the 1910 growing season. The main elements of the project include East Park Dam, Stony Gorge Dam, Rainbow Diversion Dam and East Park Feeder Canal, South Diversion Intake and South Canal, and Northside Diversion Dam and North Canal. The South Diversion Intake and Canal were built in conjunction with Black Butte Dam in 1963. Black Butte Dam, constructed by the USACE, is an authorized facility of the CVP. The CVP and Orland Project are separate projects with separate water rights.

The model logic under the Orland Project branch defines the annual water allocation to the Orland Project water users.

7.9.21.1 OrlandUnit Carryover Target
The parameter *OrlandUnit Carryover Target* is the target combined storage in East Park and Stony Gorge reservoirs for September 30. It is assigned a value of 12.5 TAF.

7.9.21.2 OrlandUnit Evaporation MartoSep
The parameter *OrlandUnit Evaporation MartoSep* is an estimate of the total reservoir evaporation during the irrigation season.

7.9.21.3 OrlandUnit Mar 1 Storage
The parameter *OrlandUnit Mar 1 Storage* is the combined storage in East Park and Stony Gorge reservoirs at the beginning of March.

7.9.21.4 OrlandUnit Water Supply Index
The parameter *OrlandUnit Water Supply Index* is a measure of the available water supply at the beginning of the irrigation season. It is based on storage and forecasted inflows less evaporative losses, stream seepage, and instream flow requirements.

7.9.21.5 OrlandUnitAllocation
The parameter *OrlandUnitAllocation* is the annual allocation to Orland water users. It is determined in March and is the ratio of *OrlandUnit Water Supply Index* to *OrlandUnitDemand*.

7.9.21.6 OrlandUnitDemand
The parameter *OrlandUnitDemand* represents the demand for surface water. It is determined based on an assumed crop water demand (WEAP’s supply requirement) of 90 TAF, and accounting for minimum groundwater pumping and conveyance losses on the transmission links.

7.9.21.7 OrlandUnitDirectDiversion
The parameter *OrlandUnitDirectDiversion* is the smaller of Stony Creek runoff and the maximum rate of diversion under the project’s water rights.

7.9.21.8 OrlandUnitDirectDiversion MaySep
The parameter *OrlandUnitDirectDiversion MaySep* is the May through September total water available under the project’s water rights.

7.9.21.9 OrlandUnitInflow
The parameter *OrlandUnitInflow* is the monthly unimpaired flow at Stony Gorge Dam.

7.9.21.10 OrlandUnitInflow MarApr
The parameter *OrlandUnitInflow MarApr* is the total unimpaired flow at Stony Gorge Dam from March through September.

7.9.21.11 OrlandUnitShare SWRCB IFR
The parameter *OrlandUnitShare SWRCB IFR* is the assigned responsibility of the Orland Project to meet proposed State Water Board flow requirements at the mouth of Stony Creek. For modeling purposes, SacWAM assumes that this responsibility is shared equally with the CVP.

7.9.21.12 OrlandUnitSpill MarApr
The parameter *OrlandUnitSpill MarApr* is an estimate of the March and April spills from East Park and Stony Gorge Dam.

7.9.21.13 Reg IFR Inc Loss

The parameter *Reg IFR Inc Loss* is the required release to meet the instream flow requirement below Northside Dam. It accounts for stream seepage losses between Black Butte Dam and Northside Dam.

7.9.21.14 Reg IFR Inc Loss MartoSep

The parameter *Reg IFR Inc Loss MartoSep* is the required release during the irrigation season to meet the instream flow requirement below Northside Dam.

7.9.21.15 StonyCreekInflow

The parameter *StonyCreekInflow* is the monthly unimpaired flow at Black Butte Dam.

7.9.21.16 StreamSeepageFactor abv DivDam

The parameter *StreamSeepageFactor abv DivDam* is the stream seepage loss above Northside Dam, expressed as a fraction of the stream flow.

7.9.21.17 StreamSeepageFactor blw DivDam

The parameter *StreamSeepageFactor blw DivDam* is the stream seepage loss between Northside Dam and the mouth of Stony Creek, expressed as a fraction of the stream flow.

7.9.21.18 SWRCB IFR Inc Loss

The parameter *SWRCB IFR Inc Loss* is the required release to meet proposed State Water Board flow requirements at the mouth of Stony Creek. It accounts for all stream seepage losses below Black Butte Dam.

7.9.21.19 SWRCB IFR Inc Loss MartoSep

The parameter *SWRCB IFR Inc Loss MartoSep* is the required release during the irrigation season to meet proposed State Water Board flow requirements at the mouth of Stony Creek.

7.9.22 Western Canal WD

Western Canal WD was formed in 1984 to provide irrigation water to lands on the left bank of the Feather River downstream from Lake Oroville. The predominant crop grown in the service area is rice. The district holds pre-1914 water rights to natural flow in the Feather River, subject to reduction during drought under trerms of a settlement agreement with the State, and a pre-1914 water right for diversion of upstream stored water, not subject to reduction. The district also has an adjudicated water right on Butte Creek.

Under a 1922 agreement between Western Canal WD and Butte Sink landowners, natural flows in Butte Creek are supplemented by releases from the district's Western Canal into the creek to maintain a flow of 200 cfs at the Sanborn Slough intake during the fall and early winter. The parameter *Western Canal Outflow* defines outflow targets based on flows in Butte Creek and recent historical canal deliveries to the creek.

7.9.23 Yuba County WA

Yuba WA[71] owns and operates the Yuba River Development Project. The project, located on the main stem of the Yuba River, North Yuba River, and Oregon Creek, is operated for flood control, water supply, and hydropower purposes. Project facilities include New Bullards Bar Reservoir and Dam, New Colgate Penstock and Powerhouse, Our House and Log Cabin diversion dams, Lohman Ridge and Camptonville tunnels, and Narrows 2 Powerhouse at Englebright Dam. The agency delivers water to its member agencies at Daguerre Point Dam on the lower Yuba River and delivers water to Browns Valley ID at the Pumpline facility located a short distance upstream. Narrows 1 Powerhouse, which is owned by PG&E, supplements Narrows 2 Powerhouse. Both Narrows 1 and 2 powerhouses receive water directly from Englebright Reservoir. Flow through these powerhouses is represented in SacWAM by the diversion arc *Narrows Powerhouse I and II*.

The UDC *YCWA TargetStorageRelease* is used to curtail discretionary hydropower releases from New Bullards Bar Dam that result in flows at Englebright Dam in excess of the capacity of the Narrows I and II powerhouses. *YCWA Target Storage Release* requires that the flow through *Narrows Powerhouse I and II* be less than the sum of the capacity of New Colgate Powerhouse, the flow requirement below New Bullards Bar Dam, outflows from the Middle and South Yuba, and local (natural) inflow to Englebright Reservoir.

The following sections describe parameters that are used to determine the annual allocation (YCWAAllocation).

7.9.23.1 AccertionsbelowDam

The parameter *AccretionsbelowDam* represents inflows to the North Yuba River below New Bullards Bar Dam and inflows to the lower Yuba River. It is estimated as the sum of the following components:

- Instream flow requirement below Spaulding Dam (*REG South Yuba blw Spaulding Dam*)
- Instream flow requirement below Bowman Dam (*REG Canyon Creek blw Bowman Dam*)
- South Yuba River accretion (*I_SFY007*) between Spaulding Dam and the USGS gauge at Jones Bar
- Local inflow to Englebright Reservoir (*I_ENGLB*)
- Inflow from the Middle Yuba River calculated as the maximum of the proposed State Water Board flow requirement (*SWRCB M Yuba Inflow*) and the combined minimum flow requirements on Oregon Creek (*REG Oregon Creek blw Log Cabin Dam*) and Middle Yuba River (*REG Middle Yuba blw Our House Dam*)
- Instream flow requirement for Deer Creek near Smartville (*Reg Deer Ck nr Smartville*)

7.9.23.2 AccretionsbelowDam AprtoSep

The parameter *AccretionsbelowDam AprtoSep* is the sum of the six monthly values of *AccretionsbelowDam* from April through September.

[71] Yuba County Water Agency changed its name to Yuba Water Agency in 2018. The SacWAM data tree has not been revised.

7.9.23.3 ForecastedInflow

The parameter *ForecastedInflow* represents inflows to New Bullards Bar Dam. It is estimated as the sum of the following components:

- Unimpaired flow Slate Creek above Slate Creek Diversion Dam (*I_SLT009*)
- Unimpaired flow North Yuba River at Goodyears Bar (*I_NFY029*)
- Local inflow to New Bullards Bar Reservoir (*I_NBLDB*)
- Less exports to the Slate Creek Tunnel calculated as the minimum of the target tunnel flow (*OPS Slate Creek Tunnel*) and Slate Creek unimpaired flow (*I_SLT009*)
- Imports from the Camptonville Tunnel, calculated as the sum of (but limited by the tunnel capacity):
    - Unimpaired flow Oregon Creek above Log Cabin Dam (*I_OGN005*)
    - Instream flow requirement for Middle Yuba below Milton Diversion Dam (*REG Middle Yuba blw Milton Dam*)
    - Middle Yuba River accretion from Milton Diversion Dam to Our House Dam (*I_MFY013*)
    - Less the maximum of the State Water Board proposed flow requirement at the mouth of the Middle Yuba (*SWRCB M Yuba Inflow*) and the combined instream flow requirements on Oregon Creek (*REG Oregon Creek blw Log Cabin Dam*) and Middle Yuba River (*REG Middle Yuba blw Our House Dam*).

7.9.23.4 ForecastedInflow AprtoSep

The parameter *ForecastedInflow AprtoSep* is the sum of the six monthly values of *ForecastedInflow* from April through September.

7.9.23.5 NewBullardsBar Apr1 Storage

The parameter *NewBullardsBar Apr1 Storage* is New Bullards Bar Reservoir storage at the beginning of April.

7.9.23.6 NewBullardsBar Carryover Target

The parameter *NewBullardsBar Carryover Target* is Yuba County WA’s storage target for September 30 in dry years when the agency’s contractors are faced with water deficiencies. A fixed value of 440,000 acre-feet is used based on modeling conducted for FERC relicensing of the Yuba River Development Project (YCWA, 2012). This value is the sum of a 234,000-acre-foot minimum pool, 45,000-acre-foot operational buffer to meet dry-year flow requirements, and a 15,000-acre-foot allowance for evaporation.

7.9.23.7 NewBullardsBar Evaporation AprtoSep

The parameter *NewBullardsBar Evaporation AprtoSep* is an estimate of the total reservoir evaporation from April through September. It is calculated as the product of the evaporation rate and the reservoir surface area assuming reservoir storage follows the Target Operating Line.

7.9.23.8 Reg IFR Inc Loss

The parameter *Reg IFR Inc Loss* equals the instream flow requirement at the Maryville gauge (*REG Yuba River nr Marysville*) increased by the groundwater loss along the lower Yuba River. Currently, all stream seepage losses are simulated as occurring below the Marysville gauge.

7.9.23.9 Reg IFR Inc Loss AprtoSep

The parameter *Reg IFR Inc Loss AprtoSep* is the sum of the six monthly values of *Reg IFR Inc Loss* from April through September.

7.9.23.10 StreamSeepageFactorAboveMarsville

The parameter *StreamSeepageFactorAboveMarysville* equals the stream seepage expressed as a fraction of stream flow for the river reach above the Marysville gauge. Currently, all stream seepage losses are simulated as occurring below the Marysville gauge; therefore, the value is zero.

7.9.23.11 StreamSeepageFactorBelowMarsville

The parameter *StreamSeepageFactorBelowMarysville* equals the stream seepage expressed as a fraction of stream flow for the river reach below the Marysville gauge. Currently, all stream seepage losses are simulated as occurring below the Marysville gauge; therefore, the value is zero.

7.9.23.12 SWRCB IFR Inc Loss

The parameter *SWRCB IFR Inc Loss* equals the proposed State Water Board instream flow requirement at the mouth of the lower Yuba River (*SWRCB Yuba River*) increased by the groundwater loss along the lower Yuba River. Currently, all stream seepage losses are simulated as occurring below the Marysville gauge.

7.9.23.13 SWRCB IFR Inc Loss AprtoSep

The parameter *SWRCB IFR Inc Loss AprtoSep* is the sum of the six monthly values of *SWRCB IFR Inc Loss* from April through September.

7.9.23.14 Target Delivery

The *TargetDelivery* is the agricultural delivery by Yuba County WA to its member agencies in dry years in the absence of any deficiency. This target delivery is assumed equal to 305,000 acre-feet based on modeling conducted for FERC relicensing of the Yuba River Development Project (YCWA, 2012). This value is also equal to the sum of water rights entitlements and contract amounts, excluding supplemental contract amounts.

7.9.23.15 WaterSupplyIndex

The parameter *WaterSupplyIndex* is an estimate of the amount of water available for delivery to Yuba County WA's member units. It is the sum of the following components:

- *ForecastedInflow AprtoSep*
- *AccretionsbelowDam AprtoSep*
- Less *NewBullardsBar Evaporation AprtoSep*
- Less *NewBullardsBar Carryover Target*
- Less the maximum of *Reg IFR Inc Loss AprtoSep* and *SWRCB IFR Inc Loss AprtoSep*

The *WaterSupplyIndex* is calculated in April and is subsequently fixed for the next 12 months.

7.9.23.16 YCWAAllocation

The parameter *YCWAAllocation* is the annual allocation by Yuba County WA to its member units. Expressed as a fraction, it is calculated each April as the ratio of the *WaterSupplyIndex* to the *Target Delivery*, each of which are reduced by 34 TAF to represent Browns Valley ID water rights and contract amounts that are not subject to deficiency. Annual allocations are restricted to the range from 0.5 to 1.0. The *YCWAAllocation* is used in conjunction with transmission links from Daguerre Dam to DUs A_14_15N_NA3 and A_15S_NA. Diversions at the 'Pumpline' facility to A_14_15N_NA2 (Browns Valley ID) are not subject to deficiencies.

7.10 Ops\Weirs

7.10.1 Tisdale

Changes to operation of a notch at the Tisdale Weir (Tisdale Weir Project) was committed to as part of the Sacramento River Voluntary Agreement (VA). The existing Tisdale Weir begins spilling at a Sacramento River flow of approximately 23,000 cfs, as measured at Wilkins Slough. SacWAM assumes that spills begin to occur at an average monthly flow greater than 18,000 cfs. The difference between the actual flow, and the model simulated flow when spills begin over the existing weir, is because of the monthly time step in the models. SacWAM assume approximately 75% of the flow above a monthly average flow of 18,000 cfs spills over the Tisdale Weir and into the Sutter Bypass. This assumption results in approximately the same volume and frequency of Tisdale Weir spill occurring in the model as historically observed.

A similar assumption was developed for spills through a notched weir. The estimated spill is based on the assumption that the notch would have a bottom elevation at 33 feet. An elevation of 33 feet is a daily flow of approximately 9,000 cfs in the Sacramento River at Wilkins Slough. The most current plans for the Tisdale Weir Project include an operable gate to provide some measure of flow control. The current plan for when the Tisdale Weir Project would open/operate the notch is from December 1 through March 15 each year.

The Tisdale branch defines the spill characteristics of the Tisdale Weir and allows the model user to simulate operation of the proposed Tisdale Weir notch. The simulation of spills over a series of control structures and weirs along the Sacramento River is discussed in Section 8.38.

7.10.1.1 Slope1

Slope1 represents the fraction of Sacramento River flow over and above 10,000 cfs that 'spills' over the Tisdale Weir. This fraction applies to Sacramento River flows from 10,000 cfs to 18,000 cfs. When *Key\VA\Tisdale Weir VA* is set to '0,' *Slope1* is set to zero, otherwise *Slope1* has a value of 0.54 from December 1 through March 15.

7.10.1.2 Slope2

Slope2 represents the fraction of Sacramento River flow over and above 18,000 cfs that spills over the Tisdale Weir. This fraction applies to Sacramento River flows from 18,000 cfs to 23,760 cfs. When *Key\VA\Tisdale Weir VA* is set to '0', *Slope2* is set to 0.752 from March 16 to November 30, and a value of '0' from December 1 through March 15.

7.10.1.3 Slope3

Slope3 represents the fraction of spill for Sacramento River flow over and above 23,760 cfs that spills over the Tisdale Weir. *Slope3* has a constant value of 0.752.

7.11 Upper Watersheds Hydrology

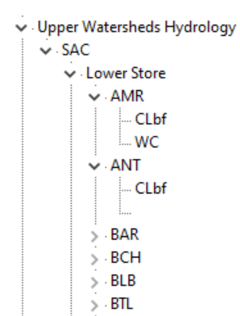
The following sections describe the application of WEAP's catchment objects to simulate the hydrology of the upper watersheds that surround the Sacramento Valley. Although SacWAM was initially developed to dynamically simulate runoff from the upper watersheds using WEAP's two-bucket concept, <u>this option is no longer used and additional model development would be required before activating this option</u>.

7.11.1 Sacramento (Sac)

The upper watersheds of SacWAM were calibrated by adjusting Soil Moisture Method hydrological parameters until stream flows agreed with DWR reported unimpaired flows. Calibration was performed at 21 locations for the largest streams. The calibration period was water years 1970 – 2009. Initially the snow parameters, crop coefficients, soil water capacity, deep water capacity, runoff resistance factor, root zone conductivity, deep conductivity, and preferred flow direction were set using parameters from an older WEAP model known as the Central Valley Planning Area (CVPA) model. During calibration additional adjustments were made to all parameters except crop coefficients and runoff resistance factors.

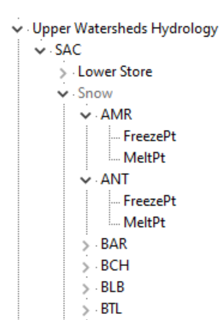
No data or logic are entered at the *Sac* level and the folder serves only as a container for other subfolders.

7.11.1.1 Lower Store



The *Lower Store* branch defines property values for the different SacWAM watersheds. Each watershed is referenced using a three-letter code, e.g., *CSM* contains properties for the Cosumnes River watershed. The list of codes and associated catchments can be found in the RegionalCalibNames tab of **Upper watershed expressions**, referenced in Table 5-6. Values are defined for water holding capacity (*WC*) of the lower one below the root zone, and the hydraulic conductivity (*CLbf*) of this lower zone.

7.11.1.2 Snow



The *Snow* branch defines *FreezePt* and *MeltPt* values, which are calibrated values for freezing and melting points associated with each catchment object. *Snow* uses the same three-letter codes used for the *Lower Store* parameters.

7.11.1.3 Upper Store

Similar to the *Lower Store*, *Upper Store* defines hydrologic parameters for the upper zone or root one for each catchment object for the upper watersheds.

7.11.1.3.1 <u>Hydraulic Conductivity (HC)</u>

The Hydraulic Conductivity, *HC*, is a measure of the soil's ability to tarnsport water through the soil profile.

7.11.1.3.2 Crop Coefficient (Kc)

The Crop Coefficient, *Kc*, of the land cover relates the potential evapotranspiration to that of a reference crop.

7.11.1.3.3 Preferred Flow Direction (PfdElev)

The Preferred Flow Direction (*Pfd*) is used to partition the flow out of the root zone layer (top "bucket") between interflow and flow to the lower soil layer (bottom "bucket") or groundwater: 1.0 = 100% horizontal, 0 = 100% vertical flow.

7.11.1.3.4 Runoff Resistant Factors (Rf)

The Runoff Resistant Factor, *Rf*, controls runoff from the land cover. Higher values of this factor lead to less surface runoof an more infiltration.

7.11.1.3.5 Soil Water Capacity (SWC)

The Soil Water Capacity, *SWC*, is a measure of the soil's ability to store water.

7.12 Valley Floor Hydrology

The Valley Floor Hydrology branch defines model parameters for crop water demands and agricultural water use, stream-groundwater interaction, rainfall-runoff, and irrigation of urban landscapes.

7.12.1 Calibration Factors

7.12.1.1 Crop_NVeg_EffPrec

The *Crop_NVeg_EffPrec* parameter is no longer used in the model.

7.12.1.2 Evaporative Loss

The *Evaporative Loss* parameter is a multiplier on the evaporative losses associated with each agricultural demand unit, which represent consumptive canal conveyance losses.

7.12.1.3 Gain from GW Factor

The *Gain from GW Factor* parameter is a multiplier that is applied to the calculation of the stream inflow from groundwater.

7.12.1.4 Lateral Flow

The *Lateral Flow* parameter is a multiplier on the lateral flow losses associated with each agricultural demand unit, which represent canal seepage to adjacent toe drains. The default value is '1'.

7.12.1.5 MaxPercRate_Alf_Past

The *MaxPercRate_Alf_Past* parameter is no longer used in the model.

7.12.1.6 MaxPercRate_NV

The *MaxPercRate_NV* parameter is associated with the catchment objects associated with urban demand units. It defines the maximum percolation rate in mm/month for the native vegetation land use category.

7.12.1.7 Operational Spill
The *Operational Spill* parameter is a multiplier on the operational losses associated with each agricultural demand unit, which represent canal operational spills to the surface drainage system. The default value is '1'.

7.12.1.8 Potential Application Efficiency
The *Potential Application Effciency* parameter is a multiplier on the operational losses associated with each agricultural demand unit, which represent field level irrigation efficiency associated with the irrigation technology (e.g., drip irrigation). The default value is '1'.

7.12.1.9 Refuges

7.12.1.9.1 MaxPercRate
The *MaxPercRate* parameter is no longer used in the model.

7.12.1.9.2 ReleaseReqmt
The *Release Reqmt* parameter is the flow-through rate for flooded wetlands to maintain healthy water quality conditions. It has a default value of 0.01 cfs per acre.

7.12.1.10 Reuse
The *Tailwater* parameter is a global multiplier on the reuse of tailwater associated with each agricultural demand unit. The default value is '1.'

7.12.1.11 Rice

7.12.1.11.1 EarlyFraction
The Crop Library in SacWAM contains two types of irrigated rice: early planting and late planting. The *EarlyFraction* parameter defines the split between these two types of rice. The default value of '0.5' is applied to all rice production in the model.

7.12.1.11.2 MaxPercRate
The *MaxPercRate* parameter is no longer used in the model.

7.12.1.11.3 ReleaseReqmt
The *Release Reqmt* parameter is the flow-through rate for flooded rice fields to maintain healthy water quality conditions. It has a default value of 0.01 cfs per acre.

7.12.1.12 Sac Valley Gain from GW Factor
Sac Valley Gain from GW Factor is a global multiplier that may be used to increase or decrease seepage rates for streams in the Sacramento Valley. The default value is '1.'

7.12.1.13 Sac Valley Loss from GW Factor
Sac Valley Loss from GW Factor is a global multiplier that may be used to increase or decrease groundwater base flow into the streams of the Sacramento Valley. Values, which vary by month and by water year type, are the result of model calibration to historical gauge data and an historical water balance.

7.12.1.14 Seepage Loss

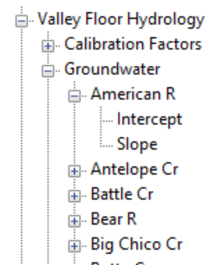
The *Seepage Loss* parameter is a multiplier on the vertival flow losses associated with each agricultural demand unit, which represent canal seepage to the underlying aquifer. The default value is '1.'

7.12.1.15 Tailwater

The *Tailwater* parameter is a multiplier on the calculation of reuse of tailwater associated with each agricultural demand unit. The default value is '1.'

7.12.1.16 Urb_InfRate

7.12.2 Groundwater



In model simulation, streams interact with the underlying groundwater aquifer through the *Groundwater Inflow* and *Groundwater Outflow* parameters on stream reaches. Subbranches under the Groundwater folder define parameter values for these inflows and outflows for each stream. The intercept parameter represents the flow from the aquifer to the stream reach (i.e., base flow). The slope parameter represents the percentage of streamflow that percolates to the underling aquifer.

7.12.3 MiscellaneousET

Miscellaneous ET was introduced in to SacWAM to provide a means of increasing or decreasing crop ET to represent other miscellaneous evaporative losses. It is currently set to zero.

7.12.4 Potential Application Efficiency

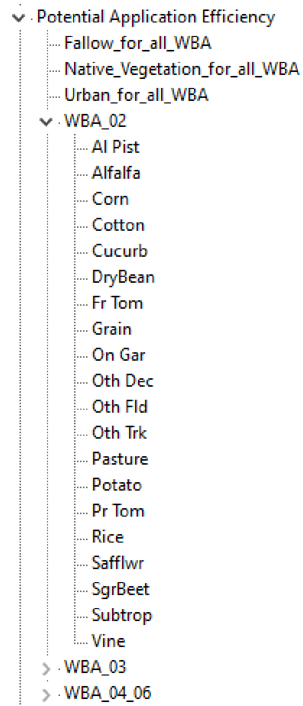
The Potential Application Efficiency is based on the concept that the applied water is sufficient to achieve average soil moisture across the least watered quarter of the field equal to field capacity. It represents the upper limit on irrigation efficiency imposed by irrigation technology assuming best management practices.

7.12.5 SCS Curve Number

The SCS curve number method is used to calculate runoff from daily precipitation.

7.12.5.1 CN_AG_I

CN_AG_I is the curve number for agricultural lands. This value was adjusted during calibration. See Appendix A, Section 4.



7.12.5.2 CN_NV_I

CN_NV_I is the curve number for native vegetation. This value was adjusted during calibration. See Appendix A, Section 4.

7.12.5.3 CN_RF_I

CN_RF_I is the curve number for refuge lands. This value was set using textbook values. See Appendix A, Section 4.

7.12.5.4 CN_UR_I

CN_UR_I is the curve number for refuge lands. This value was set using textbook values. See Appendix A, Section 4.

7.12.5.5 FactorHigh

FactorHigh is a global parameter that can be used to modify the maximum soil moisture retention. It is set to 1.25. See Section 4.4.3.4 for further details.

7.12.5.6 FactorHigh_Crops

FactorHigh_Crops is a global parameter that can be used to modify the maximum soil moisture retention. It is set to 1.25. See Section 4.4.3.4 for further details.

7.12.5.7 FactorLow

FactorLow is a global parameter that can be used to modify the maximum soil moisture retention. It is set to 0.75. See Section 4.4.3.4 for further details.

7.12.5.8 FactorLow_Crops

FactorLow_Crops is a global parameter that can be used to modify the maximum soil moisture retention. It is set to 0.75. See Section 4.4.3.4 for further details.

7.12.6 Urban Outdoor

The parameters in *Urban Outdoor* branch pertain to irrigation of residential and commercial landscaping.

7.12.6.1 Sacramento (Sac)

7.12.6.1.1 Area Factors

The purpose of *Area Factors* is to facilitate changes in the assumed land cover for urban areas in the upper watersheds. The parameters described below allow global changes to the assumed distribution of land between commercial, industrial, and industrial urban uses.

Commercial

The *Commercial* parameter is applied to that land use classification.

Residential

The *Residential* parameter is applied to that land use classification.

7.12.6.1.2 Irrigation (Irrig)

Schedule

The *Schedule* parameter has a value of 100 assigned to each month but is no longer used.

Threshold (Thresh)

The *Thresh* parameter/variable is not used and no value has been entered.

7.13 Water Allocation Priorities

WEAP uses linear programming to solve the allocation of water at each time step.[72] Two sets of objectives determine allocations of water supplies to meet consumptive demands, instream flow requirements, and reservoir storage: demand priorities; and supply preferences.

Demand priorities are used to allocate water to competing demand sites and catchments, flow requirements, and reservoir storages. The *demand priority* is attached to the demand site, catchment, reservoir, or flow requirement and ranges from 1 to 99[73], with 1 being the highest/senior priority and 99 the lowest/junior. Many demand sites can share the same priority, which is useful in representing a system of water rights and seniority. In cases of water shortage, higher priority users are satisfied as fully as possible before lower priority users are considered. If priorities are the same, shortage will be shared equally (as a percentage of demand).

SacWAM uses several general categories of demand to define the system of priorities. In general, the highest priority is assigned to operations (water storage, flow requirements, and deliveries) in the upper watersheds. Sacramento Valley operations have the next highest priority level and water users relying on Delta exports have the lowest priority level. Within the Sacramento Valley, water users are further distinguished by their demand type (i.e., urban, agriculture, refuge) and contract type (i.e., Non-Project, CVP, or SWP). The general demand priority structure of SacWAM is set up in WEAP's Data Tree under *Other Assumptions\Water Allocation Priorities*. Each demand within SacWAM then references the appropriate sub-branch within this structure. The water allocation variables and their associated priorities are presented in

[72] While WEAP uses an LP to allocate water, it is not an optimization tool. Each time step, the software allocates water hierarchically to demands with the highest priority. WEAP does not consider trade-offs between higher and lower priorities, nor does the software consider future time steps in its water allocation process.

[73] Beginning with WEAP version 2018.0105, the upper limit on the demand priority has been expanded from the default of 99 to 999,999,999.

Table 7-62.

Simulation of CVP and SWP operations relies on a series of dummy networks as described in Section 3.17. The priority structure for these dummy networks is as follows:

- Priority 43: **Minimization** – COA credit.
- Priority 58: Trinity conservation storage – internal WEAP priority.
- Priority 73: CVP deliveries to South-of-Delta exchange and water service contractors.
- Priority 73: SWP deliveries to long-term Table A contractors.
- Priority 79: CVP filling of San Luis Reservoir up to CVP rule curve.
- Priority 79: SWP filling of San Luis Reservoir up to SWP rule curve.
- Priority 80: Relax CVP/SWP split of export capacity under EI Ratio – **priority-based UDCs.**
- Priority 80: Relax CVP/SWP split of export capacity under IE Ratio – **priority-based UDCs.**
- Priority 80: Relax CVP/SWP split of export capacity under April/May Pulse – **priority-based UDCs**
- Priority 81: **Maximization** - Folsom storage.
- Priority 82: **Maximization** – Oroville and Shasta storage.
- Priority 84: CVP filling of San Luis Reservoir above CVP rule curve using excess Delta outflow – internal WEAP priority on conservation storage.
- Priority 84: SWP filling of San Luis Reservoir above SWP rule curve using excess Delta outflow – internal WEAP priority on conservation storage.
- Priority 85: Relax CVP/SWP split of export capacity under OMR – **priority-based UDCs.**
- Priority 85: **Switch** - unused Federal Share becomes available to the SWP.
- Priority 86: **Maximization** - SWP San Luis Reservoir storage
- Priority 87: Oroville conservation storage – internal WEAP priority.
- Priority 88: SWP Article 21 deliveries using excess Delta outflow.
- Priority 89: **Switch** - unused State Share becomes available to the CVP.
- Priority 90: **Maximization** - Shasta storage.
- Priority 90: **Maximization** - Shasta storage.
- Priority 90: **Maximization** - CVP San Luis Reservoir storage.
- Priority 91: **Maximization** - Folsom storage.
- Priority 92: **Switch** - allow wheeling for Cross Valley Canal.

- Priority 93: CVP deliveries to the Cross Valley Canal**.**
- Priority 94: **Switch** - allow Joint Point of Diversion.
- Priority 94: **Maximization** - CVP San Luis Reservoir storage.
- Priority 95: Folsom and Shasta conservation storage – internal WEAP priority.
- Priority 97: **Minimization** - Delta outflow.

Table 7-62. Water Allocation Priorities

Variable Name	Priority	Variable Name	Priority
CVP Trinity River Imports Preprocessed	1	PGE NF Mokelumne Buffer Storage	19
Headflow Adjustment	1	PGE YubaBear Buffer Storage	19
Hydrology	1	SWP NOD Local Reservoirs Conservation Storage	19
Upper American Watershed CU	1	SFWPA Conservation Storage	19
EID FERC Mandated Minimum Storage	6	NID Operational Objectives	20
IFR Lodi Decree nonstoragebased	6	PGE Feather River Buffer Storage	20
Upper Watershed IFRs	6	PGE NF Mokelumne Operational Objectives	20
EID Buffer Storage	8	NID Conservation Storage Bear River	20-22
SMUD Buffer Storage	9	BrownsValleyID Conservation Storage	21
SWRCB Inflow IFRs	9	EBMUD Storage Terminal Reservoirs	21
Upper Watershed High Priority Demands	9	NID Conservation Storage Yuba River	21
GDPUD Demands	12	PCWA Buffer Storage	21
SMUD Operational Objectives	12	PGE Feather River Operational Objectives	21
SWP NOD Local Reservoirs Buffer Storage	12	PGE NF Mokelumne Conservation Storage	21
Upper American Watershed Demands	12	SWRCB IFRs	21
Upper Mokelumne Watershed Demands	12	PGENewCastlePHRoute	21
Upper Watershed Reservoirs	12	NID Conservation Storage Deer Creek	22
SFWPA Buffer Storage	12	PGE Feather River Conservation Storage	22
EID Operational Objectives	13	PGE YubaBear Conservation Storage	22
EID Conservation Storage	14	PCWA Operational Objectives	24
BrownsValleyID Buffer Storage	15	PGE Drum Spaulding Power Objective	24
EID Cosumnes River Storage	15	Upper Feather Watershed CU	24
GDPUD Conservation Storage	15	IFR met by SSWD	27
JVID Conservation Storage	15	IFR met by YCWA	27
NID Buffer Storage Bear River	15	IFR NonProject Tributary	27
NID Buffer Storage Deer Creek	15	NonProject Senior TribDemand	27
PGE YubaBear Operational Objectives	15	PCWA Conservation Storage	27
SMUD Conservation Storage	15	EBMUD Deliveries	30
SWP NOD Local Reservoirs Ops Objectives	15	NonProject Trib Demand	30
SFWPA Operational Objectives	15	YCWA Buffer Storage	31
PGE Lodi Buffer Storage	15	YCWA Operational Objectives 1	32
BrownsValleyID Demand	18	EBMUD Operational Objectives	33
EID Folsom Demand	18	NonProject Trib Storage	33
IFR Lodi Decree storagebased	18	YCFCWCD Storage Indian Valley	33
SMUD Transwatershed Imports	18	YCWA Conservation Storage	33
Upper Watershed Demand	18	CVP Stony Creek Storage	34
Upper Watershed Diversions	18	EBMUD Storage Pardee	34
NID Buffer Storage Yuba River	19	YCFCWCD Storage Clear Lake	34
YCWA Operational Objectives 2	34	CVP SOD Refuge Contractors	73

Variable Name	Priority	Variable Name	Priority
EBMUD Storage Camanche	35	CVP SOD Urban Contractors	73
Contra Costa WD Operational Objectives	38	SWP Canal Losses	73
CVP Export Pumping Health and Safety	38	SWP Table A Demands	73
Delta Consumptive Use	38	Travis AFB Demand	73
SWP Export Pumping Health and Safety	38	CVP SOD Storage bw Rule Curve	79
Agriculture NonProject	39	SWP SOD Storage bw Rule Curve	79
Urban NonProject	39	Relax 5050 split on export constraints	80
Feather River IFRs	42	Maximize Folsom1 Storage	81
IFR Project Tributary	42	Maximize Oroville Storage	82
MinimizeCOACredit	43	Maximize Shasta1 Storage	82
CVP Settlement Contractors	45	CVP SOD storage ab Rule Curve using Delta surplus	84
SWP Settlement Contractors	45	SWP SOD storage ab Rule Curve using Delta surplus	84
CVP Trinity River Imports Base	48	Allow SWP use of unused Federal Share	85
CVP Trinity River Imports Additional	49	Maximize SWP San Luis Storage	86
Delta Outflow Requirement	55	SWP Oroville Conservation Storage	87
CVP Trinity River Storage	58	SWP Article 21 Demands	88
CVP Refuge Contractors	61	Allow CVP use of unused State Share	89
City of Antioch Demand	62	Maximize CVP San Luis1 Storage	90
CVP Urban Contractors	62	Maximize Folsom2 Storage	90
CVP Ag Contractors	63	Maximize Shasta2 Storage	91
RouteThruStream	65	Allow wheeling for CVC	92
Bypass Demand	66	CVP Cross Valley Canal	93
RouteThruPowerhouse	66	Allow wheeling for CVP JPOD	94
CVP Storage Folsom Buffer Storage	67	Maximize CVP San Luis2 Storage	94
MaximizeStoragePriortoSODExports	69	CVP NOD Storage	95
CVP Above San Luis	71	NBA Settlement Water	96
SWP above San Luis	71	North Bay Aqueduct Settlement Water	96
CVP Shasta Buffer Storage	72	MinimizeDeltaOutflow	97
SWP Oroville Buffer Storage	72	SWP Max Power Canal	97
CVP SOD Ag Contractors	73	Water Accounting Delta Surplus	98
CVP SOD Canal Losses	73	Water Accounting EXP1 Term	99
CVP SOD Exchange Contractors	73		

8 User-Defined Constraints

The WEAP software determines the allocation of water at each time step using a form of linear programming (LP) known as Mixed Integer Linear Programming (MILP). The MILP formulation consists of an objective function and a set of linear constraints. The objective function is defined in terms of priorities (weights) and associated decision variables (e.g., storage, streamflows, and deliveries). The linear equations that constrain the values of the decision variables typically relate to system connectivity, physical capacities, and regulatory and contractual limits on diversions and storage (e.g., water rights, flood control requirements). The WEAP solution algorithm is described in Section 2.4.

WEAP is designed to automatically build the objective function and constraints from its built-in model objects (e.g., rivers, demand nodes, groundwater nodes), each of which are endowed with properties that act as constraints (e.g., reservoir storage capacity, maximum diversion capacity) and/or objectives (e.g., priorities for flow requirements, water demands, water storage). However, for complex water resource systems, additional user-defined constraints (UDC) may be needed. This happens, most frequently, in cases where a decision variable is conditional upon another decision variable. For example, the flow over a weir is dependent on the upstream flow in the river.

User-defined variables may be ‘state’ variables or ‘decision’ variables. The values of state variables are known or are calculated at the beginning of the time step prior to solving the water allocation problem. The value of decision variables is determined by the MILP solver. State variables are defined in SacWAM under Other Assumptions. User-defined decision variables are defined under the User Defined Linear Programming Constraints branch of the WEAP data tree.

User-defined decision variables have one of the following forms:

- DefineLPVariable: A standard LP decision variable (i.e., positive real number).
- DefineIntegerLPVariable(0,1): An integer decision variable that may have a value of zero or one.
- DefineLPVariable(-999999,999999): An LP decision variable with a lower bound of -999,999 and an upper bound of 999,999.

This chapter briefly describes the UDCs implemented in SacWAM. They are described in alphabetical order. Brief background information is presented for each UDC. The section headings correspond to branches in the WEAP data tree. This information supplements material presented in Chapter 7 and addresses many of the same aspects of the model because Other Assumptions and User-Defined LP Constraints are often linked.

Elements of the data tree that are not in current use, although described, have been formatted in grey font, for example: “this branch of the data tree, although described, is not currently used in the model.” These elements of the data tree are both no longer active and have been made non-active by inserting a semi-colon as the first character of the expression.

8.1 a_Water Allocation Switches

The purpose of water allocation switches is to turn-on an action or allow a particular action to take place after a specified allocation order has been solved within each time step. Additional switches have been added to allow one project (CVP or SWP) to export the other project's unused water. They are described in Section 3.17. Water allocation switches have been added in association with wheeling of Cross Valley Canal water and Joint Point of Diversion through Banks Pumping Plant. These switches are described in the following sections.

8.1.1 CVCWheeling

When capacity is available, the SWP wheels CVP water through Banks Pumping Plant for delivery to CVP Cross Valley Canal contractors.[74] The contractors receive up to 128,300 acre-feet of CVP water per year. Typically, wheeling occurs in the spring, summer, and fall.

The UDC *CVCWheeling* restricts wheeling of Cross Valley Canal water through Banks Pumping Plant (*CVP_CVC*) to be less than the flow through the transmission link *Transmission Links\to z_CVCWheelingDemand\from Withdrawal Node CVCWheeling.* Flow through this transmission link is activated when solving for demand site *z_CVCWheelingDemand* that has an assigned priority of 92 (Water Allocation Priorities\Allow wheeling for CVC).

8.1.2 CVP_JPODWheeling

When capacity is available and certain criteria have been met under D-1641, the SWP wheels CVP water through Banks Pumping Plant for storage in San Luis Reservoir and later delivery to CVP water service contractors located south of the Delta. In SacWAM, this 'Joint Point of Diversion' wheeling has a lower priority than wheeling for the Cross Valley Canal.

The UDC *CVP_JPODWheeling* restricts wheeling of CVP water through Banks Pumping Plan (*CVP_JPOD*) to be less than the flow through the transmission link *Transmission Links\to z_JPODDemand\from Withdrawal Node JPOD.* Flow through this transmission link is activated when solving for demand site *z_JPODDemand* that has an assigned priority of 94 (Water Allocation Priorities\Allow wheeling for CVP JPOD).

8.1.3 UnusedFS

The 1986 COA and 2018 COA Addendum allows the CVP and SWP to use any unused State and Federal water, respectively. The UDC *UnusedFS* restricts State use of Federal water (*Unused_FS*) to be less than the flow through the transmission link *Transmission Links\to z_Unused_FS_Demand\from Withdrawal Node Unused_FS.* Flow through the transmission link is activated when solving for demand site *z_Unused_FS_Demand* that has an assigned priority of 85 (Water Allocation Priorities\Allow SWP use of unused Federal Share).

8.1.4 UnusedSS

The UDC *UnusedSS* restricts Federal use of State water (*Unused_SS*) to be less than the flow through the transmission link *Transmission Links\to z_Unused_FS_Demand\from Withdrawal Node Unused_SS.* Flow

[74] The Cross Valley Contractors consists of seven agencies (Lower Tule River ID, Pixley ID, Kern-Tulare WD, Hills Valley ID, Tri-Valley WD, County of Tulare, and County of Fresno.

through the transmission link is activated when solving for demand site *z_Unused_SS_Demand* that has an assigned priority of 89 (Water Allocation Priorities\Allow CVP use of unused State Share).

8.2 b_Storage Maximization

In WEAP, when a priority is attached to a reservoir, storage is maximized in the associated allocation order solution. In subsequent allocation orders, storage has no assigned weight in the LP problem; instead, a constraint is automatically written that prevents storage falling below the previously maximized value. The purpose of the *Storage Maximization* branch is to allow storage maximization to occur during multiple allocation orders within each time step. *Storage Maximization* is used for the major CVP and SWP reservoirs north of the Delta and for San Luis Reservoir.

8.2.1 Folsom

The UDC *Folsom* sets the storage in Folsom Lake to be greater than the flow through the transmission link *Transmission Links\to z_MaxFolsomStorage1Demand\from Withdrawal Node FolsomStorage1.* Flow through this transmission link is activated when solving for demand site *z_MaxFolsomStorage1Demand* that has an assigned priority of 82 (Water Allocation Priorities\Maximize Folsom1 Storage).[75]

8.2.2 Oroville

The UDC *Oroville* sets the storage in Lake Oroville to be greater than the flow through the transmission link *Transmission Links\to z_MaxOrovilleStorageDemand\from Withdrawal Node OrovilleStorage.* Flow through the transmission link is activated when solving for demand site *z_MaxOrovilleStorageDemand* that has an assigned priority of 82 (Water Allocation Priorities\Maximize Oroville Storage).

8.2.3 SanLuis_CVP1

The UDC *SanLuis_CVP1* sets the storage in CVP San Luis Reservoir to be greater than the flow through the transmission link *Transmission Links\to z_MaxCVPSanLuis1Demand\from Withdrawal Node CVPSanLuis1.* Flow through this transmission link is activated when solving for demand site *z_MaxCVPSanLuis1Demand* that has an assigned priority of 90 (Water Allocation Priorities\Maximize CVP San Luis1 Storage).

8.2.4 SanLuis_CVP2

The UDC *SanLuis_CVP2* sets the storage in CVP San Luis Reservoir to be greater than the flow through the transmission link *Transmission Links\to z_MaxCVPSanLuis2Demand\from Withdrawal Node CVPSanLuis2.* Flow through the transmission link is activated when solving for demand site *z_MaxCVPSanLuis2Demand* that has an assigned priority of 94 (Water Allocation Priorities\Maximize CVP San Luis2 Storage).

[75] The priority has been changed to 82 and no longer references the priority *Maximize Folsom1 Storage.*

8.2.5 SanLuis_SWP

The UDC *SanLuis_SWP* sets the storage in SWP San Luis Reservoir to be greater than the flow through the transmission link *Transmission Links\to z_MaxSWPSanLuisDemand\from Withdrawal Node SWPSanLuis.* Flow through this transmission link is activated when solving for demand site *z_MaxSWPSanLuisDemand* that has an assigned priority of 86 (Water Allocation Priorities\Maximize SWP San Luis Storage).

8.2.6 Shasta1

The UDC *Shasta1* sets the storage in Shasta Lake to be greater than the flow through the transmission link *Transmission Links\z_MaxShastaStorage1Demand\from Withdrawal Node ShastaStorage1* less 1.2 times wheeling of CVP water through Banks Pumping Plant*.* Flow through this transmission link is activated when solving for demand site *z_MaxShastaStorage1Demand* that has an assigned priority of 82 (Water Allocation Priorities\Maximize Shasta1 Storage).

The reference to wheeling of CVP water through Banks Pumping Plant allows withdrawals from Shasta storage to support deliveries to Cross Valley Canal contractors and Joint Point of Diversion. The factor of 1.2 is to account for carriage water costs. In SacWAM, withdrawals from Shasta storage for the Cross Valley Canal deliveries are only allowed from July through September.

8.2.7 Shasta2

The UDC *Shasta2* sets the storage in Shasta Lake to be greater than the flow through the transmission link *Transmission Links\z_MaxShastaStorage2Demand\from Withdrawal Node ShastaStorage2* less 1.2 times wheeling of CVP water through Banks Pumping Plant*.* Flow through the transmission link is activated when solving for demand site *z_MaxShastaStorage2Demand* that has an assigned priority of 90 (Water Allocation Priorities\Maximize Shasta2 Storage).

The reference to wheeling of CVP water through Banks Pumping Plant allows withdrawals from Shasta storage to support deliveries to Cross Valley Canal contractors and Joint Point of Diversion. The factor of 1.2 is to account for carriage water costs. In SacWAM, withdrawals from Shasta storage are only allowed from July through September.

8.3 c_Minimization

The purpose of the *Minimization* branch is to force selected decision variables towards zero in a particular allocation order within each time step. Minimization is used in conjunction with the COA credit and Delta outflow.

8.3.1 COACredit

During model development, a review of model results showed that local project operations were sometimes distorted by requirements of meeting the COA sharing formula in the early water allocation orders. SacWAM overcomes this problem by slightly relaxing the COA sharing formula. The user-defined decision variables *COACredit_CVP* and *COA Credit_SWP* are credits to the CVP and SWP, respectively, allowing one project to partially meet the other project's responsibility for in-basin use. These variables are introduced into the COA equations for CVP storage withdrawal and SWP storage withdrawal. A technique is used within SacWAM to minimize the values of these two variables and their resulting monthly values are typically less than 1 TAF. *COA Credit_SWP* was later set to zero in the UDC *COACredit_SWP_Zero*, because modeling experience showed it was not needed.

The UDC *COACredit* sets the user-defined variable *COACredit_CVP* to be less than the flow through the river arc *z_MinCOACredit_Arc* below the point of diversion to *z_MinCOACredit_Demand.* This demand site has an assigned priority of 43 (Water Allocation Priorities\MinimizeCOACredit).

8.3.2 COACredit2

The UDC *COACredit* sets the user-defined variable *COACredit_CVP* to be less than the flow through the river arc *z_MinCOACredit2_Arc* below the point of diversion to *z_MinCOACredit_Demand2.* This demand site has an assigned priority of 73 (Water Allocation Priorities\CVP SOD Ag Contractors).

8.3.3 FolsomExcessRelease

The UDC *FolsomExcessRelease* sets the user-defined variable *MFMS Folsom Max Release\FolsomExcessRelease* to be less than the flow through the river arc *z_MinFolsomExcessRelease_Arc* below the point of diversion to *z_MInFolsomExcessRelease.* This demand site has an assigned priority of 95 (Water Allocation Priorities\CVP NOD Storage). This UDC is used to minimize releases in excess of the value of *Other\Ops\Flow Requirements\American River\FMS\MFMS Max Release\Folsom_max_release*.

8.4 Contra Costa Water District (CCWD)

Contra Costa WD water supply facilities include four Delta intakes located on Rock Slough, Old River, Victoria Canal, and Mallard Slough, and a 160-TAF capacity offstream reservoir, Los Vaqueros. The reservoir is operated to improve water quality and provide emergency storage for district customers. Contra Costa WD operations are not fully dynamic in SacWAM. Instead, SacWAM relies on preprocessed time series data furnished from a separate WRIMS-based model, which is described in Section 7.9.2.2.

8.4.1 Los Vaqueros Reservoir

8.4.1.1 LVReleasetoKelloggCreek

The UDC *LVReleasetoKelloggCreek* limits reservoir releases to be less than the natural inflow to the reservoir. The purpose of the UDC is to prevent Delta water that has been pumped from the transfer station to Los Vaqueros Reservoir from being released through Kellogg Creek back to the Delta.

8.4.1.2 CVPWaterLimit

The UDC *CVPWaterLimit* is a legacy of model development and has been deactivated.

8.4.1.3 LV_In

LV_In, a user-defined variable, is a legacy of model development and has been deactivated.

8.4.1.4 LV_In Eqn

The UDC *LV_In Eqn* is a legacy of model development and has been deactivated.

8.4.1.5 LV_Int
LV_Int, a user-defined variable, is a legacy of model development and has been deactivated.

8.4.1.6 LV_Out
LV_Out, a user-defined variable, is a legacy of model development and has been deactivated.

8.4.1.7 LV_Out Eqn
The UDC *LV_Out Eqn* is a legacy of model development and has been deactivated.

8.4.1.8 Set LV_In
The UDC *SetLV_In* is a legacy of model development and has been deactivated.

8.4.1.9 Set LV_Out
The UDC *SetLV_Out* is a legacy of model development and has been deactivated.

8.5 City of Stockton

The City of Stockton has multiple sources of water and conjunctively manages surface water and groundwater to deliver treated water within the metropolitan area. The city purchases treated water from Stockton East WD and owns and operates its own 'Delta' water treatment plant and associated intake located on the San Joaquin River near Empire Tract.

8.5.1 Delta WTP

SacWAM does not explicitly represent City of Stockton's Delta water treatment plant. Instead, treated water supplies from the plant are represented indirectly by transmission links from the Mokelumne River and the San Joaquin River.The UDC *Delta WTP* limits supplies from these two links to the plant's 30 mgd capacity of the Delta WTP. This UDC has been deactivated, because the sum of the maximum diversions on the transmission links is less than the capacity of the Delta WTP.

8.5.2 SEWD WTP

SacWAM does not explicitly represent Stockton East WD's water treatment plant, the Joe Waidhofer WTP. Instead, treated water supplies from the plant are represented indirectly by transmission links from the Calaveras River, LittleJohns Creek, and the Upper Farmington Canal. The UDC *SEWD WTP* limits water supplies from these three links to the 60 mgd capacity of the Joe Waidhofer WTP.

8.5.3 WR1485

The UDC *WR1485* further limits diversions from the Delta to be less than the discharge from the Stockton Regional WWTP as required by the City of Stokton's water right permit and by California Water Code section 1485. This UDC has been deactivated, because diversions permitted under the project's biological opinion are less than the simulated wastewater return flow.

8.6 Coordinated Operations Agreement

The COA (Reclamation and DWR, 1986) established a framework under which the CVP and SWP operate to ensure that both projects receive an equitable share of the Central Valley's available water, while meeting their joint responsibilities for meeting water quality standards (as the standards existed in State Water Board Water Right Decision 1485 [D-1485]) and providing water for other (senior) legal uses of water within the Sacramento Valley. The COA formulae are implemented using a mix of user-defined decision variables and constraints. Available water to be shared between the two projects is known as 'unstored water for export' (UWFE). Legal uses of water in the Sacramento Valley and Delta, including Delta outflow to meet standards, is known as 'in-basin use' (IBU). The 2018 COA Addendum revisedf the sharing formulae.

During model development, a review of model results showed that local project operations were sometimes distorted by requirements of meeting the COA sharing formula in the early water allocation orders. This problem was overcome by making these COA equations priority-based (see Section 8.29). However, in some time steps, activation of the COA sharing formula in the later allocation orders again distorted simulated operations or caused infeasibilities. Therefore, SacWAM allows a small relaxation of the COA sharing formula. The user-defined decision variables *COACredit_CVP* and *COA Credit_SWP* are credits to the CVP and SWP, respectively, allowing one project to partially meet the other project's responsibility for in-basin use. These variables are introduced into the COA equations for CVP storage withdrawal and SWP storage withdrawal. A technique is used within SacWAM to minimize the values of these two variables (see Section 8.3) and their values are typically less than 1 TAF. *COA Credit_SWP* was later set to zero in the UDC *COACredit_SWP_Zero*, because modeling experience showed it was not needed.

The implementation of COA in SacWAM requires the model to determine whether there is unstored water for export (UWFE) that may be shared by the CVP and SWP, or there is in-basin use (IBU) within the Sacramento Valley and Delta that must be met by storage withdrawals from project reservoirs (or import of Trinity River water through the Clear Creek Tunnel). The existence of UWFE or IBU is determined by the UDC *In Basin Use\COA Balance* that calculates the difference between project exports and project storage withdrawals, as follows:

> *UWFE - IBU = DeltaSurplus_CVP +DeltaSurplus_SWP+ CVP_EXP1 + CCWD_EXP1 + SWP_EXP1 + (2/3)*NBA_Art21+ (2/3)*NBA_TableA - StorageRelease_SWP - StorageRelease_CVP + Unused_FS + Unused_SS*

If withdrawals from project storage exceed project exports from the Delta, then there is in-basin use within the Sacramento Valley and Delta (*IBU* is non-zero and positive). Conversely, if Delta exports are greater than storage withdrawals, then there exists unused water for export (*UWFE* is non-zero and positive). SacWAM uses the following definitions for these calculations:

- Shasta Storage Release = Sacramento below Keswick - Inflow to Shasta - Spring Creek Tunnel diversion.
- Folsom Storage Release = American below Nimbus + Folsom South Canal + Folsom Lake diversions - Inflow to Folsom.
- Whiskeytown Storage Release/Trinity Import = Clear Creek below Whiskeytown + Spring Creek Tunnel diversion – Natural inflow to Whiskeytown Reservoir.
- Oroville Storage Release = Feather River below Thermalito - Inflow to Lake Oroville - Kelly Ridge Powerhouse flow + Thermalito Afterbay diversions + Power Canal diversions.

- CVP Delta Exports = Export of CVP water at Jones Pumping Plant + Diversion of CVP water by Contra Costa WD + Export of water at Banks Pumping Plant + *Unused_SS.*
- SWP Delta Exports = Export of SWP water at Banks Pumping Water + *Unused_FS* + 2/3*Table A and Article 21 water delivered from the North Bay Aqueduct.

The ability of the two projects to use their share of water under COA may be limited by the physical and permitted capacities of their pumping plant, available storage capacity in San Luis Reservoir, and by other regulatory export constraints. The decision variables *Unused_FS* and *Unused_SS* represent one project's use of the other project's water in instances when either the CVP or SWP cannot export their share of water because of physical capacity or regulatory restrictions. The user-defined integer *int_Unused_FS_SS* and the associated pair of UDCs *int_Unused_FS_SS Eqn1* and *int_Unused_FS_SS_Eqn2* prevent both *Unused_FS* and *Unused_SS* having non-zero values in the same time step.

Delta outflow is divided into: (a) the part that is required to meet regulatory requirements and is part of in-basin use, and (b) Delta outflow that is surplus to regulatory requirements. Delta surplus outflow is further divided into CVP share (*Delta-Surplus_CVP*) and SWP share (*Delta-Surplus_SWP*).

The user-defined integer, *Int_IBU_UWFE*, and the associated pair of UDCs *IBU_force* and *UWFE_force* prevent *IBU* and *UWFE* from both having non-zero values in the same time step.

The COA defines sharing formulae for dividing UWFE between the two projects and assigning responsibilities for meeting IBU. The CVP was entitled to 55% of UWFE and SWP entitled to 45% of UWFE. Under the 1986 COA, the CVP was responsible for for making storage withdrawals to meet 75% of in-basin use and the SWP is responsible for meeting the remaining 25% of in-basin use. This was revised in the 2018 Addendum. The sharing of responsibilities between the two projects for meeting in-basin use now varies by water year type. The sharing formulae are implemented in SacWAM using the UDCs *COA_CVP* and *COA_SWP* that are reproduced below.

> *CVP_EXP1 +CCWD_EXP1 + Unused_FS = StorageRelease_CVP - 0.75*IBU + 0.55*UWFE - DeltaSurplus_CVP*
>
> *SWP_EXP1 + (2/3)* NBA_Art21 + (2/3)* NBA_TableA + Unused_SS = StorageRelease_SWP - 0.25*IBU + 0.45*UWFE - DeltaSurplus_SWP*

The use of unused Federal share (*Unused_FS)* by the SWP and unused State share (*Unused_SS*) by the CVP is controlled by a mix of constraints and priorities.

In SacWAM, code related to COA is organized into a set of seven subbranches, which are described in the following sections.

8.6.1 Delta Exports

CVP exports from the South Delta include delivery of CVP water to Contra Costa WD and flows through Jones Pumping Plant. The latter is disaggregated into components 'exp1' and 'exp2' to distinguish between diversion of CVP water and diversion of unused SWP water, respectively. Similarly, SWP exports at Banks Pumping Plant are disaggregated into components 'exp1' and 'exp2' to represent diversion of SWP water and diversion of unused CVP water, respectively. Banks pumping also includes components *CVP_CVC* and *CVP_JPOD* to simulate wheeling of CVP water through the pumping plant.

8.6.1.1 CCWD_EXP1

CCWD_EXP1 is a user-defined variable representing the diversion of CVP water by Contra Costa WD.

8.6.1.2 CCWD_EXP2

CCWD_EXP2 is a user-defined variable representing the diversion of unused SWP water by Contra Costa WD.

8.6.1.3 CVP_CVC

CVP_CVC is a user-defined variable representing the wheeling of CVP water through Banks Pumping Plant for delivery to the Cross Valley Canal contractors.

8.6.1.4 CVP_EXP1

CVP_EXP1 is a user-defined variable representing the export of CVP water at Jones Pumping Plant.

8.6.1.5 CVP_EXP2

CVP_EXP2 is a user-defined variable representing the export of unused SWP water at Jones Pumping Plant.

8.6.1.6 CVP_JPOD

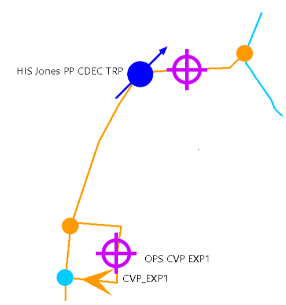
CVP_JPOD is a user-defined variable representing the wheeling of CVP water through Banks Pumping Plant for storage or later delivery to the CVP contractors in the Delta Unit and San Luis Unit of the CVP.

8.6.1.7 Set CCWD_EXP1_EXP2

The UDC *Set CCWD_EXP1_EXP* sets the sum of *CCWD_EXP1* and *CCWD_EXP2* equal to the diversion of CVP water by Contra Costa WD.

8.6.1.8 Set CVP_EXP1

The SacWAM schematic was modified for the purposes of distinguishing between CVP water moved through Jones Pumping Plant and unused SWP water routed through the plant. A diversion arc *CVP_EXP_1* diverts water from the Delta-Mendota Canal, only to return it downstream. The UDC *Set CVP_EXP1* sets the flow through this diversion arc to be equal to (or less than) the variable *CVP_EXP1*.

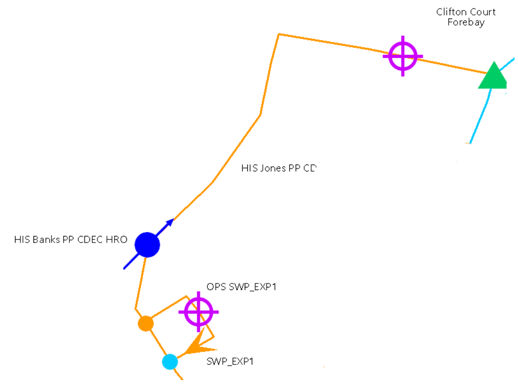


8.6.1.9 Set CVP_EXP1_EXP2

The UDC *Set CVP_EXP1_EXP* sets the sum of *CVP_EXP1* and *CVP_EXP2* equal to the export of water at the Jones Pumping Plant.

8.6.1.10 Set SWP_EXP1

The SacWAM schematic was modified for the purposes of distinguishing between SWP water moved through Banks Pumping Plant and unused CVP water routed through the plant. A diversion arc *SWP_EXP_1* diverts water from the California Aqueduct, only to return it downstream. The UDC *Set SWP_EXP1* sets the flow through this diversion arc to be equal to (or less than) the variable *SWP_EXP1*.



8.6.1.11 Set SWP_EXP1_EXP2

The UDC *Set SWP_EXP1_EXP* sets the sum of *SWP_EXP1* and *SWP_EXP2* equal to the export of SWP water at the Banks Pumping Plant less any CVP water wheeled through the facility.

8.6.1.12 SWP_EXP1

SWP_EXP1 is a user-defined variable representing the export of SWP water at Banks Pumping Plant.

8.6.1.13 SWP_EXP2

SWP_EXP2 is a user-defined variable representing the export of unused CVP water at Banks Pumping Plant.

8.6.1.14 Set CCWD_EXP2

The UDC *Set CCWD_EXP2* sets the diversion of unused SWP water (*CCWD_EXP2*) by Contra Costa WD to zero.

8.6.2 Delta Outflow

The *Delta Outflow* branch divides Delta outflow into two components:

- the *Delta Outflow Requirement* is the outflow needed to meet all regulatory requirements, including that for water quality purposes.
- *DeltaSurplus* is outflow over and above this requirement. For the purposes of COA accounting, Delta surplus is divided in to CVP water and SWP water.

A series of five equations (*DOR Eqn 1, 2…5*) constrain Delta outflow to be greater than that needed to meet MRDO, X2, salinity requirements, and proposed State Water Board standards (*SWRCB Delta:Minimum Flow Requirement*).

For output purposes, the SacWAM schematic includes a diversion arc *Delta Surplus* that removes and then returns a portion of Delta outflow from the main channel. A pair of UDCs, *DeltaSurplusRouting1* and *DeltaSurplusRouting2*, constrain the flow in the main channel, after *Delta Surplus* outflow, to be within 1 cfs of the Delta outflow requirement.

8.6.2.1 Define DeltaSurplus

The UDC *Define DeltaSurplus* sets *DeltaSurplus* to equal the difference between the flow below the IFR object REF MRDO and *Deta Outflow Requirement.*

8.6.2.2 Define DOR

The UDC *Define DOR* sets minimum Delta outflow requirement as the sum of flow-based D-1641 standards, outflow for X2, and any new State Board requirements. The UDC has been deactivated.

8.6.2.3 Delta Outflow Requirement

Deta Outflow Requirement is a user-defined standard LP variable (i.e., must be zero or positive) representing the net Delta Outflow required to meet all Delta standards.

8.6.2.4 DeltaSurplus

DetaSurplus is a user-defined standard LP variable representing the net Delta Outflow over and above that needed to meet all Delta standards.

8.6.2.5 DeltaSurplus_CVP

DetaSurplus_CVP is a user-defined standard LP variable representing the portion of Delta surplus flows (i.e., the flow over and above that needed to meet standards) that is designated as CVP water under COA.

8.6.2.6 DeltaSurplus_SWP

DetaSurplus_SWP is a user-defined standard LP variable representing the portion of Delta surplus flows (i.e., the flow over and above that needed to meet standards) that is designated as SWP water under COA.

8.6.2.7 DeltaSurplusRouting1

The UDC *DeltaSurplusRouting1* sets the net Delta Outflow to be greater than the variable *Deta Outflow Requirement*.

8.6.2.8 DeltaSurplusRouting2

The UDC *DeltaSurplusRouting2* sets the net Deta Outflow to be less than the variable *Deta Outflow Requirement* + 1 cfs.

8.6.2.9 DOR Eqn 1

The UDC *DOR Eqn 1* sets the variable *Deta Outflow Requirement* to be greater than D-1641 flow-based standard, excluding X2.

8.6.2.10 DOR Eqn 2

The UDC *DOR Eqn 2* sets the variable *Deta Outflow Requirement* to be greater than that needed to meet D-1641 X2 standards, as determined by the ANN.

8.6.2.11 DOR Eqn 3

The UDC *DOR Eqn 3* sets the variable *Deta Outflow Requirement* to be greater than that needed to meet D-1641 X2 standards, as determined by the G-model.

8.6.2.12 DOR Eqn 4

The UDC *DOR Eqn 4* sets the variable *Deta Outflow Requirement* to be greater than that needed to meet any new State Water Board outflow standards. Outflow to meet new standards includes that derived from miscellaneous ungaged Delta inflows.

8.6.2.13 DOR Eqn 5

The UDC *DOR Eqn 5* sets the variable *Deta Outflow Requirement* to be greater than that needed to meet D-1641 Delta salinity standards, as determined by the ANN.

8.6.2.14 split DeltaSurplus

The UDC *split DeltaSurplus* disaggregates surplus Delta outflow into CVP (*DetaSurplus_CVP*) and SWP (*DetaSurplus_SWP*) portions.

8.6.2.15 SWRCB_DeltaEff

SWRCB_DeltaEff is a user-defined LP variable that may be positive or negative. It represents the effective net Delta outflow, not including outflow derived from miscellaneous ungaged Delta inflows.

8.6.2.16 setSWRCB_DeltaEff

The UDC *SWRCB_DeltaEff* sets the variable *SWRCB_DeltaEff* to equal the flow as represented in the SacWAM schematic less miscellaneous ungaged Delta inflows.

8.6.3 In-Basin Use

The *In-Basin Use* branch defines the two decision variables *IBU* and *UWFE* and contains the *COA Balance* constraint for determining the values of these variables. The integer decision variable *int_IBU_UWFE* and the associated constraints *IBU_force* and *UWFE_force* prevent *IBU* and *UWFE* from both having non-zero values.

8.6.3.1 COA Balance

The UDC *COA Balance* determines the the amount of *IBU* and *UWFE* by comparing CVP and SWP exports to project storage withdrawals.

8.6.3.2 IBU

IBU is a user-defined standard LP variable that represents legal uses of water in the Sacramento Basin including Delta outflow to meet regulatory requirements.

8.6.3.3 IBU_force

IBU_force and *UWFE_force* is a pair of UDCs that prevent *IBU* and *UWFE* from both having non-zero values.

8.6.3.4 Int_IBU_UWFE

Int_IBU_UWFE is a user-defined integer (0,1) variable that is used to prevent *IBU* and *UWFE* from both having non-zero values.

8.6.3.5 UWFE

UWFE is a user-defined standard LP variable that represents the positive difference between project exports and project storage withdrawals.

8.6.3.6 UWFE_force

UWFE_force and *IBU_force* is a pair of UDCs that prevent *IBU* and *UWFE* from both having non-zero values.

8.6.4 Sharing Formulae

The *Sharing Formulae* branch contains the COA sharing formulae (*COA_CVP* and *COA_SWP*).

8.6.4.1 COA_CVP

The UDC *COA_CVP* defines the CVP share of water as defined by the 2018 COA Addendum. CVP exports and diversions are defined as the sum of the user-defined variables *CVP_Exp1*, *CCWD_EXP1*, *CVP_CVC*, *CVP_JPOD*. CVP water is defined as the sum of storage withdrawals from CVP north-of-Delta reservoirs (*StorageRelease_CVP*) less the CVP share of responsibility (*CVP IBU*) for meeting in-basin use (*IBU*) plus CVP share (*CVP_UWFE*) of unstored water for export (*UWFE*). CVP water that is not exported and is not part of IBU is assigned to the user-defined variables *DeltaSurplus_CVP* and *Unused_FS*.

8.6.4.2 COA_SWP

The UDC *COA_SWP* defines the CVP share of water as defined by the 2018 COA Addendum. SWP exports are defined as the sum of the user-defined variables *SWP_Exp1*, 2/3**NBA_Art21*, and 2/3**NBA_TableA*. SWP water is the storage withdrawals from Lake Oroville (*StorageRelease_SWP*) less the SWP share of responsibility (*SWP IBU*) for meeting in-basin use (*IBU*) plus SWP share (*SWP_UWFE*) of unstored water for export (*UWFE*). SWP water that is not exported and is not part of IBU is assigned to the user-defined variables *DeltaSurplus_SWP* and *Unused_SS*.

8.6.5 Storage Release

The *Storage Release* branch contains the COA definitions for storage withdrawals from Shasta (*SHADS*), Folsom (*FOLDS*), Whiskeytown (*WHSSW*), and Oroville (*StorageRelease_SWP*). Collectively, CVP storage withdrawals are set equal to the decision variable *StorageRelease_CVP*.

The 1986 COA includes Whiskeytown Reservoir in the definition of CVP storage withdrawals. However, Whiskeytown Reservoir is not included in the definition of CVP diversion to storage. In SacWAM, changes in Whiskeytown Reservoir storage are divided into storage increases (*WHSSI*) and storage withdrawals (*WHSSW*). Only the decision variable WHSSW is included as part of the COA balance. The integer variable *int_WHS* and the associated UDCs *WHSSW force* and *WHSSI force* prevent WHSSW and WHSSI from both being non-zero.

8.6.5.1 COACredit_CVP

COACredit_CVP is a user-defined standard LP variable that represents credit that the CVP may gain when the CVP provides a greater share of in-basin use than required under the COA accounting. This variable was introduced to provide some flexibility in model simulation of CVP and SWP operations under COA and overcome relaxation of constraint errors.

8.6.5.2 COACredit_SWP

COACredit_SWP is a user-defined standard LP variable that represents credit that the SWP may gain when the SWP provides a greater share of in-basin use than required under the COA accounting. This variable was introduced to provide some flexibility in model simulation of CVP and SWP operations under COA and overcome relaxation of constraint errors.

8.6.5.3 COACredit_SWP_Zero
The UDC *COACredit_SWP_Zero* sets the variable *COACredit_SWP* to zero. During model development it was found that providing the SWP with credit under the COA accounting did not improve the model simulation.

8.6.5.4 define FOLDS
The UDC *define FOLDS* determines the storage withdrawal from Folsom Lake, *FOLDS*, based on a flow balance between reservoir inflows and outflows.

8.6.5.5 define SHADS
The UDC *define SHADS* determines the storage withdrawal from Shasta Lake, *SHADS*, based on a flow balance between reservoir inflows and outflows.

8.6.5.6 FOLDS
FOLDS is a user-defined LP variable that may be positive or negative. It represents storage withdrawals from Folsom Lake.

8.6.5.7 Int_WHS
IntWHS is a user-defined integer (0, 1) variable that is used to prevent *WHSSI* and *WHSSW* from both having non-zero values.

8.6.5.8 Limit_COACredit_CVP
The UDC *Limit_COACredit_CVP* sets an upper bound on *COACredit_CVP* of 20 TAF. During model development it was found thatthis amount of credit under the COA accounting was sufficient to improve model simulation.

8.6.5.9 Set StorageRelease_CVP
The UDC *Set StorageRelease_CVP* determines the total storage withdrawal from CVP north of Delta reservoirs as the sum of *SHADS*, *FOLDS*, and *WHSSW* and accounting for *COACredit_CVP* and *COACredit_SWP*.

8.6.5.10 Set StorageRelease_SWP
The UDC *Set StorageRelease_SWP* determines storage withdrawal from Lake Oroville based on a flow balance between reservoir inflows and outflows, and accounting for *COACredit_CVP* and *COACredit_SWP*.

8.6.5.11 SHADS
SHADS is a user-defined LP variable that may be positive or negative. It represents storage withdrawals from Shasta Lake.

8.6.5.12 StorageRelease_CVP
StorageRelease_CVP is a user-defined LP variable that may be positive or negative. It represents storage withdrawals from CVP north-of-Delta reservoirs.

8.6.5.13 StorageRelease_SWP
StorageRelease_SWP is a user-defined LP variable that may be positive or negative. It represents storage withdrawals from Lake Oroville.

8.6.5.14 WHS StorChange
The UDC *WHS StorChange* determines the storage withdrawal from Whiskeytown Reservoir based on a flow balance on reservoir inflows and outflows, including Trinity River imports.

8.6.5.15 WHSSI
WHSSI is a user-defined standard LP variable that represents the increase in storage in Whiskeytown Reservoir and accounts for the import of water from the Trinity River.

8.6.5.16 WHSSI force
WHSSI force and *WHSSW force* is a pair of UDCs that prevent *WHSSI* and *WHSSW* from both having non-zero values.

8.6.5.17 WHSSW
WHSSW is a user-defined standard LP variable that represents the storage withdrawal from Whiskeytown Reservoir and accounts for the import of water from the Trinity River.

8.6.5.18 WHSSW force
WHSSW force and *WHSSI force* is a pair of UDCs that prevent *WHSSW* and *WHSSI* from both having non-zero values.

8.6.6 Unused Water

The *Unused Water* branch contains a set of user-defined decision variables and constraints that allow the use of one party's unused water by the other party, as described in the 1986 COA. Two decision variables are defined: *Unused_FS* and *Unused_SS*. The UDCs *constrain unused FS* and *constrain unused SS* set these decision variables equal to the 'exp2' terms in the COA sharing formulae. Simulation of unused CVP and SWP water is activated using the dummy networks described in Section 3.17 and the UDCs *Unused_FS constrain* and *Unused_SS constrain*. An integer variable, *Int_Unused_FS_SS,* and the associated UDCs *Int_Unused_FS_SS* and *Int_Unused_FS_SS* prevent *Unused_FS* and *Unused_SS* from both being non-zero.

8.6.6.1 constrain unused FS
The UDC *constrain unused FS* sets the variable *Unused_FS* equal to the variable *SWP_Exp2*.

8.6.6.2 constrain unused SS
The UDC constrain *unused SS* sets the variable *Unused_SS* equal to the sum of variables *CVP_Exp2* and *CCWD_Exp2*.

8.6.6.3 Int_Unused_FS_SS
Int_Unused_FS-SS is a user-defined integer (0,1) variable that is used to prevent *Unused_FS* and *Unused_SS* from both having non-zero values.

8.6.6.4 Int_Unused_FS_SS Eqn1
Int_Unused_FS_SS Eqn 1 and *Int_Unused_FS_SS Eqn* 2 is a pair of UDCs that prevent *Unused_FS* and *Unused_SS* from both having non-zero values.

8.6.6.5 Int_Unused_FS_SS Eqn2

Int_Unused_FS_SS Eqn 2 and *Int_Unused_FS_SS Eqn* 1 is a pair of UDCs that prevent *Unused_FS* and *Unused_SS* from both having non-zero values.

8.6.6.6 Unused_FS

Unused_FS is a user-defined standard LP variable that represents the portion of CVP water, as defined by COA, that is exported by the SWP at Banks Pumping Plant.

8.6.6.7 Unused_SS

Unused_SS is a user-defined standard LP variable that represent the portion of SWP water, as defined by COA, that is exported by the CVP at Jones Pumping Plant or wheeled through Banks Pumping Plant.

8.6.7 Wheeling

The purpose of the *Wheeling* branch is to simulate wheeling of CVP water through Banks Pumping Plant and subsequently through the California Aqueduct to the Cross Valley Canal (*CVP_CVC*) and wheeling of CVP water for storage in San Luis Reservoir (*CVP_JPOD*).

Code was initially developed to only allow Joint Point of Diversion wheeling when export at Jones Pumping Plant is limited by its physical capacity (4,600 cfs). However, because of numerical solution problems, these constraints were deactivated. These deactivated variables and constraints include C*onstrain_CVP_JPO, intJUC*, *JonesUnusedCapacity*, *JUCConstrain1*, *JUCConstrain2*, *JUCneg*, *JUCnegconstrain*, *JUCpos, and JUCposconstrain*.

8.6.7.1 Constrain_CVP_JPOD

The UDC *Constrain_CVP_JPOD* limits Joint Point of Diversion (CVP_JPOD) to *JUCneg*. This constraint has been deactivated.

8.6.7.2 CVC Wheeling

The UDC *CVC Wheeling* routes Cross Valley Canal water wheeled through Banks Pumping Plant (*Delta Exports\CVP_CVC*) to the demand site *Cross Valley Canal*. In the SacWAM simulation, Cross Valley Canal water cannot be stored in San Luis Reservoir for later delivery.

8.6.7.3 CVP JPOD

The UDC *CVP JPOD* routes CVP water diverted under the Joint Point of Diversion through Banks Pumping Plant (*Delta Exports\CVP_JPOD)* and along the initial reaches of the California Aqueduct to be stored in the CVP share of San Luis Reservoir for later delivery.[76]

8.6.7.4 intJUC

IntJUC is a user-defined integer (0,1) variable that is used to prevent *JUCpos* and *JUCneg* from both having non-zero values. The definition of this variable has been deactivated.

[76] CVP water moved under Joint Point of Diversion is conveyed through the diversion arc *CVP_JPOD* that connects the California Aqueduct to the CVP share of San Luis Reservoir.

8.6.7.5 JonesUnusedCapacity

JonesUnnusedCapacity is a user-defined LP variable that may be positive or negative. It represents the unused or available physical capacity at Jones Pumping Plant. The definition of this variable has been deactivated.

8.6.7.6 JUCconstrain1

The UDC *JUCconstrain1* equates JonesUnusedCapacity to the difference between the physical capacity of Jones Pumping Plant (4,600 cfs) and the simulated flow at the head of the Delta-Mendota Canal. This constraint has been deactivated.

8.6.7.7 JUCconstrain2

The UDC *JUCconstrain2* equates JonesUnusedCapacity to *JUCpos*. This constraint has been deactivated.

When *JonesUnnusedCapacity* has a positive non-zero value (i.e., the flow at the head of the Delta-Mendota Canal is less than its physical capacity), *intJUC* is assigned a value of 1 through the UDC *JUCposconstrain*. *JUCpos* is non-zero and equal to tha available capacity. *JUCneg* is zero and no wheeling allowed.

When *JonesUnnusedCapacity* has a zero value (i.e., the flow at the head of the Delta-Mendota Canal is at its physical capacity), *intJUC* may be zero or 1. This allows wheeling to occur through the UDC *Constrain_CVP_JPOD.*

8.6.7.8 JUCneg

JUCneg is a user-defined standard LP variable that represents the upper bound to Joint Point wheeling. The definition of this variable has been deactivated.

8.6.7.9 JUCnegconstrain

JUCnegconstrain and *JUCposconstrain* is a pair of UDCs that prevent *JUCneg* and *JUCpos* from both having non-zero values. *JUCneg* should have an upper bound of 6,680 cfs – the assumed California Aquduct capacity for wheeling. This constraint has been deactivated.

8.6.7.10 JUCpos

JUCpos is a user-defined standard LP variable that represents unused or available physical capacity at Jones Pumping Plant. The definition of this variable has been deactivated.

8.6.7.11 JUCposconstrain

JUCposconstrain and *JUCnegconstrain* is a pair of UDCs that prevent *JUCpos* and *JUCneg* from both having non-zero values. This constraint has been deactivated.

8.6.8 Output

8.6.8.1 Calculations

A total of 6 user-defined variables are defined and subsequently set equal to an expression for output purposes and model debugging. These variables include: *CVPShareError, CVPWheelingIBU, CVP_DeltaSurplus_State, DeltaSurplus, SWPShareError, UnusedFS, and UnusedSS*.

8.6.8.2 CVPCVC
The intermediate value of the user-defined variable *CVPCVC* is output for various priorities (69, 79, 82. 83, 87, 88, 91, 93, and 98). This is achieved through defining eight variables and eight associated UDCs.

8.6.8.3 CVPExp1
Similar to *CVPCVC*, the intermediate value of the user-defined variable *CVPExp1* is output for various priorities.

8.6.8.4 CVPExp2
Similar to *CVPCVC*, the intermediate value of the user-defined variable *CVPExp2* is output for various priorities.

8.6.8.5 CVPJPOD
Similar to *CVPCVC*, the intermediate value of the user-defined variable *CVPJPOD* is output for various priorities.

8.6.8.6 CVPSanLuis
Similar to *CVPCVC*, the intermediate value of the user-defined variable *CVPSanLuis* is output for various priorities.

8.6.8.7 CVPStorageRelease
Similar to *CVPCVC*, the intermediate value of the user-defined variable *CVPStorageRelease* is output for various priorities.

8.6.8.8 DOR
Similar to *CVPCVC*, the intermediate value of the user-defined variable *DOR* is output for various priorities.

8.6.8.9 DSCVP
Similar to *CVPCVC*, the intermediate value of the user-defined variable *DSCVP* is output for various priorities.

8.6.8.10 DSSWP
Similar to *CVPCVC*, the intermediate value of the user-defined variable *DSSWP* is output for various priorities.

8.6.8.11 Folsom
Similar to *CVPCVC*, the intermediate value of the user-defined variable *Folsom* is output for various priorities.

8.6.8.12 IBU
Similar to *CVPCVC*, the intermediate value of the user-defined variable *IBU* is output for various priorities.

8.6.8.13 Oroville
Similar to *CVPCVC*, the intermediate value of the user-defined variable *Oroville* is output for various priorities.

8.6.8.14 Shasta
Similar to *CVPCVC*, the intermediate value of the user-defined variable *Shasta* is output for various priorities.

8.6.8.15 SWPExp1
Similar to *CVPCVC*, the intermediate value of the user-defined variable *SWPExp1* is output for various priorities.

8.6.8.16 SWPExp2
Similar to *CVPCVC*, the intermediate value of the user-defined variable *SWPExp2* is output for various priorities.

8.6.8.17 SWPSanLuis
Similar to *CVPCVC*, the intermediate value of the user-defined variable *SWPSanLuis* is output for various priorities.

8.6.8.18 SWPStorageRelease
Similar to *CVPCVC*, the intermediate value of the user-defined variable *SWPStorageRelease* is output for various priorities.

8.6.8.19 Trinity
Similar to *CVPCVC*, the intermediate value of the user-defined variable *Trinity* is output for various priorities.

8.6.8.20 UnusedFS
Similar to *CVPCVC*, the intermediate value of the user-defined variable *UnusedFS* is output for various priorities.

8.6.8.21 UnusedSS
Similar to *CVPCVC*, the intermediate value of the user-defined variable *UnusedSS* is output for various priorities.

8.6.8.22 UWFE
Similar to *CVPCVC*, the intermediate value of the user-defined variable *UWFE* is output for various priorities.

8.7 Delta Cross Channel

The Delta Cross Channel is a gated diversion channel off the Sacramento River near Walnut Grove. The channel is operated to improve water quality in the interior and south Delta, and to improve the transfer of water from the Sacramento River to CVP and SWP export pumps in the south Delta. When the gates are open, water flows from the Sacramento River through the Delta Cross Channel to the Lower Mokelumne River and thence to the San Joaquin River. Water from the Sacramento River also flows through the ungated Georgiana Slough to the Mokelumne River.

When the Delta Cross Channel gates are open, flows through the channel are determined by the upstream stage in the Sacramento River. In SacWAM, the flow (*Q_DXC*) is calculated using the following empirical regression equation:

Q_DXC [cfs] = 0.1896 * QSac_WG [cfs] – 36

where:

Q_DXC = Delta Cross Channel flow

Q_SacWG = Sacramento River flow at Walnut Grove

Similarly, flow through Georgiana Slough (*Q_GS*) is calculated using the empirical regression equation:

Q_GS [cfs] = 0.1321 * Q_SacWG [cfs] + 1087

D-1641 (SWRCB, 2000) and the NMFS BiOp (2009) specify when the Delta Cross Channel gates must be closed to improve migration of anadromous fish species through the Delta. Additionally, Reclamation procedures call for the gates to be closed when flows in the Sacramento River reach the 20,000 cfs to 25,000 cfs range. For modeling purposes, SacWAM uses a Sacramento River flow threshold of 25,000 cfs for gate closure. The following set of equations are used in SacWAM to disaggregate flows in the Sacramento River into components above and below the flow threshold for gate closure of 25,000 cfs:

Q_SacWG = 25,000 + SAC_above - SAC_below

*SAC_above < int_SAC_above * 999,999*

*SAC_below < 999,999 – int_above * 999,999*

The user-defined integer variable *int_above* can be either zero or one. A value of zero indicates that the Sacramento River flow is below the 25,000 cfs threshold by an amount *SAC_below*. A value of one indicates that the Sacramento River flow is above the threshold by an amount *SAC_above*.

Finally, flow through the Delta Cross Channel is calculated using the following equation:

*Q_DXC = [0.1896*25,000 *(1 - int_above) - 36 *(1 - int_above) - 0.1896*SAC_below] * DXC_fraction*

where:

DXC_fraction = number of days in the month that the DXC is open, expressed as a fraction.

8.7.1 DXC

DXC is a user-defined variable representing flow through the Delta Cross Channel.

8.7.2 DXC Eqn1

The UDC *DXC Eqn1*, in combination with *DXC Eqn 2* and *DXC Eqn 3* calculates the components of the Sacramento River flow at Walnut Grove above and below 25,000 cfs. The flow in the Sacramento River is calculated as the sum of 25,000 cfs and *Sac_above*, less *Sac_below*. Either *Sac_above* or *Sac_below* must be zero.

8.7.3 DXC Eqn2

The UDC *DXC Eqn2*, in combination with *DXC Eqn 1* calculates the flow, if any, of the Sacramento River at Walnut Grove above 25,000 cfs.

8.7.4 DXC Eqn3

The UDC *DXC Eqn3*, in combination with *DXC Eqn 1* calculates the flow, if any, of the Sacramento River at Walnut Grove below 25,000 cfs.

8.7.5 DXC Eqn4

The UDC *DXC Eqn4* determines the flow through the Delta Cross Channel using a linear regression equation. The flow is weighted by the number of days that the gate is open, as determined by *Other\Ops\Delta Channels\DXC\DXC_Standardfraction*. This is further described in Section 7.5.1.4.

8.7.6 GeorgSlough

GeorgSlough is a user-defined variable representing flow through Georgiana Slough.

8.7.7 GeorgSlough Eqn

The UDC *Set GeorgSlough* determines the flow through Georgiana Slough using a linear regression equation. The coefficients in the equation are derived from DSM2 output.

GeorgSlough[CFS] = 0.1415 * QSac_WG[CFS] + 973.48

8.7.8 Int_above

Int_above is a user-defined integer variable that indicates whether flow in the Sacramento River is above or below the threshold of 25,000 cfs.

8.7.9 QSac_WG

QSac_WG is a user-defined variable representing the flow in the Sacramento River at Walnut Grove.

8.7.10 Sac_above

Sac_above is a user-defined variable for the flow in the Sacramento River above the threshold of 25,000 cfs.

8.7.11 Sac_below

Sac_below is a user-defined variable for the flow in the Sacramento River below the threshold of 25,000 cfs.

8.7.12 Set C400

The UDC *QSac_WG* sets the Sacramento River flow at Walnut Grove, *QSac_WG*, to the equivalent flow through the SacWAM schematic.

8.7.13 Set DXC

The UDC *Set DXC* determines the flow through the Delta Cross Channel using a linear regression equation.

8.7.14 Set GeorgSlough

The UDC *Set GeorgSlough* sets the flow through Georgiana Slough, *GeorgSlough*, to the equivalent flow through the SacWAM schematic.

8.8 Delta Export Constraints

The UDCs under *Delta Export Constraints* implement CVP and SWP Delta pumping limits described in Chapter 7. *Delta Export Constraints* work in conjunction with *Split Exports* (see Section 8.35), such that export limits apply only to the portion of water that is pumped directly from the Delta. In the future, exports also may be delivered through tunnels under the Delta as part of the Delta Conveyance Project.

8.8.1 April May Pulse Period

D-1641 restricts export pumping during a 31-day pulse period in April and May depending on flows in the San Joaquin River at Vernalis. During the pulse period, exports may not exceed 1,500 cfs, or 100 percent of the 3-day running average of Vernalis flow, whichever is greater. In SacWAM, the two UDCs *AprilMayPulse_CVP* and *AprilMayPulse_SWP* restrict CVP and SWP exports from the south Delta to be less than this pulse period requirement. Export capacity during the pulse period is initially shared between the two projects according to the 2018 COA Addendum, but subsequently relaxed so one project may take advantage of the other project's unused export share.

8.8.2 Artificial Neural Network

SacWAM implements export-Delta inflow relationships for salinity control using ANN output that is referenced by the following six UDCs: *meetJP*, *meetEM*, *meetCO*, *meetRS1*, *meetRS2*, and *meetRS3*.

These UDCs have the following form:

Qexp < b + m * QSacValley[77]

where:

Qexp = combined flow through Banks and Jones pumping plants

[77] SacWAM uses the variable name *D409* for Delta exports, *C400* for Sacramento River flow, and *C157* for Yolo Bypass flow. These names are derived from the CalSim II model.

QSacValley = combined flow of Sacramento River at Hood and Yolo Bypass at Lisbon Weir

b and m = coefficients determined by the ANN function AnnLineGenArray.

The coefficients b and m are determined separately for each of the four water quality control stations within the Delta — Collinsville, Emmaton, Jersey Point, and Rock Slough. Because of the highly non-linear flow-salinity relationship at Rock Slough, the ANN calculates three separate sets of coefficients that represent a three-piece linearization of the relationship. This results in six separate constraints for *Qexp*, one each for Collinsville, Emmaton, and Jersey Point, and three for Rock Slough.

Five types of Delta conditions may exist, as implied by the coefficients returned by the ANN and the resulting export-inflow relationship required to meet D-1641 water quality standards:

1. Intercept (b) = 0, and slope (m) <= 0.001: Delta salinity is insensitive to Delta exports, salinity control is not possible, therefore, the inflow-export constraint is relaxed, and exports are capped at 1,500 cfs (*export cap*).
2. m < 0: the inflow-export constraint is relaxed, and exports are unconstrained.
3. -b/m < 15,000 cfs (or 12,000 cfs in dry and critical years): the Sacramento Valley inflow to the Delta for salinity control is greater than 15,000 cfs (or 12,000 cfs) for zero exports, therefore, to prevent large storage withdrawals to meet salinity requirements, combined project exports are capped at 1,500 cfs, and the inflow-export constraint is relaxed.
4. m > 1: known as negative carriage water; required Delta outflow for salinity control diminished as exports increase, therefore, exports are unconstrained by salinity control requirements.[78]
5. For all other values of b and m, the export-inflow relationship is enforced in SacWAM.

The implementation of this logic in SacWAM is illustrated with respect to the Emmaton water quality standard. The UDC *meetEM* is as follows:

D409 < EM_c1 * ExportCap + EM_c2 * 999999 + EM_c3 * ExportCap + EM_c4 * 999999

+ EM_c5 * C400 * EM_m + EM_c5 * C157 * EM_m + EM_c5 * EM_b

Delta inflow is the sum of *C400* and *C157*. *D409* is the combined CVP/SWP export. The parameters *EM_c1, EM_c2, EM_c3, EM_c4,* and *EM_c5* are either zero or one depending on Delta conditions. The sum of these parameters is one. The right-hand side of the equation is the upper bound on Delta exports for a given Delta inflow to meet the Emmaton standard.

8.8.3 D-1641 EI Ratio

D-1641 requires Reclamation and DWR to comply with an export limit objective to restrict CVP and SWP export rates from the Delta. The E/I ratio is measured as the average 3-day export rate at the Clifton Court intake and Jones Pumping Plant divided by the estimated average inflow to the Delta over a 3-day

[78] Condition 4 has been removed from the current version of SacWAM.

or 14-day period. In SacWAM, *Delta Exports* are constrained to being less than or equal to *Delta Inflow* multiplied by the export ratio, *EIRatio_Requirement*.

8.8.3.1 Delta Inflow Eqn

Delta Inflow is defined as a user-defined standard LP variable. The UDC *Delta Inflow Eqn* sets *Delta Inflow* to equal the sum of the Sacramento River at Freeport, wastewater discharge from the Sacramento Regional WWTP, San Joaquin River at Vernalis, Calaveras River below New Hogan Dam, Cosumnes River at Michigan Bar, Mokelumne River below Woodbridge, Sacramento Weir spills, Fremont Weir spills, Cache Creek at Rumsey, and South Fork Putah Creek at Interstate 80. This measure of Delta inflow follows that defined in D-1641 (SWRCB, 2000), with the following exceptions:

- SacWAM uses Calaveras River flow below New Hogan Dam rather than flow at Bellota as specified in D-1641.
- SacWAM does not include inflow from miscellaneous streams (Bear Creek, Dry Creek, Stockton Diverting Canal, French Camp Slough, Marsh Creek, and Morrison Creek) as specified in D-1641.

These changes from D-1641 are consistent with how Reclamation and DWR operate the CVP and SWP to meet State Water Board regulatory requirements (Chu, 2016).

8.8.3.2 Available Export

Available Export is a user-defined decision variable representing the available export capacity under D-1641 E/I ratio.

8.8.3.3 AvailableExport Eqn

The UDC *AvailableExport Eqn* sets *Available Export* to the product of the *EIRatio_Requirement* and the *Delta Inflow*.

8.8.3.4 Constraint

The UDC *Constraint* simply assigns through-Delta exports at Banks and Jones pumping plants to the user-defined variable *Export*. The purpose of the UDC is to keep expressions as short as possible.

8.8.3.5 Delta Inflow

Delta Inflow, a user-defined variable, represents the inflow to the Delta as defined by the State Water Board in D-1641.

8.8.3.6 Delta Inflow Eqn

The UDC *Delta Inflow Eqn* calculates the Delta Inflow using the D-1641 definition.

8.8.3.7 EIRatio_ CVP

SacWAM assumes that available export capacity under the E/I requirement is shared between the CVP and SWP according to the 2018 COA Addendum, unless one project is unable to pump its share of export capacity. The UDC *EIRatio_CVP* initially restricts CVP exports to be less than 60% of the available regulatory export capacity. This constraint is relaxed in a later allocation order to allow one project to use the other project’s unused export capacity, if any. As such, this UDC is a priority-based constraint.

8.8.3.8 EIRatio_ SWP

The UDC *EIRatio_SWP* initially restricts SWP exports to be less than 40% of the available regulatory export capacity. This constraint is relaxed in a later allocation order to allow one project to use the other project's unused export capacity, if any. As such, this UDC is a priority-based constraint.

8.8.3.9 EIRatio_Total

The UDC *EIRatio_Total* restricts combined CVP and SWP exports to be less than the regulatory export capacity. This constraint is always maintained.

8.8.3.10 Export

Export is a user-defined variable representing 'through-Delta' export of water at Banks and Jones pumping plants. Although not modeled, it does not include any water diverted north of the Delta as part of the proposed Delta Conveyance Project.

8.8.3.11 Unused EI

Unused EI is a user-defined decision variable representing the available export capacity under the D-1641 E/I requirement that is unused.

8.8.3.12 Unused EI Eqn

The UDC *Unused EI Eqn* sets *Unused EI* equal to the difference between *Available Export* and simulated exports at Banks and Jones pumping plants.

8.8.4 SJR IE Ratio

The NMFS BiOp (2009) established export restrictions to reduce the vulnerability of emigrating Central Valley steelhead within the lower San Joaquin River to entrainment into the channels of the South Delta caused by CVP and SWP export pumping. Under RPA Action IV.2.1, from April 1 to May 31 CVP and SWP exports are restricted to a fraction, expressed as a ratio, of the San Joaquin River flow at Vernalis. The ratio is based on the San Joaquin River index. Details of the pumping restriction are described in Section 7.4.4.

8.8.4.1 IERatio_CVP

The UDC *IERatio_CVP* restricts CVP exports to be less than 60% of the state variable *Other\Ops\ExportOps\SJR_EIRatio\SJ_MaxExp*. This constraint is relaxed in a later allocation order to allow one project to use the other project's unused export capacity, if any. As such, this UDC is a priority-based constraint.

8.8.4.2 IERatio_SWP

The UDC *IERatio_SWP* restricts SWP exports to be less than 40% of the state variable *Other\Ops\ExportOps\SJR_EIRatio\SJ_MaxExp*. This constraint is relaxed in a later allocation order to allow one project to use the other project's unused export capacity, if any. As such, this UDC is a priority-based constraint.

8.8.4.3 IERatio_Total

The UDC *IERatio_Total* restricts the combined CVP and SWP exports to be less than the state variable *Other\Ops\ExportOps\SJR_EIRatio\SJ_MaxExp*. This constraint is always maintained.

8.8.5 Banks Pumping Plant (BanksPP)

8.8.5.1 LimitExports

LimitExports is a user-defined variable representing the water demands below Banks Pumping Plant.

8.8.5.2 DefineLimitExports

The UDC *DefineLimitExports* sets the variable *LimitExports* equal to the smaller of the regulatory/physical capacity of the plant and the downstream demand for water, including the desire to fill San Luis Reservoir to rule curve.

8.8.5.3 SetLimitExports

The UDC *SetLimitExports* constrains the export of SWP water at Banks Pumping Plant to be less than LimitExports. This UDC has been deactivated.

8.8.6 Jones Pumping Plant (JonesPP)

8.8.6.1 LimitExports

LimitExports is a user-defined variable representing the water demands below Jones Pumping Plant.

8.8.6.2 DefineLimitExports

The UDC *DefineLimitExports* sets the variable *LimitExports* equal to the smaller of the regulatory/physical capacity of the plant and the downstream demand for water, including the desire to fill San Luis Reservoir to rule curve.

8.8.6.3 SetLimitExports

The UDC *SetLimitExports* constrains the export of CVP water at Jones Pumping Plant to be less than LimitExports. This UDC has been deactivated.

8.8.7 Delta Cross Channel

Under certain circumstances the Delta Cross Channel may remain open in order to meet the water quality standard at Rock Slough. From October 1 – December 14, if BO requirements call for the gates to be closed, however water quality conditions are a concern and the Delta Cross Channel gates remain open, then Delta exports are limited to 2,000 cfs.

8.8.7.1 DXC_CVP

The UDC *DXC_CVP* restricts CVP exports to be less than 60% of the state variable *Other\Ops\Delta Channels\DXC\NMFS_MaxExp_DCC*. This constraint is relaxed in a later allocation order to allow one project to use the other project's unused export capacity, if any. As such, this UDC is a priority-based constraint.

8.8.7.2 DXC_SWP

The UDC *DXC_SWP* restricts SWP exports to be less than 40% of the state variable *Other\Ops\Delta Channels\DXC\NMFS_MaxExp_DCC*. This constraint is relaxed in a later allocation order to allow one project to use the other project's unused export capacity, if any. As such, this UDC is a priority-based constraint.

8.8.7.3 DXC_Total

The UDC *DXC_Total* restricts the combined CVP and SWP exports to be less than the state variable *Other\Ops\Delta Channels\DXC\NMFS_MaxExp_DCC*. This constraint is always maintained.

8.9 Delta Reverse Flows

The WEAP modeling software does not allow bi-directional flow in rivers. However, there are two channel reaches within the Delta where bi-directional flows need to be simulated. The first channel reach is the combined flow in Old and Middle River, *OMR*,[79] between the intake to the Delta-Mendota Canal/Jones Pumping Plant and the confluence of the Old and Middle River and San Joaquin River. The second channel reach is the lower San Joaquin River downstream from the Old and Middle River confluence and above the Sacramento River confluence.

SacWAM uses two parallel river arcs to represent bi-directional flow and an associated pair of equations to restrict flows so that water can move in only one direction during a single time step. The form of the equations is as follows:

$$Q_{Downstream} < Integer_{ReverseFlow} * 999{,}999$$

$$Q_{Upstream} < 999{,}999 - Integer_{ReverseFlow} * 999{,}999$$

Where $Q_{Downstream}$ is the natural (positive) flow direction, $Q_{Upstream}$ is the reverse flow direction, and $Integer_{ReverseFlow}$ is an integer decision variable that has a value of either 0 or 1. If $Integer_{ReverseFlow}$ equals 0, flow is in the natural direction; reverse flow occurs when $Integer_{ReverseFlow}$ equals 1.

8.9.1 OMR

The user-defined decision variable *OMR Net Flow* represents the net combined flow in the Old and Middle rivers at Bacon Island at the location of the USGS gauges. Net flow is calculated as *OMR Positive Flow* minus *OMR Reverse Flow*. When the integer variable *OMR_Int* has a value of 1, there is no reverse flow. During model testing, the requirement that flow in one of the channels be zero sometimes caused numerical difficulties for the MILP solver. Therefore, these requirements are currently relaxed in SacWAM.

8.9.1.1 OMR Net Flow

OMR Net Flow is a user-defined variable representing the net northward flow in the Old and Middle rivers. The definition allows the variable to be either positive or negative.

8.9.1.2 OMR Positive Flow

OMR Positive Flow is a user-defined variable representing northward flow in the Old and Middle rivers.

8.9.1.3 OMR Positive Flow Eqn

The UDC *OMR Positive Flow Eqn* in conjunction with the UDC *OMR Reverse Flow Eqn* prevents flows in the Old and Middle rivers from having non-zero northward and southward flow components. This UDC has been deactivated.

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[79] SacWAM represents the Old River and Middle River as a single river.

8.9.1.4 OMR Reverse Flow

OMR Reverse Flow is a user-defined variable representing southward flow in the Old and Middle rivers.

8.9.1.5 OMR Reverse Flow Eqn

The UDC *OMR Reverse Flow Eqn* in conjunction with the UDC *OMR Positive Flow Eqn* prevents flows in the Old and Middle rivers from having non-zero northward and southward flow components. This UDC has been deactivated.

8.9.1.6 OMR_Int

OMR_Int is a user-defined integer variable used to prevent flows in the Old and Middle rivers from having non-zero northward and southward flow components. This UDC has been deactivated.

8.9.1.7 Set OMR Net Flow

The UDC *Set OMR Net Flow* determines the net flow in the Old and Middle rivers as the sum of northward and southward flow components.

8.9.1.8 Set OMR Positive Flow

The UDC *Set OMR Positive Flow* equates *OMR Positive Flow* to the corresponding flow in the SacWAM schematic.

8.9.1.9 Set OMR Reverse Flow

The UDC *Set OMR Reverse Flow* equates *OMR Reverse Flow to the corresponding flow in the SacWAM schematic*.

8.9.2 Qwest

Qwest is defined as the net westward flow of the San Joaquin River at Jersey Point averaged over a tidal cycle. Under natural conditions, Qwest is positive. However, under certain tidal, river inflow, and south Delta export conditions, net reverse flows may occur, i.e., the net flow direction is eastward. Negative values of Qwest occur when Delta diversions and agricultural demands in the south and central Delta exceed the inflow into the central Delta. Qwest is typically positive during wetter water years and always positive in the spring. Qwest is typically negative in the summer of drier years. Qwest criteria are not included in the 1995 Bay-Delta Plan (SWRCB, 1995); however, Qwest criteria have previously been considered as a regulatory parameter for protection of central Delta fish.

In SacWAM, *Qwest* reverse flow is represented as an outflow from the Sacramento River upstream from its confluence with the San Joaquin River. SacWAM labels this diversion arc ‘Qeast’ to indicate the flow direction. *Qwest* positive flow is represented as the San Joaquin River below the OMR confluence. During model testing, the requirement that flow in one of the channels be zero sometimes caused numerical difficulties for the MILP solver. Therefore, this requirement is currently relaxed in SacWAM.

8.9.2.1 Qwest

Qwest is a user-defined variable representing positive outflow from the San Joaquin River.

8.9.2.2 QWest Eqn

The UDC *QWest Eqn* uses an integer variable to prevent both westward and eastward flow in the San Joaquin River. This UDC has been deactivated.

8.9.2.3 QWest_Int

Qwest_Int is a user-defined integer variable that is used to prevent *Qwest* and *SanJ* both being positive or non-zero. The variable is no longer used.

8.9.2.4 SanJ

SanJ is a user-defined variable representing positive outflow from the San Joaquin River. The variable is no longer used.

8.9.2.5 SanJ Eqn

The UDC *SanJ Eqn* uses an integer variable to prevent both westward and eastward flow in the San Joaquin River. This UDC has been deactivated.

8.9.2.6 Set SanJ

The UDC *Set SanJ* equates the user-defined variable *SanJ* to the corresponding flow in the SacWAM schematic. This UDC has been deactivated.

8.9.2.7 Set Qwest

The UDC *Set Qwest* equates the user-defined variable *Qwest* to the corresponding flow in the SacWAM schematic.

8.10 Delta Salinity

The purpose of the decision variables and UDCs defined under *Delta Salinity* is to calculate the outflow requirement for salinity control. This requirement is needed for the COA balance as required Delta outflow is part of IBU that the CVP and SWP are jointly obligated to meet. SacWAM contains 12 decision variables and 18 constraints under the *Delta Salinity* branch. For the purposes of documentation, these are described in the following three sections – there are no corresponding branches in the SacWAM data tree.

8.10.1 Compliance Stations

The user-defined decision variables *CO*, *EM*, *JP*, *RS1*, *RS2*, and *RS3* represent the outflow required to meet D-1641 water quality standards at Collinsville, Emmaton, Jersey Point, and Rock Slough.[80] The value of these variables is determined by six UDCs (*setCO, setEM, setJP, setRS1, setRS2*, and *setRS3*) using the ANN export to inflow relationship for water quality compliance and a Delta flow balance.

8.10.2 Delta Flow Balance

The required Delta outflow for salinity control is calculated from a flow balance. Components of this flow balance are as follows:

DeltaExports = Diverted inflow to the California Aqueduct and Delta-Mendota Canal

[80] The D-1641 salinity requirement at Rock Slough is represented using three variables because of piecewise linear approximation of the inflow to export relationship for salinity control.

DeltaFlows = Delta inflow from the San Joaquin River, Littlejohn Creek, Calaveras River, Mokelumne River, Kellogg Creek, and Marsh Creek

MiscFlows = Delta diversions/exports at Barker Slough Pumping Plant, Old River Pipeline intakes on the Old River and Victoria Canal, Contra Costa Canal intake on Rock Slough

Net DICU = Net Delta island consumptive use of net channel depletion

8.10.3 Outflow for Salinity Control

The user-define variable *OutflowRequirement* is the net Delta outflow required for salinity control. It is the maximum of the outflow needed for compliance at the individual stations. This is enforced using a set of seven UDCs (*OR eqn1, OR eqn2, OR eqn3, OR eqn4, OR eqn5, OR eqn6,* and *OR eqn7*). The UDC OR eqn7 has been deactivated.

8.11 Delta SOD Channels

Flow requirements for OMR, first established by USFWS (2008), may limit export pumping from December 15 to June 30.[81] However, SacWAM cannot simulate the tidal hydrodynamics of the south Delta. Instead, the model uses a set of empirical regression equations and a flow balance to determine OMR flows. Hutton (2008a) developed flow relationships for south Delta channels based on the following flow balance:

$$OMR = (SJR_{V} – SJR_{HOR}) + IS_{OR} – CCF – JPP – CCWD - NCD_{SD}$$

where:

SJR_{V} = San Joaquin River at Vernalis

SJR_{HOR} = San Joaquin River downstream from Head of Old River

IS_{OR} = Indian Slough at Old River

CCF = Clifton Court Forebay diversion

JPP = Jones Pumping Plant diversion

CCWD = Contra Costa WD Old and Middle River diversion

NCD_{SD} = Net channel depletion in the South Delta

Assuming: (1) a linear relationship between San Joaquin River flow at Vernalis and the flow at the Head of Old River, and (2) a linear relationship between the flow in Indian Slough and OMR flow, the flow balance can be rewritten as:

[81] Originally, compliance with OMR flow requirements were determined through 5-day and 14-day running averages of tidally filtered daily OMR flow measured by USGS gauges near Bacon Island. Compliance is now met using the OMR index based on Hutton.

$$OMR = a*SJR_v + b*(CCF + JPP + CCWD + NCD_{SD}) + c$$

The values of coefficients a, b, c, as reported by Hutton (2008a), are listed in Table 8-1.

Table 8-1. Coefficients for Old and Middle River Flow Equation

Barriers		San Joaquin River at Vernalis (cfs)	Coefficients		
Head of Old River	Grant-Line Canal		a	b	c
Out	Out	< 16,000	0.471	-0.911	83
Out	Out	16,000 – 28,000	0.681	-0.940	-3008
Out	Out	>28,000	0.633	-0.940	-1644
Out	In	All	0.419	-0.924	-26
In (Spring)	Out/In	All	0.079	-0.940	69
In (Fall)	Out/In	All	0.238	-0.930	-51

8.11.1 Q_IndianSlough

Q_IndianSlough is a user-defined variable that represents flow from the San Joaquin River through Indian Slough to the Old River, at a point south of the OMR flow compliance location.

8.11.2 Q_SOD

Q_SOD is a user-defined variable that represents combined diversions and exports from the south Delta. It may be positive or negative as it includes rainfall runoff in the south Delta.

8.11.3 Set Q_IndianSlough 1

The UDC *SetQ_IndianSlough1* applies the Hutton equation, which is described above, to determine flow through Indian Slough. Flow through the slough is equal to (1+*coefB*)* *Q_SOD*.

8.11.4 Set Q_IndianSlough 2

The UDC *SetQ_IndianSlough2* establishes net flow through Indian Slough as the eastward flow less the westward flow, which are represented in SacWAM by two separate arcs.

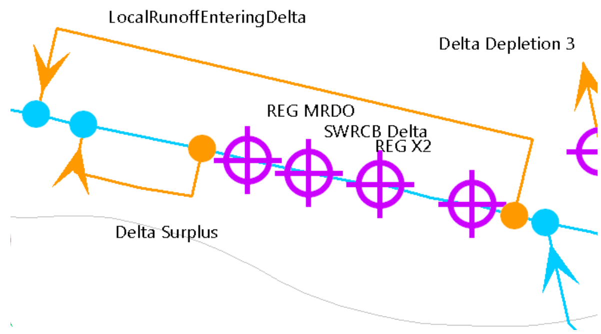
8.11.5 Set Q_SOD

The UDC *SetQ_SOD* sets *Q_SOD* equal to the sum of the headflows in the California Aqueduct and Delta-Mendota Canal, Contra Costa WD diversions at the Old River and Middle River intakes, and south-of-Delta net consumptive use (consumptive use less precipitation).

8.12 Delta Outflow Routing

SacWAM explicitly represents a Delta inflow contribution from runoff that originates from lands adjacent to, but outside of the Delta. This flow component has not traditionally been included in water operations models, such as CalSim II. Additionally, these flows are not part of the D-1641 definition of Delta inflow. In SacWAM, to provide greater consistency with past modeling, these miscellaneous runoff contributions are routed around Delta outflow IFR objects (diversion arc *LocalRunoffEnteringDelta*)

For post-processing purposes, the SacWAM schematic includes a diversion arc *Delta Surplus* that removes and then returns a portion of Delta outflow from the main channel.



8.12.1 RouteAroundCompliance

Miscellaneous runoff terms are represented by *UDC\Delta Salinity\miscFlows1* and *UDC\Delta Salinity\miscFlows2. MiscFlows1* represents runoff from agricultural lands. *MiscFlows2* represents runoff from urban areas south of the American River. The UDC *RouteAroundCompliance* sets the flow in the diversion arc *LocalRunoffEnteringDelta* to equal the sum of *MiscFlows1 and MiscFlows2.*

8.13 El Dorado Irrigation District Project 184 (EID Project 184)

El Dorado ID and Project 184 are described in Section 7.9.4. El Dorado ID diverts water from Folsom Lake under both a CVP water service contract and a Warren Act contract for diversion of its own water right (Permit 21112) water. These diversions are simulated using two separate transmission links from the district's water treatment plant to its El Dorado Hills service area. Water right water is assigned the higher supply preference from October through March. CVP is assigned first preference from April to September. SacWAM tracks the use and remaining supply of both sources.

8.13.1 PermitWater21112

PermitWater21112 is a user-defined decision variable representing the availability of permit water at Folsom Lake.

8.13.2 PermitWaterAvailability

The UDC *PermitWaterAvailability* sets *PermitWater21112* equal to the sum of water available during the period of direct diversion (November through July) and the period of rediversion of storage withdrawals (August through October). The direct diversion is limited to the unimpaired flow at the El Dorado Canal Diversion Dam. Water imported through the Echo Lake conduit may not be rediverted at Folsom Lake.

El Dorado ID Project 184 diversions from Folsom Lake have been reduced to a maximum of 8,500 acre-feet per year to reflect restrictions imposed under the district's 2016 Warren Act contract with Reclamation.

8.13.3 PermitWaterConstraint1

The UDC *PermitWaterConstraint* restricts flows through the water right transmission link from the district's El Dorado Hills WTP to the El Dorado Hills service area to be less than the variable *PermitWater21112*.

8.13.4 PermitWaterConstraint2

The UDC *EID Project 184\PermitWaterConstraint2* limits diversion of Permit 21112 water from Folsom Lake during the period of direct diversion (November through July) to a maximum of 156 cfs.

8.14 Feather River Service Area

Two UDCs relate to operation of canals within the FRSA. These are described in the sections below.

8.14.1 Cox Spill

The Joint Board Canal conveys water from the Thermalito Afterbay to four water districts that collectively are known as the Joint Water District: Biggs-West Gridley WD, Butte WD, Richvale ID, and Sutter Extension WD. Excess water in the Joint Board Canal is spilled back to the Feather River through a wasteway known as the Cox Spill. Based on an analysis of canal data from 2000 to 2009 (NCWA, 2014), Cox Spill flows are set equal to 1.5 percent of the Joint Board Canal diverted inflow (UDC *Cox Spill*). This is equivalent to approximately 9 TAF/year.

8.14.2 Western Canal Outflow

Based on a 1922 agreement, Western Canal WD supplies water to managed wetlands located in the Butte Sink. After September drainage of rice fields, up to 200 cfs of water is released from the Western Canal to Butte Creek to achieve a flow rate at Sanborn Slough of 250 cfs. From 2000 to 2009, these releases averaged approximately 14 TAF/year.

In SacWAM, the desired Western Canal release is defined by the state variable *Western Canal Outflow*. When the flow in Butte Creek near Chico (USGS gauge 11390000) is less than 15 TAF/month, *Western Canal Outflow* is set to 40 cfs in September, to 140 cfs in October, and to 30 cfs in November. In all other months, the release is set to zero. These flow objectives are imposed by the UDC *Western Canal Outflow* constraint. The release requirements to Butte Creek are modeled using a UDC rather than using WEAP's flow requirement object, in order to limit flows to Butte Creek to the desired target.

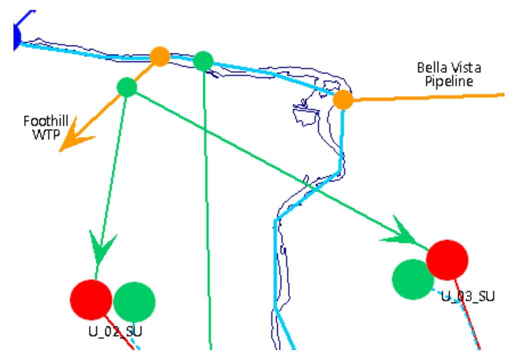
8.14.3 Shared Water Supply

The major agricultural water users in the Feather River Service Area comprise five districts that divert water from the Thermalito Afterbay: Western Canal WD, Richvale ID, Biggs-West Gridley WD, Butte WD, and Sutter Extension WD. Each of these districts holds water rights to the Feather River and have signed settlement agreements with DWR relating to water supplies from the Afterbay. SacWAM assumes that water is transferred between districts so as to meet each district's water demands while complying with the total available water under the settlement agreements.

The UDC *Shared Water Supply* restricts total diversions from the Thermalito Afterbay to be less than the sum of water available under the districts' settlement agreements.

8.15 Fix Leaks

WEAP diversion arcs are used in SacWAM to represent canals, channels, and pipelines that deliver water from a stream or river to a demand site or catchment object. For example, the *Foothill WTP* arc and associated transmission links connect the Sacramento River to demand sites U_02_SU and U_03_SU, which represent the City of Redding on the west and east banks of the Sacramento River. In certain high flow situations, SacWAM may wish to remove water from the system by diverting water in excess of demand through the *Foothill WTP* arc and out of the model domain.



SacWAM uses 16 UDCs to prevent outflow from the model domain through the following diversion arcs: *Bella Vista* (Pipeline), *CA East and West Branch*, *CA Joint Reach*, *CVP San Luis*, *DMC*, *El Dorado Hills WTP, Foothill WTP*, *GCC* (Glenn-Colusa Canal), *Joint Board Canal*, *Miners Ranch Canal*, *NBA* (North Bay Aqueduct), *Old River Pipeline*, *Richvale Canal*, *SBA* (South Bay Aqueduct), *SWP San Luis*, and *TCC* (Tehama-Colusa Canal). In this manner, excess water flows to the Delta and leaves the model domain as surplus Delta outflow. Additionally, all diversion arc outflows are summed and set equal to the decision variable *CanalOutflows*. Subsequently, the UDC *Fix Leaks\StopOutflows* sets *CanalOutflows* to zero.

8.15.1 Bella Vista

The UDC *Bella Vista* sets outflow from the Bella Vista Pipeline to zero.

8.15.2 CA East and West Branch

The UDC *CA East and West Branch* ets outflow from the East and West Branches of the California Aqueduct to zero.

8.15.3 CA Joint Reach

The UDC *CA Joint Reach* sets outflow from the Joint Reach of the California Aqueduct to zero.

8.15.4 CaminoConduit

The UDC *CaminoConduit* sets outflow from the Camino Conduit to zero.

8.15.5 CanalOutflows

CanalOutflows is a user-defined variable that represents the sum of outflow from various canals.

8.15.6 CVP San Luis

The UDC *CVP San Luis* sets outflow from the artificial river, which is the location of CVP San Luis Reservoir, to zero.

8.15.7 DMC

The UDC *DMC* sets outflow from the Delta-Mendota Canal to be less than the CVP water demands at the Mendota Pool and Sack Dam. This UDC has been deactivated.

8.15.8 El Dorado Hills WTP

The UDC *El Dorado Hills WTP* sets outflow from the conveyance to the El Dorado WTP, downstream of this plant, to zero.

8.15.9 Electra Tunnel

The UDC *Electra Tunnel* sets outflow from the Electra Tunnel to zero.

8.15.10 Foothill WTP

The UDC *Foothill WTP* sets outflow from the conveyance to the Foothill WTP, downstream of this plant, to zero.

8.15.11 GCC

The UDC *GCC* sets outflow from the Glenn-Colusa Canal to zero.

8.15.12 Joint Board Canal

The UDC *Joint Board Canal* sets outflow from the Joint Board Canal to zero.

8.15.13 Miners Ranch Canal

The UDC *Miners Ranch Canal* outflow from the Miners Ranch Canal to zero.

8.15.14 NBA

The UDC *NBA* sets outflow from the North Bay Aqueduct to zero.

8.15.15 Old River Pipeline

The UDC *Old River Pipeline* sets outflow from the Old River Pipeline to zero.

8.15.16 Putah South Canal

The UDC *Putah South Canal* sets outflow from the Putah South Canal to zero.

8.15.17 Richvale Canal

The UDC *Richvale Canal* sets outflow from the Richvale Canal to zero.

8.15.18 SBA

The UDC *SBA* sets outflow from the Bella Vista Pipeline to zero. This UDC is currently not active.

8.15.19 StopOutflows

The UDC *StopOutflows* sets the variable *CanalOutflows* to zero.

8.15.20 SumCanalOutflows

A user-defined variable that sets the variable *CanalOutflows* to the sum of outflow from many canals.

8.15.21 SWP San Luis

The UDC *SWP San Luis* sets outflow from the artificial river, which is the location of CVP San Luis Reservoir, to zero.

8.15.22 TCC

The UDC *TCC* sets outflow from the Tehama-Colusa Canal to zero.

8.15.23 YCWA

The UDC *YCWA* sets outflow from the North Yuba Canal, South Yuba Canal, and Browns Valley ID Pumpline Facility to zero.

8.16 Freeport Regional Water Project

EBMUD built the Freeport Regional Water Project in partnership with Sacramento County WA. The project enables EBMUD to take delivery of CVP water to meet a portion of its drought year water demands. The CVP contract allows EBMUD to divert up to 133,000 acre-feet of American River water each year with a total not to exceed 165,000 acre-feet in three consecutive years. This diversion is permitted only in years when EBMUD's total system carryover storage is forecast to be less than 500,000 acre-feet. The maximum diversion rate is 100 mgd.

8.16.1 Freeport_EBMUD

The UDC *Freeport_EBMUD* limits EBMUD’s use of Freeport to the user-defined variable *FPT_Diversion* as described in Chapter 7.

8.16.2 NoSupplyFromFolsom

The UDC *NoSupplyFromAmerican* prevents American River water that is diverted into the Folsom South Canal at Lake Natoma subsequently being delivered to EBMUD.

8.17 Glenn-Colusa ID

A single UDC is located under this branch.

8.17.1 GCC_Transfers

Glenn-Colusa ID sells district water to the Colusa Basin Drain water users. In SacWAM, these users are represented by demand unit A_08_PA. Water sales are delivered from the Glenn-Colusa Canal. The UDC *GCC_Transfers* limits the sale of water to that available to Glenn-Colusa ID under the district's water rights and CVP contract, less the amount of water delivered to district farmers.

8.18 Knights Landing Ridge Cut

The Knights Landing Ridge Cut (Ridge Cut) was constructed to provide an outlet from the Colusa Basin when high Sacramento River stage prevents discharge of excess water through the Knights Landing Outfall Gates. The Ridge Cut, which passes through the Knights Landing Ridge, consists of two dredged channels with a center island. The Ridge Cut has a total width of approximately 400 feet, and a capacity of 15,000 to 20,000 cfs. Floodwater, which would otherwise have ponded between the back levee along the east side of Colusa Basin Drain and higher ground to the west, flows through the Ridge Cut into the Yolo Bypass. The Ridge Cut also provides irrigation water during the summer months. Flows through the Ridge Cut are ungauged; however, DWR estimates flows based on the stage at the Knights Landing Outfall Gates. During the summer, water levels in the Ridge Cut were controlled by a temporary weir at the southern end of the channel to facilitate irrigation diversions. In 2016, as part of the Wallace Weir Fish Rescue Project, the temporary weir was replaced by a permanent structure.

SacWAM defines the LP variables *CBD* and *KRLC* to represent outflow from the drain to the Sacramento River and flow through the Ridge Cut, respectively. The user-defined decision variable *QSac* represents flow in the Sacramento River below Wilkins Slough at the Navigation Control Point. This flow is divided into two components, *QSac_0* and *QSac_1*, which represent flow up to a 15,000 cfs threshold and the flow above this threshold. SacWAM uses an integer variable, *Int_KLRC*, and a set of equations to divide the flows, as follows:

$$Q_{Sac\_0} <= 15{,}000 - Int\_KLRC * 15{,}000$$

$$Q_{Sac\_1} <= Int\_KLRC * 999{,}999$$

$$Q_{Sac} = Q_{Sac\_0} + Q_{Sac\_1} + 15{,}000 * Int\_KLRC$$

Outflow through the Colusa Basin Drain to the Sacramento River is restricted when flows in the Sacramento River exceed 15,000 cfs.

$$CBD < 999{,}999 - Int\_KLRC * 999{,}999$$

The historical flow through the Ridge Cut is stored in a csv file and assigned to the state variable *KLRCmax*. Under normal non-flood operations, flow through the Ridge Cut is unconstrained and the model selects the preferred path to route water. This may result in an incorrect balance between flows through the Ridge Cut and discharge through the Knights Landing Outfall Gates to the Sacramento River. Originally, flow through the Ridge Cut outside periods of high Sacramento River stage was limited to the historical flow, using the UDC *KLRC Eqn*. However, this approach was later abandoned.

8.18.1 CBD

CBD is a user-defined variable that represents the outflow from the Colusa Basin Drain through the Knights Landing Outfall Gates to the Sacramento River.

8.18.2 CBD Eqn

The UDC *CBD Eqn* closes the outflow from the Colusa Basin Drain to the Sacramento River when the integer *Int_KLRC* takes a value of 1.

8.18.3 CBD Outflow

The UDC *CBD Outflow* has been deactivated.

8.18.4 Int_KLRC

Int_KLRC is a user-defined integer variable that represents the outflow from the Colusa Basin Drain through the Knights Landing Ridge Cut to the Sacramento River.

8.18.5 KLRC

KLRC is a user-defined variable that represents the outflow from the Colusa Basin Drain through the Knights Landing Ridge Cut to the Sacramento River.

8.18.6 KLRC Eqn

The UDC *KLRC Eqn* has been deactivated.

8.18.7 KLRCmax

8.18.8 QSac

QSac is a user-defined variable that represents the flow in the Sacramento River above the Colusa Basin Drain outfall.

8.18.9 QSac Eqn1

The UDC *QSac Eqn 1* forces *QSac_0* to be zero if the Saramento River flow is greater than the 15,000 cfs threshold.

8.18.10 QSac Eqn2

The UDC *QSac Eqn 2* forces *QSac_1* to be zero if the Saramento River flow is less than the 15,000 cfs threshold.

8.18.11 QSac Surplus Flow

The UDC *QSac Surplus Flow* sets the Saramento River flow above the Colusa Basin Drain outfall to be equal to the sum *QSac_0 + QSac_1 + 15,000 cfs*.

8.18.12 QSac_0

QSac_0 is a user-defined variable that represents the portion of flow in the Sacramento River above the Colusa Basin Drain outfall that is below a threshold of 15,000 cfs.

8.18.13 QSac_1

QSac_1 is a user-defined variable that represents the portion of flow in the Sacramento River above the Colusa Basin Drain outfall that is in excess of 15,000 cfs.

8.18.14 Set CBD

The UDC *Set CBD* equates the variable *CBD* to the corresponding flow in the SacWAM schematic.

8.18.15 Set KLRC

The UDC *Set KLRC* equates the variable *KLRC* to the corresponding flow in the SacWAM schematic.

8.18.16 set KLRCmax

The UDC *Set KLRCmax* equates the variable *KLRCmax* to the flow read in the file Data\Param\SACVAL_KLRCmax.csv.

8.18.17 Set QSac

The UDC *Set QSac* equates the variable *QSac* to the corresponding flow in the SacWAM schematic.

8.19 Minimum Groundwater Pumping

Typically, SacWAM DUs are supplied with a mix of surface water and groundwater. Surface water is usually assigned the first supply preference and groundwater assigned the second supply preference. In the model, a minimum groundwater pumping fraction acts as a surrogate for representing those lands within the demand unit that are dependent on groundwater, i.e., not having access to surface water. The fraction is calculated from DWR's county land use surveys in which each agricultural parcel is assigned a source of water: surface water, groundwater, or mixed. The fraction is set equal to the area of lands supplied only by groundwater divided by the total area of irrigated lands. Applied water demands in excess of minimum groundwater pumping are met from surface water supplies and subsequently additional groundwater pumping, if necessary.

In cases where SacWAM DUs are supplied from a single surface water transmission link, surface water deliveries are constrained using the WEAP transmission link property *Maximum Flow Percent of Demand.* This property is set equal to (1-minimum groundwater pumping factor). In cases where a demand unit is supplied from multiple surface water transmission links, the constraint on surface water use must be imposed using a UDC. The form of the UDC is as follows:

> ∑(Flow through transmission links) < (1-minimum groundwater pumping factor) * supply requirement
>
> The minimum groundwater pumping factors and supply requirements for each DU are listed under *Demand Sites and Catchments**[DU name*].

8.19.1 MinGW_02_NA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 02_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.2 MinGW_03_NA

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 03_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.3 MinGW_04_06_NA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 04_06_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.4 MinGW_04_06_PA3

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 04_06_PA3 and (1 – the minimum groundwater pumping factor) for the DU. This UDC is not active.

8.19.5 MinGW_05_NA

The sum of flows through four surface water transmission links must be less than the product of the supply requirement for DU 05_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.6 MinGW_08_PA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 08_PA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.7 MinGW_08_PR

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 08_PR and (1 – the minimum groundwater pumping factor) for the DU.

8.19.8 MinGW_08_SA1

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 08_SA1 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.9 MInGW_08_SA2

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 08_SA2 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.10 MinGW_08_SA3

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 08_SA3 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.11 MinGW_09_NA

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 09_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.12 MinGW_09_SA1

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 09_SA1 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.13 MinGW_09_SA2

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 09_SA2 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.14 MinGW_10_NA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 10_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.15 MinGW_11_PR

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 11_PR and (1 – the minimum groundwater pumping factor) for the DU.

8.19.16 MinGW_11_SA4

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 11_SA4 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.17 MinGW_12_13_NA

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 12_13_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.18 MinGW_14_15N_NA3

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 14_15N_NA3 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.19 MinGW_15S_SA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 15S_SA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.20 MinGW_16_SA

The sum of flows through four surface water transmission links must be less than the product of the supply requirement for DU 16_SA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.21 MinGW_17_PR2

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 17_PR2 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.22 MinGW_18_19_NA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 18_19_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.23 MinGW_18_19_SA

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 18_19_SA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.24 MinGW_21_SA

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 21_SA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.25 MinGW_22_SA1

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 22_SA1 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.26 MinGW_23_NA

The sum of flows through two surface water transmission links must be less than the product of the supply requirement for DU 23_NA and (1 – the minimum groundwater pumping factor) for the DU.

8.19.27 MinGW_24_NA1

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 24_NA1 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.28 MinGW_24_NA3

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 24_NA3 and (1 – the minimum groundwater pumping factor) for the DU.

8.19.29 MinGW_60S_PA

The sum of flows through three surface water transmission links must be less than the product of the supply requirement for DU 60S_PA and (1 – the minimum groundwater pumping factor) for the DU.

8.20 MFMSFolsom Max Release

8.20.1 Int_MaxReleaseCtrl

Int_maxReleaseCtrl is a user-defined integer variable. It is no longer used in SacWAM.

8.20.2 FolsomExcessRelease

FolsomExcessRelease is a user-defined variable that may be positive or negative.

8.20.3 MaxRelease

The UDC *MaxRelease* constrains the release from Folsom Lake to be less than *Other\Ops\Flow Requirements\American\FMS\Folsom_max_release*. This UDC has been deactivated.

8.20.4 Set FolsomExcessRelease

The UDC *Set FolsomExcessRelease* is the difference between the simulated release from Folsom Lake and Other\Ops\Flow Requirements\American\FMS\MFMS Max Release\Folsom_max_release.

8.21 Mokelumne

The Mokelumne Branch of SacWAM’s User-Defined Constraints imposes: (1) requirements on Pardee and Camanche reservoir storage to meet flood control; and (2) restrictions on lower Mokelumne River diversions when inflows to Pardee Reservoir are less than required releases for State Water Board proposed flow requirements immediately upstream from the Cosumnes River confluence.

8.21.1 Flood Control

Pardee and Camanche reservoirs are owned and operated by EBMUD to meet flood control requirements specified in the USACE flood-control manual. These requirements are in place from September 15 to August 1 of the following year. During this period, required flood space is divided into a rain-flood reservation and a snowmelt flood reservation. The maximum flood control space is 200,000 acre-feet, with a minimum of 130,000 acre-feet of space to be provided in Pardee and Camanche reservoirs. Up to 70,000 acre-feet may be provided by available space in PG&E's Salt Spring and Lower Bear reservoirs, which are located in the upper watershed.

The UDC *FloodControl* requires that the difference between combined Pardee and Camanche storage capacity and the volume in storage be greater than the flood space requirement as calculated by the state variable *Other\Ops\Mokelumne\FloodSpaceRequirement*.

8.21.2 Lower Mokelumne River Diversions

The purpose of the following decision variables and constraints was to share the burden of proposed State Water Board instream flow requirements among EBMUD and the lower Mokelumne River diverters. The constraints were imposed in months when EBMUD has declared deficiencies in deliveries to its customers. This approach is no longer used in SacWAM and all associated decision variables, and UDCs have been deactivated.

8.21.2.1 AvailableWater

The user-defined LP variable *AvailableWater* is an estimate of the water supply available to lower Mokelumne River diverters. It may be either positive or negative. This variable is defined so that it may be either positive or negative in value. A negative value indicates that the required release from Camanche Dam to meet the proposed State Water Board flow requirement is greater than the inflow to Pardee Reservoir.

8.21.2.2 AvailableWaterNeg

AvailableWaterNeg is a user-defined standard LP variable representing the negative part of *AvailableWater.*

8.21.2.3 AvailableWaterPos

AvailableWaterPos is a user-defined standard LP variable representing the positive part of *AvailableWater.*

8.21.2.4 Define AW Parts

The UDC *Define AW Parts* divides the variable *AvailableWater* in to positive and negative components.

8.21.2.5 Define AWN

The UDCs *Define AWN* and *Define AWP* prevent *AvailableWater* from having both positive and negative components.

8.21.2.6 Define AWP

The UDCs *Define AWN* and *Define AWP* prevent *AvailableWater* from having both positive and negative components.

8.21.2.7 DefineLowerMokelumneDiversions
The UDC *DefineLowerMokelumneDiversions sets the variable LowerMokelumneDiversions equal to the total river diversion below Camanche Dam.*

8.21.2.8 LowerMokelumneDiversions
LowerMokelumneDiversions is a user-defined LP variable that represents the combined diversion from the lower Mokelumne River below Camanche Dam.

8.21.2.9 Mok_Int
Mok_Int is a user-defined integer variable that can have a value of zero or one. It is used to prevent *AvailableWater* having both negative and positive components.

8.21.2.10 AvailableWaterPos and AvailableWaterNeg
Used in conjunction with the integer variable *Mok_Int*, the two UDCs *AvailableWaterPos* and *AvailableWaterNeg* prevent *AvailableWater* having both negative (*AWN*) and positive (*AWP*) components.

8.21.2.11 Define AvailableWater
The UDC *Define AvailableWater* sets *AvailableWater* equal to an estimate of the current month's water supply in years when EBMUD has imposed a delivery deficiency on its customers (i.e., Local Projects\Mokelumne\EBMUD Deficiency\DroughtTrigger =1). This estimate is equal to the current month inflow to Pardee Reservoir less the Camanche Dam release to meet the State Water Board proposed instream flow requirement immediately upstream from the Cosumnes River confluence (under the 'Existing' simulation, this flow requirement is zero). The required Camanche Dam release accounts for seepage losses from the lower Mokelumne River. In months when no EBMUD deficiency has been declared, *AvailableWater* is set equal to a large number.

8.21.2.12 LowerMokelumneDiversions
The user-define variable *LowerMokelumneDiversions* is the total diversion from the lower Mokelumne River below Camanche Dam. This includes diversions by North San Joaquin WCD, by Woodbridge ID for irrigation purposes and their water sales to the City of Lodi and the City of Stockton, and riparian diversions.

8.21.2.13 Define LowerMokelumneDiversions
The UDC *Define LowerMokelumneDiversions* sets *LowerMokelumneDiversions* equal to the sum of flows through the transmission links from the lower Mokelumne River to demand sites (cities of Galt and Stockton) and catchment objects (North San Joaquin WCD, Woodbridge ID, riparian diverters).

8.21.2.14 RestrictLowerMokelumneDiversions
The UDC *RestrictLowerMokelumneDiversions* limits the total diversions from the lower Mokelumne River to be less than the positive value of *AvailableWater* (i.e., *AWP*).

8.21.2.15 PGEStorage
The UDC *PGEStorage* sets PG&E storage equal to the combined water stored in Salt Springs and Lower Bear Reservoir.

8.22 Nevada ID

Nevada ID's Yuba-Bear Project is described in Section 7.9.8. The model tracks and differentiates between Nevada ID and PG&E water. It is assumed that Nevada ID does not purchase any PG&E water at the Deer Creek Powerhouse. It is also assumed that the district does not purchase PG&E water at Rollins Reservoir. In SacWAM, purchases of PG&E water by Nevada ID are limited to buying points along the Wise Canal.

8.22.1 BelowBRC_NID

BelowBRC_NID is a decision variable representing the portion of water in the Bear River below the Bear River Diversion Dam that is Nevada ID water.

8.22.2 BelowBRC_NID_Min

The UDC *BelowBRC_NID_constrain* requires that the 1963 FERC flow requirement below the Bear River Canal Diversion Dam be met using Nevada ID water. However, this UDC has been commented out as it may cause an infeasibility in cases of water shortage.

8.22.3 BelowBRC_PGE

BelowBRC_PGE is a decision variable representing the portion of water in the Bear River below the Bear River Diversion Dam that is PG&E water. Under the 1963 Consolidated Contract, this is treated as abandoned water that is available to Nevada ID.

8.22.4 BelowBRC_Split

The UDC *BelowBRC_Split* divides the total flow below the Bear River Canal Diversion Dam between Nevada ID (*BelowBRC_NID*) and PG&E (*BelowBRC_PGE*).

8.22.5 BRC_NID

BRC_NID is a decision variable representing the portion of water in the head of the Bear River Canal that is Nevada ID water.

8.22.6 BRC_NID_Max

The UDC *BRC_NID_Max* constrains wheeling of Nevada ID water through the Bear River Canal to be less than 120 cfs.

8.22.7 BRC_NID_Routing

The UDC *BRC_NID_Routing* routes water through a parallel of arc of a bifurcation of the Bear River Canal for output purposes.

8.22.8 BRC_PGE

BRC_PGE is a decision variable representing the portion of water in the head of the Bear River Canal that is PG&E water.

8.22.9 BRC_PGE_Split

The UDC *BRC_PGE_Split* divides PG&E water in the Bear River Canal amongst sale to Nevada ID (*BRC_PGE_ToNID*), sale to Placer County WA (*BRC_PGE_ToPCWA*), sale to other entities (*BRC_PGE_ToOther*), canal conveyance losses (assumed to be 6.9% of the headflow), and flow through the Newcastle Powerhouse (including required upstream discharge to the Mormon Ravine).

8.22.10 BRC_PGE_ToNID

BRC_PGE_ToNID is a decision variable representing the sale of PG&E water that has been diverted into the Bear River Canal to Nevada ID.

8.22.11 BRC_PGE_ToOther

BRC_PGE_ToOther is a decision variable representing sale of PG&E water to entities other than Nevada ID and Placer County WA. In the past, PG&E has sold water to South Sutter WD. Currently, SacWAM limits PG&E sale of Drum-Spaulding water to Nevada ID and Placer County WA.

8.22.12 BRC_PGE_ToPCWA

BRC_PGE_ToPCWA is a decision variable representing sale of PG&E water to Placer County WA for use in that agency's Zone 1 and Zone 5 – it does not include sale of PG&E water at the head of the lower Boardman Canal for use in Zone 3.

8.22.13 BRC_Split

The UDC *BRC_Split* divides the total flow in the head of the Bear River Canal between Nevada ID (*BRC_NID*) and PG&E (*BRC_PGE*).

8.22.14 BRC_ToNID

BRC_ToNID is a decision variable representing deliveries from the Bear River Canal to Nevada ID. It consists of both Nevada ID water and PG&E water.

8.22.15 BRC_ToNID_constrain

The UDC *BRC_ToNID_constrain* sets deliveries from the Bear River Canal to Nevada ID as the sum of deliveries from the Wise Canal to North Auburn (part of U_24_NU1) and Nevada ID agricultural water users (A_24_NA1) and deliveries to the latter conveyed through Auburn Ravine.

8.22.16 BRC_ToNID_Split

The UDC *BRC_ToNID_Split* sets the total Bear River Canal deliveries to Nevada ID (*BRC_ToNID*) equal to the sum of Nevada ID water (*BRC_NID*) excluding the district's share of conveyance losses, and deliveries of PG&E water (*BRC_PGE_ToNID*).

8.22.17 DeerCreekPowerhouse1

The UDC *DeerCreekPowerhouse1* limits flow at the head of the Chalk Bluff Canal, which leads to PG&E's Deer Creek Powerhouse, to be less than delivery of Nevada ID water to Lake Spaulding through the Bowman-Spaulding Conduit. It is assumed that Nevada ID does not purchase PG&E water to support Deer Creek operations. Historically, Nevada ID purchase of PG&E water for the district's Deer Creek system has been very limited. The water accounting between Nevada ID and PG&E assumes a 12.5 percent conveyance loss along the Chalk Bluff Canal, which is simulated in SacWAM. Therefore, this constraint is equivalent to restricting flow through the Deer Creek Powerhouse to be less than 87.5% of the inflow to Lake Spaulding from the Bowman-Spaulding Conduit.

8.22.18 DeerCreekPowerhouse2

The UDC *DeerCreekPowerhouse2* limits flow through the Deer Creek Powerhouse to be less than the variable *Other\Ops\Local Projects\Nevada ID YubaBear Project\DeerCreekPHMaxFlows* (see Section 7.9.8.4).

8.22.19 NIDRollinsWater

NIDRollinsWater is a decision variable representing the portion of releases from Rollins Dam that is Nevada ID water.

8.22.20 NIDRollinsWater_constrain1

The UDC *NIDRollinsWater_constrain1* sets the variable *NIDRollinsWater* to equal the sum of the following components: (1) flows through the Bowman-Spaulding Conduit less flows through the Deer Creek Powerhouse, less conveyance losses along the Chalk Bluff Canal (assumed to be 12.5%), less a conveyance loss of 7.8%; (2) natural inflow to the Bear River above Rollins Dam over and above 350 cfs; (3) storage withdrawals from Rollins Reservoir; and (4) less Rollins Reservoir evaporation.

8.22.21 NIDRollinsWater_constrain2

The UDC *NIDRollinsWater_constrain2* sets the variable *NIDRollinsWater* equal to the sum of Nevada ID water in the Bear River Canal (*BRC_NID*) and Nevada ID water that remains in the Bear River below the diversion dam (*BelowBRC_NID*).

8.22.22 JacksonRelease

California Department of Fish and Wildlife requirements limit changes in regulated flow below Jackson Meadows Reservoir. Nevada ID is allowed to increased reservoir releases twice and decrease reservoir releases twice per year, excluding spills. The first increase occurs at the tail end of the spring runoff in April or May. Nevada ID keeps the second allowed increase in reserve. The first decrease occurs mid-September, down to 80-110 cfs. The second decrease occurs in mid-December, down to 10 cfs. The UDC *JacksonRelease* attempts to mimic these regulatory restrictions on reservoir releases. However, the UDC has been temporarily deactivated as it causes infeasibilities in some months and needs to be further refined in the future.

8.23 North Bay Aqueduct

Water pumped from the Barker Slough Pumping Plant into the North Bay Aqueduct is a mix of SWP contract water and water right water. Tracking of the different types of water (Table A Water, Article 21 Water, Vallejo Permit Water, and Settlement Water) is implemented by dividing urban water demands between two demand sites and by using multiple transmission links to a single demand site; one transmission link for each type of water. Simulation of Permit Water and Settlement Water are described in the sections below.

8.23.1 SettlementWater

In 1998, the Cities of Benicia, Fairfield, and Vacaville filed applications with the State Water Board to appropriate a total of 31,620 acre-feet. This water would be wheeled through North Bay Aqueduct facilities. DWR, City of Vallejo, and others protested these applications. In a subsequent settlement agreement between DWR, Solano County WA, and the three applicants, DWR agreed to deliver up to 31,620 acre-feet to the applicants. This water, known as ‘settlement water,’ is not available when State Water Board Term 91 is in effect.

8.23.1.1 Benicia

Demand unit U_BNCIA_SU represents the City of Fairfield’s demand for setttlement water. Demand unit U_BNCIA_PU represents the City of Benicia’s total water demand, but this DU is only supplied by project water. The UDC *Benicia* restricts the delivery of Settlement Water to U_BNCIA_SU to be less than the unmet demand after delivery of all other types of water to U_FRFLD_PU, which are delivered first.

8.23.1.2 Fairfield

Demand unit U_FRFLD_SU represents the City of Fairfield’s demand for setttlement water. Demand unit U_FRFLD_PU represents the City of Faifield’s total water demand, but this DU is only supplied by project water. The UDC *Fairfield* restricts the delivery of Settlement Water to U_FRFLD_SU to be less than the unmet demand after delivery of all other types of water to U_FRFLD_PU, which are delivered first.

8.23.1.3 Vacaville

Demand unit U_20_25_SU represents the City of Fairfield’s demand for setttlement water. Demand unit U_20_25_PU represents the City of Faifield’s total water demand, but this DU is only supplied by project water. The UDC *Vacaville* restricts the delivery of Settlement Water to U_20_25_SU to be less than the unmet demand after delivery of all other types of water to U_20_25_PU, which are delivered first.

8.23.2 VallejoPermitWater

The City of Vallejo holds a water right (Permit 8993) issued in 1948 for the diversion of up to 31.52 cfs year-round from Cache Slough, primarily for M&I purposes. This is equivalent to a maximum of 22,780 acre-feet per year. However, through contracts and agreements, DWR has limited the annual amount of permit water to 17,287 acre-feet. Permit water is senior to SWP water rights and is not subject to Term 91 curtailments.

8.23.2.1 AnnualVolumeConstraint

SacWAM tracks the use of permit water. The UDC *AnnualVolumeConstraint* sets the delivery of Vallejo Permit Water in any month to be less than the remaining amount (*VPWRemainingTotal*) of the beginning-of-year volume of 22,780 acre-feet. This constraint has been deactivated because it is never limiting.

8.23.2.2 FlowConstraint

The UDC *FlowConstraint* sets the total delivery of Vallejo Permit Water in any month to be less than 31.52 cfs. Deliveries include those to the Cities of Vallejo (U_VLLJO_PU), Fairfield (U_FRFLD_PU), Vacaville (U_20_25_PU), and Benicia (U_BNCIA_PU), and Napa County WA (U_NAPA_PU).

8.24 OMR BO Actions

8.24.1 OMRReverseFlow

The UDC *OMR Reverse Flow* restricts the reverse flow (i.e., from North to South) to be less than the state variable *Other\OMR and Health and Safety\Q_OMR_ReverseBound*. This is further described in Section 7.4.4.6.

8.25 Oroville Fall Operations

In SacWAM, October and November simulated flows in the Feather River high-flow channel (i.e., downstream from the Thermalito Afterbay release to the river) are constrained to be less than 4,000 cfs in October and 2,500 cfs in November, except when Oroville is spilling. This is an operational constraint in place to prevent triggering increased November to March flow requirements under the 1983 MOU between DWR and CDFW (formerly California Department of Fish and Game). Section 7.7.5 provides a more detailed description of this operation.

The maximum Feather River flow not to trigger CDFW requirements is given in *Other\Ops\Flow Requirements\Feather\Fall based HFC minflow\HighFlow Channel max.* From July through September, this variable has a value of 10,000 cfs, in October and November values are 4,000 cfs and 2,500 cfs, respectively. In all other months, the variable has a value of 100,000 cfs.

8.25.1 HFC Flow

The decision variable *HFC flow* is the flow in the Feather River High Flow Channel (HFC).

8.25.2 HFC Set

The UDC *HFC set* constrains HFC flow to equal the Feather River flow below the Sunset Pumps diversion.[82]

8.25.3 intOroFloodRelease

The integer variable *intOroFloodRelease* is used to indicate whether Oroville is spilling.

8.25.4 Set1_intOroFloodRelease

A pair (see section below) of UDCs establishes the value of *intOroFloodRelease*. The integer has a value of 0 when storage in Lake Oroville is less than 1 TAF below the bottom of the flood control space (*set1_IntOroFloodRelease*). Otherwise, the integer is assigned a value of 1 (*set2_IntOroFloodRelease*).

8.25.5 Set2_intOroFloodRelease

A pair (see section above) of UDCs establishes the value of *intOroFloodRelease*. The integer has a value of 0 when storage in Lake Oroville is less than 1 TAF below the bottom of the flood control space (*set1_IntOroFloodRelease*). Otherwise, the integer is assigned a value of 1 (*set2_IntOroFloodRelease*).

8.25.6 Fall Release Constraint

The UDC *Fall release constraint* requires *HFC flow* to be less than *HighFlowChannel max* when *intOroFloodRelease* has a value of 1.

8.26 Placer County Water Agency Middle Fork Project (PCWA MFP)

Placer County WA's Middle Fork Project is described in Section 7.9.10. The project is operated for water supply, environmental, recreational, and hydropower purposes. This section of the document describes UDCs that constrain project operations.

8.26.1 ARPS Mitigation

The UDC *ARPS Mitigation* limits the discharge of water from the American River Pump Station to Auburn Ravine to 50 cfs. This limit is in place until the Auburn Ravine mitigation studies and associated fishery issues are resolved.

8.26.2 FolsomDiversion

Placer County WA holds water rights for both direct diversion and diversion to storage. Outside the period of direct diversion (*Other\Ops\Local Projects\PCWA MFP\PeriodofDirectDiversion*), the UDC *FolsomDiversion* limits the total diversion of MFP water at the agency's American River Pump Station and at Folsom Lake to be less than storage withdrawals from French Meadows and Hell Hole reservoirs.

[82] The Sunset Pumps divert water at RM 39 to supply Sutter Extension WD.

8.26.3 setMFPStorageConstraint

The UDC *setMFPStorageConstraint* requires that the combined storage in French Meadows and Hell Hole reservoirs can only increase during the period of diversion to storage.

8.26.4 LimitMFPSeptStorage

The UDC *LimitMFPSeptStorage* requires that the combined storage in French Meadows and Hell Hole reservoirs in September to be less than the previous year's carryover storage, except in dry years.

8.26.5 LimitMFPNovStorage

The UDC *LimitMFPNovStorage* requires that the combined storage in French Meadows and Hell Hole reservoirs in November and December to be less than the previous year's carryover storage, except in dry years.

8.26.6 LimitMFPJulDecStorage

The UDC *LimitMFPJulDecStorage* requires that the combined storage in French Meadows and Hell Hole reservoirs from July to December to be less than the combined storage in the prior month, except in dry years.

8.26.7 FRMDWConstraint

The UDC *FRMDWConstraint* requires that the storage in French Meadows can only increase during the period of diversion to storage.

8.27 PG&E Drum-Spaulding

PG&E's Drum-Spaulding Project is described in Section 7.9.12. The project is operated for water supply, environmental, and hydropower purposes.

8.27.1 AuburnRavineRouting1

PG&E sells water to Placer County WA for delivery to Zone 5. Water from PG&E's South Canal is delivered at buying point YB-136 to Auburn Ravine and hence to Placer County WA's Zone 5. Water supplies are supplemented by deliveries of Placer County WA's own water that is diverted at the American River Pump Station. The UDC *AuburnRavineRouting1* requires that the Auburn Ravine delivery to Placer County WA Zone 5 (A_24_NA2) equals the discharge of water to Auburn Ravine from the American River Pump Station and from PG&E's sale to the agency, less stream evaporative and seepage losses. Seepage is assumed to be 6.25 percent of channel flow, based on agreements between PG&E, Nevada ID, and Placer County WA.

8.27.2 AuburnRavineRouting2

The UDC *AuburnRavineRouting2* requires that the Auburn Ravine diversion to Nevada ID (A_24_NA1) equals the discharge of water to Auburn Ravine from PG&E Wise Powerhouse less a 6.25% seepage loss to groundwater. The discharge may be a mix of Nevada ID water and PG&E water.

8.27.3 FordyceDrawdown

PG&E gradually reduces storage in Lake Fordyce in late spring for accessibility to Fordyce Dam. This drawdown is made such that no additional spill occurs at Lake Spaulding when transferring water from Lake Fordyce to Lake Spaulding. The end of water year carryover storage target to support minimum flow requirements below Fordyce Reservoir in the fall is between 7,500 to 10,000 acre-feet. To the extent that there is a storage space available in Lake Spaulding for the water transfer, releases are made from Fordyce Dam until the storage in Fordyce Lake is lowered to 29,000 acre-feet. After the storage in Fordyce Lake reaches 29,000 acre-feet, the subsequent release rate is determined by calculating the difference between 29,000 acre-feet and the end of year storage target.

The UDC *FordyceDrawdown* implements drawdown of the reservoir by requiring releases from the dam to be greater than the state variable *Other\Ops\Local Projects\PGE Drum Spaulding\FordyceDrawdown2*.

8.27.4 Lower Boardman Canal

The UDC *Lower Boardman Canal* sets the outflow from the canal to Secret Ravine to zero. Canal spills are implicitly represented by return flows from the agricultural demand units.

8.27.5 PGE Sale to PCWA

PG&E delivers water to Placer County WA at various buying points along its canal infrastructure. In SacWAM these buying points comprise the following:

- Wise Canal - Lower Boardman Intertie
- South Canal to U_24_NU2 (lower Zone 1)
- South Canal to A_24_NA3 (lower Zone 1)
- Halsey Forebay to U_24_NU1 (upper Zone 1)
- South Canal to Auburn Ravine (for Zone 5)

The UDC *PGE Sale to PCWA* restricts the sum of the above flows to be less than the annual contract (100,400 acre-feet) amount multiplied by the annual allocation (*Other\Ops\Local Projects\PGE Drum Spaulding\PCWA WaterAllocation*), multiplied by a fixed monthly pattern. The monthly patternn of the annual allocation is based on 2001-2009 delivery data from FERC relicensing of Drum-Spaulding Project.

8.27.6 Zone3toZone1

PG&E sells water to Placer County WA for delivery from the Alta Powerhouse tailrace via the lower Boardman Canal to Zone 3. For much of the year, flows in the lower Boardman Canal below the Zone 3 delivery point are negligeable, of the order of 1 cfs, except during PG&E's annual outage of the Bear River Canal. The UDC *Zone3toZone1* limits these flows to a 3-week period corresponding to the assumed Bear River Canal outage for maintenance. During this simulated outage period (October 18 - November 7) flows are limited to 29 cfs (the assumed canal capacity). At all other times flows are set to zero.

8.27.7 Deactivated Constraints

The following sections describe UDCs that balance PG&E water supplies and water use. Water supplies are derived from PG&E's water rights associated with Fordyce, Spaulding, Lake Valley, and Rollins reservoirs. Water use includes flows through the Newcastle Powerhouse, abandoned flows in the Bear River below the Bear River Canal Diversion Dam, PG&E canal conveyance losses, and water sales to Nevada ID and Placer County WA. SacWAM does not simulate PG&E's Texas-Fall system and the diversion of this water into the Bowman-Spaulding Conduit.

These UDCs are currently inactive as they have been replaced by a more exact accounting of PG&E water and Nevada ID water based on the 1963 Consolidated Contract between the two entities.

8.27.7.1 PGEWaterSupply

PGEWaterSupply is a decision variable representing water supplies available to PG&E.

8.27.7.2 PGEWaterSupplyDefine

The UDC *PGEWaterSupplyDefine* sets *PGEWaterSupply* equal to the sum of the unimpaired flow for the South Yuba at Lake Spaulding, the natural inflow to Rollins Reservoir up to a maximum of 350 cfs, and imports to the Drum Canal through Lake Valley Canal.

8.27.7.3 PGEWaterUse

PGEWaterUse is a decision variable representing water use by PG&E; it can be positive or negative.

8.27.7.4 PGEWaterUseDefine

The UDC *PGEWaterUse* is calculated as the sum of diversions to storage in Fordyce and Spaulding reservoirs, releases from Lake Spaulding to the South Yuba River, flows through the Newcastle Powerhouse, sale of water to Placer County WA's Zones 1, 3, and 5, and sale of water to Nevada ID at Rock Creek on the Wise Canal and below the Wise Powerhouse.

8.27.7.5 PGEWaterBalance

The UDC *PGEWaterBalance* constrains PG&E use of water (*PGEWaterUse*) to be less than its supply (*PGEWaterSupply*). The UDC has since been deactivated and commented out. Tracking and constraining Nevada ID water supply, combined with mass balance requirements is sufficient to ensure correct accounting of PG&E water.

8.28 Priority-Based Constraints

WEAP has the ability to activate and deactivate constraints during each time step according to the water allocation order/priority. This functionality is implemented using a text file named

'UDCActivePriority.yes' placed in the WEAP areas directory. For SacWAM, the content of this file is as follows:

- *User Defined LP Constraints\Coordinated Operations Agreement\Delta Outflow\DOR Eqn 1,45,99*
- *User Defined LP Constraints\Coordinated Operations Agreement\Delta Outflow\DOR Eqn 2,45,99*
- *User Defined LP Constraints\Coordinated Operations Agreement\Delta Outflow\DOR Eqn 3,45,99*
- *User Defined LP Constraints\Coordinated Operations Agreement\Delta Outflow\DOR Eqn 4,45,99*
- *User Defined LP Constraints\Coordinated Operations Agreement\Delta Outflow\DOR Eqn 5,45,99*
- *User Defined LP Constraints\Coordinated Operations Agreement\Sharing Formulae\COA_CVP,45,99*
- *User Defined LP Constraints\Coordinated Operations Agreement\Sharing Formulae\COA_SWP,45,99*
- *User Defined LP Constraints\PriorityBasedConstraints\Mokelumne Aqueduct,30,99*
- *User Defined LP Constraints\PriorityBasedConstraints\CA1,1,72*
- *User Defined LP Constraints\PriorityBasedConstraints\DMC1,1,72*
- *User Defined LP Constraints\Delta Export Constraints\AprilMayPulsePeriod\AprMayPulse_CVP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\AprilMayPulsePeriod\AprMayPulse_SWP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\D1641EIRatio\EIRatio_CVP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\D1641EIRatio\EIRatio_SWP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\SJRIERatio\IERatio_CVP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\SJRIERatio\IERatio_SWP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\OMR\OMR_CVP,1,79*
- *User Defined LP Constraints\Delta Export Constraints\OMR\OMR_SWP,1,79*

The first part of each row (delimited by a comma) refers to a UDC in SacWAM's data tree. The following two numbers indicate the priorities for which the UDC is active. For example, the UDCs *COA_CVP* and *COA_SWP* are activated in priority 45 (the priority assigned to CVP settlement contractors) and remain active through the remaining priorities and allocation orders.

The model user must ensure that the priorities listed in the CSV file are up to date and consistent with the priorities defined in the SacWAM data tree under other assumptions.

The logic associated with the priority-based constraints with regard to CVP and SWP operations is illustrated in Figures 8-1 through 8-4.

	Storage Zone/Priority or Dummy Demand Site/Priority	Priority Variable Name	UDC Turned On/Off
CVP Settlement Contractors **Priority = 45**			
Maximize Trinity Storage **Priority = 58** Storage cannot subsequnetly drop below this level	Trinity Conservation	CVP Trinity River Storage	
CVP NOD Refuges **Priority = 61**		CVP Refuge Contractors	
CVP NOD M&I Contractors **Priority = 62**		CVP Urban Contractors	
CVP NOD Ag Contractors **Priority = 63**		CVP Ag Contractors	
Set Buffer Storage for Folsom **Priority = 67** Storage cannot subsequnetly drop	Folsom Buffer	CVP Storage Folsom Buffer Storage	
Dummy Network to Maximize NOD storage **Priority = 69** No constraint on subsequent allocation orders - for information	z_MaxNODCVPSWPStorageDemand	MaximizeStoragePriortoSODExports	
Deliver water to SOD contractors upstream from San Luis Reservoir **Priority = 71** California Aqueduct no longer constrained to 300 cfs Delta-Mendota Canal no longer constrained to 600 cfs Drawdown of CVP San Luis Reservoir allowed		CVP Above San Luis SWP above San Luis	**On** c_Minimization\COACredit2 **Off** PriorityBasedConstraints\CA1 PriorityBasedConstraints\DMC1 PriorityBasedConstraints\DeltaOutflowRequirement_NoExport PriorityBasedConstraints\MaxStorageBeforeExports CVPSanLuis_MaintainStorage SWPSanLuis_MaintainStorage COACredit
Set Buffer Storage for Shasta and Oroville **Priority = 72** The only reference to Priority 72 is when Oroville is below 850 TAF, otherwise this priortity is skipped		CVP Shasta Buffer Storage SWP Oroville Buffer Storage	On PriorityBasedConstraints\SWPBufferExpLimit_P72 PriorityBasedConstraints\CVPBufferExpLimit_P72

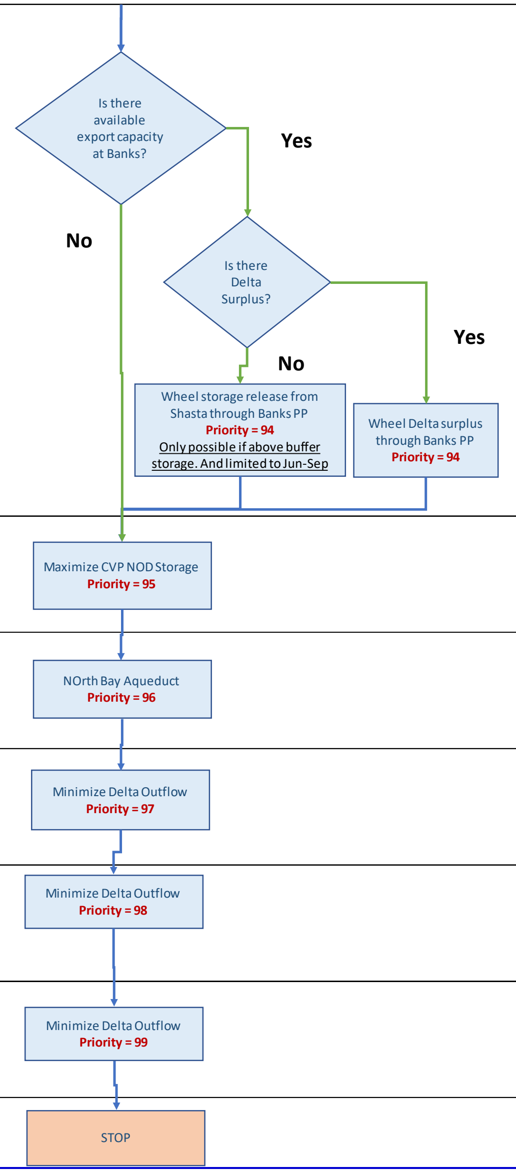
Figure 8-1. Simulation of CVP and SWP Operations Using Priority-Based Constraints – Part 1

Deliver Project Water to CVP/SWP SOD Contractors	z_MinCOACredit2_Demand	CVP SOD Ag Contractors CVP SOD Canal Losses CVP SOD Exchange Contractors CVP SOD Refuge Contractors CVP SOD Urban Contractors SWP Canal Losses SWP Table A Demands Travis AFB Demand	**On** San Luis Reservoir\CVP_SanLuis\ConstraintoRuleCurve San Luis Reservoir\SWP_SanLuis\ConstraintoRuleCurve
Fill San Luis with Delta Surplus or Storage Releases	CVP San Luis Buffer SWP San Luis Buffer	CVP SOD Storage bw Rule Curve SWP SOD Storage bw Rule Curve	
Remove constraint on sharing of regulatory export capacity **Priority = 80** Experience suggests that this constraint was limiting storage maximization in subsequent allocations		Relax 5050 split on export constraints *Note: variable name is incorrect split is 60:40*	**Off** Delta Export Constraints\AprilMayPulsePeriod\AprMayPulse_CVP Delta Export Constraints\AprilMayPulsePeriod\AprMayPulse_SWP Delta Export Constraints\D1641EIRatio\EIRatio_CVP Delta Export Constraints\D1641EIRatio\EIRatio_SWP Delta Export Constraints\SJRIERatio\IERatio_CVP Delta Export Constraints\SJRIERatio\IERatio_SWP Delta Export Constraints\Artificial Neural Network\meetJP_CVP Delta Export Constraints\Artificial Neural Network\meetJP_SWP Delta Export Constraints\Artificial Neural Network\meetCO_CVP Delta Export Constraints\Artificial Neural Network\meetCO_SWP Delta Export Constraints\Artificial Neural Network\meetEM_CVP Delta Export Constraints\Artificial Neural Network\meetEM_SWP Delta Export Constraints\Artificial Neural Network\meetRS1_CVP Delta Export Constraints\Artificial Neural Network\meetRS1_SWP Delta Export Constraints\Artificial Neural Network\meetRS2_CVP Delta Export Constraints\Artificial Neural Network\meetRS2_SWP Delta Export Constraints\Artificial Neural Network\meetRS3_CVP Delta Export Constraints\Artificial Neural Network\meetRS3_SWP
Maximize Folsom, Oroville and Shasta Storage **Priority = 82** Oroville storage cannot drop below this level. Shasta storage allowed to decrease	z_MaxFolsomStorage1Demand z_MaxOrovilleStorageDemand z_MaxShastaStorage1Demand	Maximize Folsom1 Storage *commented out* Maximize Oroville Storage Maximize Shasta1 Storage	**Off** San Luis Reservoir\CVP_SanLuis\ConstraintoRuleCurve San Luis Reservoir\SWP_SanLuis\ConstraintoRuleCurve
Calculate True Deta Outflow Requirement **Priority = 83** No constraints related to dummy network Z_TrueDeltaOutflow	z_TrueDeltaOutflow		**On** PriorityBasedConstraints\EnforceTrueDeltaOutflow_P83 **Off** PriorityBasedConstraints\SWPBufferExpLimit_P72 PriorityBasedConstraints\CVPBufferExpLimit_P72
Is there SWP Delta Surplus? **Yes**: Fill San Luis with Delta Surplus above Rule Curve **Priority = 84** **COA sharing formulae turned off** **No**	CVP San Luis Conservation SWP San Luis Conservation	CVP SOD storage ab Rule Curve using Delta surplus SWP SOD storage ab Rule Curve using Delta surplus	**On** PriorityBasedConstraints\CVPSanLuisAbvRC PriorityBasedConstraints\SWPSanLuisAbvRC PriorityBasedConstraints\PreventCheating PriorityBasedConstraints\OrovilleStorageMax_P84 **Off** Coordinated Operations Agreement\Sharing Formulae\COA_CVP Coordinated Operations Agreement\Sharing Formulae\COA_SWP PriorityBasedConstraints\EnforceTrueDeltaOutflow_P83
Allow SWP use of Unused Federal Share **Priority = 85** **UDC No Unused_FS deactivated.** **Dummy network no longer used.**	z_Unused_FS_Demand	Allow SWP use of unused Federal Share	**Off** PriorityBasedConstraints\No Unused_FS Delta Export Constraints\OMR\OMR_CVP Delta Export Constraints\OMR\OMR_SWP PriorityBasedConstraints\CVPSanLuisAbvRC PriorityBasedConstraints\SWPSanLuisAbvRC PriorityBasedConstraints\PreventCheating PriorityBasedConstraints\OrovilleStorageMax_P84

Figure 8-2. Simulation of CVP and SWP Operations Using Priority-Based Constraints – Part 2

Deliver Project Water to CVP/SWP SOD Contractors	z_MinCOACredit2_Demand	CVP SOD Ag Contractors CVP SOD Canal Losses CVP SOD Exchange Contractors CVP SOD Refuge Contractors CVP SOD Urban Contractors SWP Canal Losses SWP Table A Demands Travis AFB Demand	**On** San Luis Reservoir\CVP_SanLuis\ConstraintoRuleCurve San Luis Reservoir\SWP_SanLuis\ConstraintoRuleCurve
Fill San Luis with Delta Surplus or Storage Releases	CVP San Luis Buffer SWP San Luis Buffer	CVP SOD Storage bw Rule Curve SWP SOD Storage bw Rule Curve	
Remove constraint on sharing of regulatory export capacity **Priority = 80** Experience suggests that this constraint was limiting storage maximization in subsequent allocations		Relax 5050 split on export constraints *Note: variable name is incorrect split is 60:40*	**Off** Delta Export Constraints\AprilMayPulsePeriod\AprMayPulse_CVP Delta Export Constraints\AprilMayPulsePeriod\AprMayPulse_SWP Delta Export Constraints\D1641EIRatio\EIRatio_CVP Delta Export Constraints\D1641EIRatio\EIRatio_SWP Delta Export Constraints\SJRIERatio\IERatio_CVP Delta Export Constraints\SJRIERatio\IERatio_SWP Delta Export Constraints\Artificial Neural Network\meetJP_CVP Delta Export Constraints\Artificial Neural Network\meetJP_SWP Delta Export Constraints\Artificial Neural Network\meetCO_CVP Delta Export Constraints\Artificial Neural Network\meetCO_SWP Delta Export Constraints\Artificial Neural Network\meetEM_CVP Delta Export Constraints\Artificial Neural Network\meetEM_SWP Delta Export Constraints\Artificial Neural Network\meetRS1_CVP Delta Export Constraints\Artificial Neural Network\meetRS1_SWP Delta Export Constraints\Artificial Neural Network\meetRS2_CVP Delta Export Constraints\Artificial Neural Network\meetRS2_SWP Delta Export Constraints\Artificial Neural Network\meetRS3_CVP Delta Export Constraints\Artificial Neural Network\meetRS3_SWP
Maximize Folsom, Oroville and Shasta Storage **Priority = 82** Oroville storage cannot drop below this level. Shasta storage allowed to decrease	z_MaxFolsomStorage1Demand z_MaxOrovilleStorageDemand z_MaxShastaStorage1Demand	Maximize Folsom1 Storage *commented out* Maximize Oroville Storage Maximize Shasta1 Storage	**Off** San Luis Reservoir\CVP_SanLuis\ConstraintoRuleCurve San Luis Reservoir\SWP_SanLuis\ConstraintoRuleCurve
Calculate True Deta Outflow Requirement **Priority = 83** No constraints related to dummy network Z_TrueDeltaOutflow	z_TrueDeltaOutflow		**On** PriorityBasedConstraints\EnforceTrueDeltaOutflow_P83 **Off** PriorityBasedConstraints\SWPBufferExpLimit_P72 PriorityBasedConstraints\CVPBufferExpLimit_P72
Is there SWP Delta Surplus? **Yes**: Fill San Luis with Delta Surplus above Rule Curve **Priority = 84** **COA sharing formulae turned off** **No**	CVP San Luis Conservation SWP San Luis Conservation	CVP SOD storage ab Rule Curve using Delta surplus SWP SOD storage ab Rule Curve using Delta surplus	**On** PriorityBasedConstraints\CVPSanLuisAbvRC PriorityBasedConstraints\SWPSanLuisAbvRC PriorityBasedConstraints\PreventCheating PriorityBasedConstraints\OrovilleStorageMax_P84 **Off** Coordinated Operations Agreement\Sharing Formulae\COA_CVP Coordinated Operations Agreement\Sharing Formulae\COA_SWP PriorityBasedConstraints\EnforceTrueDeltaOutflow_P83
Allow SWP use of Unused Federal Share **Priority = 85** **UDC No Unused_FS deactivated.** **Dummy network no longer used.**	z_Unused_FS_Demand	Allow SWP use of unused Federal Share	**Off** PriorityBasedConstraints\No Unused_FS Delta Export Constraints\OMR\OMR_CVP Delta Export Constraints\OMR\OMR_SWP PriorityBasedConstraints\CVPSanLuisAbvRC PriorityBasedConstraints\SWPSanLuisAbvRC PriorityBasedConstraints\PreventCheating PriorityBasedConstraints\OrovilleStorageMax_P84

Figure 8-3. Simulation of CVP and SWP Operations Using Priority-Based Constraints – Part 3



z_JPODDemand z_MaxCVPSanLuis2Demand	Allow wheeling for CVP JPOD Maximize CVP San Luis2 Storage	**On** PriorityBasedConstraints\Limit JPOD **Off** PriorityBasedConstraints\No CVP_JPOD San Luis Reservoir\CVP_SanLuis\ConstraintoRuleCurve San Luis Reservoir\SWP_SanLuis\ConstraintoRuleCurve
Shasta Conservation Folsom Conservation z_MinFolsomExcessRelease z_MinFolsomVAReOp z_MinShastaVAReOp		
	NBA Settlement Water North Bay Aqueduct Settlement Water	
z_MinOutflowDemand	MinimizeDeltaOutflow SWP Max Power Canal	
	Water Accounting Delta Surplus	
Shasta Buffer Oroville Buffer	Water Accounting EXP1 Term	

Figure 8-4. Simulation of CVP and SWP Operations Using Priority-Based Constraints – Part 4

8.28.1 Butte Slough Outfall Gates (BSOG)

The UDC *BSOG* fixes the outflow from the Buttel Slough Outfall Gates to the Sacramento River to equal that determined in the allocation order associated with priority 66.

8.28.2 CA1

The UDC *CA1* sets the flow in the California Aqueduct in the initial allocation orders to that required for Health and Safety, which in SacWAM is assumed to be 300 cfs.

8.28.3 CA2

The UDC *CA2* sets flows at the head of the California Aqueduct to be less than that required ofr Health and Safety. The UDC has been deactivated.

8.28.4 DMC1

The UDC *DMC1* sets the flow in the Delta-Mendota Canal in the initial allocation orders to that required for Health and Safety, which in SacWAM is assumed to be 600 cfs.

8.28.5 DMC2

The UDC *DMC2* sets flows at the head of the Delta-Mendota Canal to be less than that required ofr Health and Safety. The UDC has been deactivated.

8.28.6 CVPBufferExpLimit_P72

The UDC *CVPBufferExpLimit_P72* prevents additional exports at Jones Pumping Plant when storage In Shasta Lake is below buffer storage. For low storage, exports are contrained to be less than that achieved in the allocation order associated with Priority 72.

8.28.7 CVPSanLuis_MaintainStorage

The UDC *CVPSanLuis_MaintainStorage* prevents releases from CVP San Luis Reservoir.

8.28.8 CVPSanLuisAbvRC

The UDC *CVPSanLuisAbvRC* limits the storage in the CVP share of San Luis Reservoir to be less than the sum of storage in the previous allocation order plus CVP Delta surplus from the previous allocation order. This prevents the CVP from releasing additional water from Shasta Lake or Folsom Lake to fill San Luis Reservoir above rule curve.

8.28.9 Debug1

Debug1 is a user-defined standard LP variable that was created during model development for debugging purposes.

8.28.10 Debug2

Debug2 is a user-defined standard LP variable that was created during model development for debugging purposes.

8.28.11 DeltaOutflowRequirement_NoExport

The UDC *DeltaOutflowRequirement_NoExport* simply assigns the maximum of the Delta outflow requirements that are not export related to the variable DeltaOuflowRequirement. The UDC has been deactivated.

8.28.12 EnforceTrueDeltaOutflow_P83

The UDC *EnforceTrueDeltaOutflow_P83* sets the variable *DeltaOuflowRequirement* to equal that the value determined in the allocation order associated with Priority 82.

8.28.13 FixIBU

The UDC *FixIBU* sets the user-defined variable IBU equal to that determined in the allocation order associated with Priority 69 less the Delta outflow requirement for that allocation order plus the Delta outflow requirement in the current allocation order. The UDC has been deactivated.

8.28.14 KLRC

The UDC *KLRC* sets the flow through the Knights Landing Ridge Cut to that determined in the allocation order associated with Priority 66. The UDC has been deactivated.

8.28.15 Limit JPOD

The UDC *LimitJPOD* limits storage in the CVP share of San Luis Reservoir to be lower than the maximum of the CVP San Luis rule curve and the storage determined in the allocation order associated with Priority 91. The UDC has been deactivated.

8.28.16 Maintain Jones Pumpimg

The UDC *Maintain Jones Pumping* sets the export of water at Jones Pumping Plant to be greater than that determined in the allocation order associated with Priority 91. The UDC has been deactivated.

8.28.17 MaxStorageBeforeExports

The UDC *MaxStorageBeforeExports* attempts to maximize the combined storage in Shasta Lake, Lake Oroville, and Folsom Lake using a dummy network. The UDC has been deactivated.

8.28.18 Mokelumne Aqueduct

The UDC Mokelumne Aqueduct sets the flow in the aqueduct at milepost 57 to zero. The UDC has been deactivated.

8.28.19 No CVP_CVC

The UDC *No CVP_CVC*sets wheeling of CVP water through Banks Pumping Plant for delivery to the Cross Valley Canal contractors to zero.

8.28.20 No CVP_JPOD

The UDC *No CVP_JPOD* sets wheeling of CVP water through Banks Pumping Plant as part of the Joint Point of Diversion to zero.

8.28.21 No Unused_FS

The UDC *No Unused_FS* sets unused Federal share of Delta water to zero.

8.28.22 No Unused_SS

The UDC *No Unused_SS* sets unused Federal share of Delta water to zero.

8.28.23 OrovilleStorageMax_P84

The UDC *OrovilleStorageMax_P84* requires storage in Lake Oroville to be less than that achieved in the allocation order associated with Priority 73.

8.28.24 PreventCheating

The UDC *PreventCheating* enforces the requirements of COA by equating the sum of CVP export of CVP water and CVP Delta surplus to that achieved under the allocation order associated with Priority 83.

8.28.25 setDebug1

The UDC *setDebug1* outputs the flow in head of the California Aqueduct in the allocation order for Priorty 71 when storage in Lake Oroville is below Top of Buffer.

8.28.26 setDebug2

The UDC *setDebug2* outputs the flow in head of the Delta-Mendota Canal in the allocation order for Priorty 71 when storage in Shasta Lake is below Top of Buffer.

8.28.27 SetTrueDeltaOutflow_P82

The UDC *SetTrueDeltaOutflow_P82* sets the variable TrueDeltaOutflow_P82 equal to the larger of the outflow needed to be meet required outflow, X2 location requirements, Delta salinity standards, and any new Board unimpaired flow criteria. These latter are as determined in the allocation order associated with Priority 82.

8.28.28 SWPBufferExpLimit_P72

The UDC *SWPBufferExpLimit_P72* prevents additional exports at Banks Pumping Plant when storage In Lake Oroville is below buffer storage. For low storage, exports are contrained to be less than that achieved in the allocation order associated with Priority 72.

8.28.29 SWPSanLuis_MaintainStorage

The UDC *SWPSanLuis_MaintainStorage* prevents releases from SWP San Luis Reservoir.

8.28.30 SWPSanLuisAbvRC

The UDC *SWPSanLuisAbvRC* limits the storage in the SWP share of San Luis Reservoir to be less than the sum of storage in the previous allocation order plus SWP Delta surplus from the previous allocation order. This prevents the SWP from releasing additional water from Lake Oroville to fill San Luis Reservoir above rule curve.

8.28.31 TrueDeltaOutflow_P82

TrueDeltaOutflow_P82 is a user-defined standard LP variable that represents the required Delta outflow to meet D-1641 Delta standards.

8.29 City of Roseville (Roseville)

The City of Roseville (U_26_PU1) holds a water contract with Reclamation for CVP water and a contract with Placer County WA for Middle Fork Project (MFP) water. Additionally, the city may obtain water from San Juan WD in normal and wet years. All water supplies are drawn from Folsom Lake and treated at the city's Barton Road Water Treatment Plant. Simulated deliveries of CVP water and MFP water to U_26_PU1 are conveyed through separate transmission links. In SacWAM, CVP water is assigned first preference and MFP water is assigned second preference. Groundwater is the last preference.

8.29.1 Roseville_CVPWater

The UDC *Roseville_CVPWater* limits the City of Roseville's use of CVP water to the remaining unused allocation for the current contract year (see Section 7.9.2).

8.29.2 Roseville_MFPWater

The UDC *Roseville_MFPWater* limits the City of Roseville's use of MFP water to the remaining unused amount for the current water year (see Section 7.9.2).

8.30 San Juan Water District

San Juan WD is described in Section 7.9.16. The district holds both pre-1914 and post-1914 water rights. Additionally, it has a signed a contract with Reclamation for CVP water, and a contract with Placer County WA for Middle Fork Project (MFP) water. All water supplies are drawn from Folsom Lake and treated at the Peterson Water Treatment Plant. Treated water is subsequently delivered to San Juan

WD's retail service area and to Orange Vale WC, Cirus Heights WD, and Fair Oaks WD (collectively represented as U_26_PU2). Deliveries of water right water, CVP water, and MFP water to U_26_PU2 are conveyed through separate transmission links.

Under the pre-1914 water right, San Juan WD is entitled to divert up to 26,400 acre-feet per year from the American River at a rate of up to 60 cfs. The post-1914 water right (Permit 4009, License 6234, A5830) is for a diversion of 15 cfs from the North Fork American River from June 1 through November 1. In 1954, the district entered an agreement with Reclamation to limit diversions under its water rights to 33,000 acre-feet per year at a maximum rate of 75 cfs. In SacWAM, water right water is assigned first preference and CVP and MFP water are assigned joint second preference. Groundwater is the last preference.

8.30.1 SplitCVPMFP

The UDC *San Juan WD\splitCVPMFP* restricts delivery of CVP water to 50 percent of the monthly water demand less 60 cfs, less 15 cfs for the months of June through October. The purpose of the constraint is to balance use of CVP and MFP water. Constraints on the two transmission links that convey CVP water and MFP water limit the volume of diversion to the remaining annual supply.

8.31 San Luis Reservoir

San Luis Reservoir is a joint CVP-SWP offstream storage facility used to temporarily store project water before delivery to project contractors. In SacWAM, San Luis Reservoir is represented as two separate reservoirs: *CVP_SanLuis* and *SWP_SanLuis*.

8.31.1 CVP_SanLuis

Water from the Delta-Mendota Canal is delivered to San Luis Reservoir through the O'Neill and Gianelli pumping-generating plants. CVP water from San Luis Reservoir is subsequently released into the San Luis Canal or to the Delta-Mendota Canal for delivery to CVP contractors. Additionally, the CVP diverts water from the west end of San Luis Reservoir through the Pacheco Tunnel and Pacheco Conduit to supply CVP water service contractors in Santa Clara and San Benito counties.

SacWAM's simulated operations of the CVP share of San Luis Reservoir are driven by the CVP San Luis rule curve. During the fall, winter, and spring the reservoir is filled up to rule curve with a mix of unstored water supplies and storage withdrawals from CVP reservoirs. Subsequently, if additional unstored water supplies exist, the reservoir is filled above rule curve, up to capacity, according to the amount of water available. Lastly, the CVP may use any unused State Share of water under COA to fill the CVP share of the reservoir.

The variables and constraints listed below were developed during early model development and are no longer used. The initial approach for operating San Luis Reservoir has been replaced by the use of dummy networks, multiple priorities and water allocations, and priority constraints.

8.31.1.1 Constrain DrainConstraint

The UDC *Constrain DrainConstraint* limits releases from CVP San Luis Reservoir to be less than *DrainConstraint.*

8.31.1.2 ConstrainFillConstraint

The UDC *Constrain FillConstraint* limits filling of CVP San Luis Reservoir to be less than *FillConstraint.*

8.31.1.3 CVPSanLuis_Int

The user-defined variable *CVPSanLuisInt* is an integer variable associated with CVP simulated operations of San Luis Reservoir. The associated UDCs *Fill* and *Release* prevent the reservoir from both filling and draining in the same time step.

8.31.1.4 Define DrainConstraint

The UDC *Define DrainConstraint* limits releases from CVP San Luis Reservoir based on the downstream water demand and water allocation.

8.31.1.5 DrainConstraint

DrainConstraint is a user-defined standard LP variable.

8.31.1.6 Fill

Fill and *Release* are a pair of UDCs that prevent both filling of CVP San Luis Reservoir and release of water from San Luis Reservoir during the same time step.

8.31.1.7 FillConstraint

FillConstraint is a user-defined standard LP variable.

8.31.1.8 Release

Fill and *Release* are a pair of UDCs that prevent both filling of CVP San Luis Reservoir and release of water from San Luis Reservoir during the same time step.

8.31.1.9 ConstraintoRuleCurve

The UDC *ConstraintoRuleCurve* limits San Luis Reservoir storage from May to September to be less than the upper bound *Other\Ops\CVPSWP\San Luis\CVP\SL_UpperBound_MaySep*.

8.31.2 SWP_SanLuis

The SWP share of San Luis Reservoir allows DWR to meet peak seasonal SWP demands. DWR stores water in the reservoir when pumping at Banks Pumping Plant exceeds SWP contractor demands, and releases water to the San Luis Canal/California Aqueduct when pumping at Banks Pumping Plant is insufficient to meet these demands.

SacWAM's simulated operations of the SWP share of San Luis Reservoir are driven by the SWP rule curve for the reservoir. During the fall, winter, and spring the reservoir is filled up to rule curve with a mix of unstored water and storage withdrawals from Lake Oroville. Subsequently, if additional unstored water supplies exist, San Luis Reservoir is filled above rule curve, up to the SWP's share of capacity according to the amount of water available. Lastly, SWP may use any unused Federal Share of water under COA to fill the reservoir.

The variables and constraints listed below were developed during early model development and are no longer used. The initial approach for operating San Luis Reservoir has been replaced by the use of dummy networks, multiple priorities and water allocations, and priority constraints.

8.31.2.1 Constrain DrainConstraint
The UDC *Constrain DrainConstraint* limits releases from SWP San Luis Reservoir to be less than *DrainConstraint.*

8.31.2.2 ConstrainFillConstraint
The UDC *Constrain FillConstraint* limits filling of SWP San Luis Reservoir to be less than *FillConstraint.*

8.31.2.3 CVPSanLuis_Int
The user-defined variable *SWPSanLuisInt* is an integer variable associated with SWP simulated operations of San Luis Reservoir. The associated UDCs *Fill* and *Release* prevent the reservoir from both filling and draining in the same time step.

8.31.2.4 Define DrainConstraint
The UDC *Define DrainConstraint* limits releases from SWP San Luis Reservoir based on the downstream water demand and water allocation.

8.31.2.5 DrainConstraint
DrainConstraint is a user-defined standard LP variable.

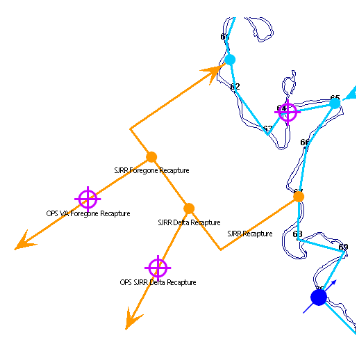
8.31.2.6 Fill
Fill and *Release* are a pair of UDCs that prevent both filling of SWP San Luis Reservoir and release of water from SWP San Luis Reservoir during the same time step.

8.31.2.7 FillConstraint
FillConstraint is a user-defined standard LP variable.

8.31.2.8 Release
Fill and *Release* are a pair of UDCs that prevent both filling of SWP San Luis Reservoir and release of water from San Luis Reservoir during the same time step.

8.31.2.9 ConstraintoRuleCurve
The UDC *ConstraintoRuleCurve* limits SWP San Luis Reservoir storage from May to September to be less than the upper bound *Other\Ops\CVPSWP\San Luis\SWP\SL_UpperBound_MaySep*.

8.32 SJRR Inflow Routing



The SacWAM schematic was modified to facilitate modeling of recapture of San Joaquin River Restoration flows. The diversion arc *SJRR Recapture* diverts water from the San Joaquin River downstream from Vernalis and returns it back to the river. The UDC *SJRR Inflow Routing* sets the flow through this diversion to zero.

8.33 South Feather Water and Power Agency (SFWPA)

The purpose of the SFWPA branch is to represent the water rights of South Feather Water and Power Agency to export water from Salte Creek and imposrt this water into the Sly Creek watershed. The water right includes both direct diversion and diversion to storage.

8.33.1 SlyCreekRes

The UDC *SlyCreekRes* imposes limits on the total storage in Little Grass Valley and Sly Creek reservoirs based on theh agnecy's diversion to storage water rights.

8.33.2 Slate Creek Tunnel Direct Diversion

Slate Creek Tunnel Direct Diversion is a user-defined standard LP variable that represent the direct diversion of Slate Creek water through the Slate Creek Tunnel to Sly Creek.

8.33.3 Slate Creek Tunnel Diversion to Storage

Slate Creek Tunnel Diversion to Storage is a user-defined standard LP variable that represent the diversion of Slate Creek water through the Slate Creek Tunnel to storage in Sly Creek Reservoir.

8.33.4 SlateCreekTunnelConstraint1

The UDC *Slate CreekTunnelConstraint1* sets the flow through the Slate Creek Tunnel to equal the sum of a direct diversion component and a diversion to storage component.

8.33.5 SlateCreekTunnelConstraint2

The UDC *Slate CreekTunnelConstraint2* sets the diversion to storage component of Slate Creek Tunnel flows equal to be less than 35 TAF per year.

8.33.6 SlateCreekTunnelConstraint3

The UDC *Slate CreekTunnelConstraint2* sets the diversion to storage component of Slate Creek Tunnel flows equal to the maximum diversion less 300 cfs.

8.33.7 SlyCreekConstraint1

The UDC *SlyCreekConstraint1* sets the flow below Sly Creek Reservoir to be less than the sum of the previous end-of-month storage in Sly Creek Reservoir, direct diversion of Slate Creek, inflow from the South Fork Tunnel, and the unimpaired inflow from Sly Creek (*I_SLYCK*).

8.34 South Sutter Water District

South Sutter WD (A_23_NA) is described in Section 7.9.19. Its primary source of surface water is Camp Far West Reservoir and associated diversions from the lower Bear River. Additionally, in wetter years, water is diverted from the Auburn Ravine.

8.34.1 AuburnRavine

The UDC *South Sutter WD\AuburnRavine* restricts district diversions from Auburn Ravine to the natural flow in the ravine. The purpose of the UDC is to prevent South Sutter WD accessing PG&E and Nevada ID water that is discharged into the Auburn Ravine from the Wise and South canals.

8.35 Split Exports

The UDCs under *Split Exports* disaggregate Delta exports into different flow components. Variables defined under *Split Exports* are referenced by *Delta Export Constraints* (see Section 8.8) and by COA (see Section 8.6).

8.35.1 North Bay Aqueduct

Water conveyed through the North Bay Aqueduct consist of SWP Table A and Article 21 deliveries, and Settlement Water and Vallejo Permit Water (see Section 8.23). These types of water are represented by the user-defined variables: NBA_TableA, NBA_Art21, NBA_Settlement, and NBA_Vallejo. Four UDCs subsequently set these variables equal to the sum of flows in specific transmission links, as follows:

- Table A water is conveyed to Napa County WA (U_NAPA_PU), Travis AFB, and the Cities of Vaccavile, Benicia, Vallejo, and Fairfield through transmission links from the North Bay Aqueduct at channel miles 27a, 9, 11a, 21a, 21a, 11a.
- Article 21 water is conveyed to Napa County WA (U_NAPA_PU_A21) through transmission link *North Bay Aqueduct CM 027a.*
- Settlement Water is conveyed to the Cities of Benicia (U_BNCIA_SU), Fairfield (U_FRFLD_SU), and Vacaville (U_20_25_SU) through transmission links from the North Bay Aqueduct at channel miles 21a, 11a, 11a.
- Vallejo Permit Water is conveyed to Napa County WA (U_NAPA_PU) and the Cities of Benicia (U_BNCIA_PU), Fairfield (U_FRFLD_PU), Vacaville (U_20_25_PU), and Vallejo (U_VLLJO_PU) through transmission links from the North Bay Aqueduct at channel miles 027b, 021b, 011b, 011b, and 21b.

8.35.1.1 NBA_Art21

NBA_Art21 is a user-defined standard LP variable representing the delivery of SWP Article 21 water to SWP contractors supplied from the North Bay Aqueduct.

8.35.1.2 NBA_Settlement

NBA_Settlement is a user-defined standard LP variable representing the delivery of Settlement water to the Cities of Benicia, Fairfield, and Vacaville and conveyed through the North Bay Aqueduct.

8.35.1.3 NBA_TableA

NBA_TableA is a user-defined standard LP variable representing the delivery of SWP Table A water to SWP contractors supplied from the North Bay Aqueduct.

8.35.1.4 NBA_Vallejo

NBA_Vallejo is a user-defined standard LP variable representin the diversion of water right water at the Barker Slough Pumping Plant by the City of Vallejo.

8.35.1.5 Set NBA_Art21

The UDC *Set NBA_Art21* equates the total Article 21 water delivered to the North Bay Aqueduct to Article 21t water delivered through a transmiision link that supplies Napa County FCWCD.

8.35.1.6 Set NBA_Settlement

The UDC *Set NBA_Settlement* equates the total Settlement water delivered to the North Bay Aqueduct to Settlement water delivered through three transmiision links that supply individual demand units.

8.35.1.7 Set NBA_TableA

The UDC *Set NBA_Table A* equates the total Table A delivered to the North Bay Aqueduct to Table A water delivered through six transmiision links that supply individual demand units.

8.35.1.8 Set NBA_Vallejo

The UDC *Set NBA_Vallejo* equates the diversion of water right water by the City of Vallejo at the Barker Slough Pumping Plant to water right water delivered through five transmiision links that supply individual demand units.

8.35.1.9 Split_NBA

The UDC Split_NBA disaggeragtes flows in the North Bay Aqueduct into Table A water, Article 21 water, Settlement water, and Vallejo Permit water. Split_NBA has been deactivated as it overconstrains North Bay Aqueduct operations.

8.35.2 WaterFix

Flows through Banks and Jones pumping plants are disaggregated for the purposes of implementing D-1641 standards and BiOp requirements under a simulated scenario that includes the Water Fix (i.e., the Delta Tunnels originally envisaged as part of the Bay Delta Conservation Plan (BDCP)). For example, restrictions on Delta pumping to satisfy OMR flow requirements and the Export-to-Inflow ratio are applied only to the portion of exports that are derived directly from the Delta. Disaggregated flows consist of a 'through-Delta' component and an 'isolated facility' component. User-defined variables for the various export components are listed in Table 8 2.

Table 8-2. Split Delta Exports Variables

Variable	Description
CA_TD	Portion of flow into the California Aqueduct derived from the Delta
CA_IF	Portion of flow into the California Aqueduct that is diverted around the Delta through the Delta tunnels
DM_TD	Portion of flow into the Delta-Mendota Canal derived from the Delta
DM_IF	Portion of flow into the Delta-Mendota Canal that is diverted around the Delta through the Delta tunnels
CA_exp	Flow into the California Aqueduct from all sources
DM_exp	Flow into the Delta-Mendota Canal from all sources
Export_TD	Total export that is derived from the Delta
Export_IF	Total export diverted around the Delta through the Delta tunnels
CC_TD	The portion of Contra Costa Water District diversions derived from the Delta

Key:
IF=Isolated Facility
TD=through Delta

Eight UDCs are used to sum the various components of exports to obtain the total diverted inflows to the California Aqueduct and Delta-Mendota Canal and the total through-Delta and isolated facility flows.

8.35.2.1 CA_exp
CA_exp is a user-defined standard variable representing export of water from the South Delta through Banks Pumping Plant.

8.35.2.2 CA_exp Eqn1
The UDC *CA_exp_Eqn1* sets the total flow in the California Aqueduct downstream from Banks Pumping Plant equal to the sum of the through Delta and Isolated Facility components.

8.35.2.3 CA_exp Eqn2
The UDC *CA_exp_Eqn2* sets the variable *CA_exp* equal to the flow at the head of the California Aqueduct.

8.35.2.4 CA_IF
CA_IF is a user-defined standard variable representing water at the head of the California Aqueduct that has been conveyed through the Isolated Facility.

8.35.2.5 CA_TD
CA_TD is a user-defined standard variable representing water at the head of the California Aqueduct that has been conveyed through the Delta and through Banks Pumping Plant.

8.35.2.6 CC Eqn
The UDC *CC Eqn* set the variable *CC_TD* equal to the diversion by Contra Costa WD at their Rock Slough, Old River, and Victoria Canal intakes.

8.35.2.7 CC_TD
CC_TD is a user-defined standard variable representing water at the head of the Contra Costa Canal and at the head of the Old River Pipeline that has been conveyed through the Delta.

8.35.2.8 DM_exp
DM_exp is a user-defined standard variable representing export of water from the South Delta through Jones Pumping Plant.

8.35.2.9 DM_exp Eqn1
The UDC *CA_exp_Eqn1* sets the total flow in the Delta-Mendota Canal downstream from Jones Pumping Plant equal to the sum of the through-Delta and Isolated Facility components.

8.35.2.10 DM_exp Eqn2
The UDC *DM_exp_Eqn2* sets the variable *DM_exp* equal to the flow at the head of the Delta-Mendota Canal.

8.35.2.11 DM_IF
DM_IF is a user-defined standard variable representing water at the head of the Delta-Mendota Canal that has been conveyed through the Isolated Facility.

8.35.2.12 DM_TD
DM_TD is a user-defined standard variable representing water at the head of the Delta-Mendota Canal that has been conveyed through the Delta and through Jones Pumping Plant.

8.35.2.13 Export_IF

Export_IF is a user-defined standard variable representing water moved through the Isolated Facility for export and diversion from the South Delta.

8.35.2.14 Export_IF Eqn1

The UDC *Export_IF_Eqn1* sets the total flow in the Isolated Facility equal to the sum of components delivered to the California Aqueduct and the Delta-Mendota Canal.

8.35.2.15 Export_IF Eqn2

The UDC *Export_IF_Eqn2* sets the variable *Export_IF* equal to the flow at the head of the Isolated Facility.

8.35.2.16 Export_TD

Export_TD is a user-defined standard variable representing export of water from the South Delta through Banks Pumping Plant, Jones Pumping Plant, and diversion to the Contra Costa Canal, but excluding any water moved through the Isolated Facility. Export_TD represents 'through-Delta' exports and diversions.

8.35.2.17 Export_TD Eqn

The UDC Export_TD_Eqns sets the variable Export_TD equal to the sum of through Delta exports at Banks Pumping Plant, Jones Pumping Plant, and through-Delta diversions by Contra Costa WD.

8.36 VA Project Operations

8.36.1 FolsomReleaseReOp

FolsomReleaseReOp is a user-defined variable representing the required change in release from Folsom Lake as the result of VA operations. The variable may be positive or negative.

8.36.2 SetFolsomReleaseReOp

The UDC *SetFolsomReleaseReOp* sets *FolsomReleaseReOp* to equal the difference between the Folsom Lake release and the downstream VA flow requirement.

8.36.3 ShastaReleaseReOp

ShastaReleaseReOp is a user-defined variable representing the required change in release from Shasta Lake as the result of VA operations. The variable may be positive or negative.

8.36.4 SetShastaReleaseReOp

The UDC *SetShastaReleaseReOp* sets *ShastaReleaseReOp* to equal the difference between the Shasta Lake release and the downstream VA flow requirement.

8.36.5 FolsomReleaseReOpNeg

FolsomReleaseReOpNeg is a user-defined variable representing the required change in release from Folsom Lake as the result of VA operations. The variable may be positive or negative.

8.36.6 SetFolsomReleaseReOpNeg

The UDC *SetFolsomReleaseReOpNeg* sets *FolsomReleaseReOpNeg* to equal the difference between the VA flow requirement and Folsom Lake release.

8.36.7 ShastaReleaseReOpNeg

ShastaReleaseReOpNeg is a user-defined variable representing the required change in release from Shasta Lake as the result of VA operations. The variable may be positive or negative.

8.36.8 SetShastaReleaseReOpNeg

The UDC *SetShastaReleaseReOpNeg* sets *ShastaReleaseReOpNeg* to equal the difference between the VA flow requirement and Shasta Lake release.

8.37 Weirs

Six weirs, all located along the Sacramento River, are included in SacWAM. Flows over these weirs are set equal to a fixed fraction of Sacramento River flow above a defined threshold at each weir location. The calculation requires the use of integer variables to determine flow conditions within the Sacramento River at each weir. The values of the integer variables are equal to 1 when flow thresholds are exceeded and equal to zero otherwise. Flow thresholds and fractions of flow above these thresholds that spills over the weirs are presented in Table 8 3.

For each weir, there is a UDC named *Q_[weirname]_HistFix*. This constraint is for testing purposes only and is used to fix weir flows to their historical observed values. Historical data are stored in the file Data\Param\SACVAL_WeirInflows.csv. If this constraint is activated by the model user, all other weir constraints must be deactivated.

Table 8-3. Flow Parameters for Sacramento River Weirs

Weir	Flow Threshold (cfs)	Spill as a Fraction of Flow Above Threshold	Integer Variable
Eastside to Butte Basin	90,000	0.73071	Int_eastside
Moulton Weir	60,000	0.33152	Int_moulton
Colusa Weir	30,000	0.76788	Int_colusa
Tisdale Weir	18,000	0.75177	Int_tisdale
Fremont Weir	62,000	0.79808	Int_fremont
Sacramento Weir	73,000	0.87380	Int_sacramento

An example of the implementation of the weir logic is provided by the Eastside weir. Floodwaters in the Sacramento River overflow the left bank of the river into Butte Basin at three sites in a reach known as the Butte Basin Overflow Area, or the Butte Basin Reach. The northernmost overflow point is at a degraded levee called the M&T flood relief structure. The second overflow point is the 3Bs natural overflow site. The last overflow point is at another degraded levee known as the Goose Lake flood relief structure. In SacWAM, these three structures are simulated as a single weir located downstream from the Sacramento River confluence with Stony Creek. Water spills into the Butte Basin when Sacramento

River flows exceed 90,000 cfs. Sacramento River flows upstream from the weir (i.e., *QSac_RM184*) are split in to two components: *QSac_RM184_0* that represents flows up to 90,000 cfs; and *QSac_RM184_1* that represents the incremental flows above 90,000 cfs.

> *QSac_RM184* = Supply and Resources\River\Sacramento River\Reaches\Below Stony Creek Inflow to Sacramento RM 193:Streamflow
>
> *QSac_RM184* = *QSac_RM184_0* + *QSac_RM184_1*
>
> *QSac_RM184_0* <= 90,000 + 1

The weir equations are set up so that the integer variable, *Int_eastside*, is forced to a value of one when flows are greater than 90,000 cfs, or a value of zero when flows are less than this threshold.

> *QSac_RM184_0 >= Int_eastside * 90,000*
>
> *QSac_RM184_1 <= Int_eastside * 999,999*

Above the weir threshold, flows over the weir, *Q_Overflow*, are a function of the incremental flow *QSac_RM184_1*.

> *Q_Overflow* = Supply and Resources\River\M andT 3Bs Goose Lake\Reaches\Below M andT 3Bs Goose Lake Diverted Inflow:Streamflow
>
> *Q_Overflow* = 0.73071 * *QSac_RM184_1*

8.37.1 Colusa Weir

8.37.1.1 Int_Colusa
Int_Colusa is a user-defined integer (0, 1) variable that determines whether the weir is spilling or not.

8.37.1.2 Q_ColusaWeir
Q_ColusaWeir is a user-defined standard LP variable that represents spill over the Colusa Weir.

8.37.1.3 Q_ColusaWeir Eqn1
The UDC *Q_ColusaWeir Eqn1* sets the variable *Q_ColusaWeir* equal to the corresponding flow in the SacWAM schematic.

8.37.1.4 Q_ColusaWeir Eqn2
The UDC *Q_ColusaWeir Eqn2* calculates the spill over the weir as a linear fraction of the upstream flow that is above the weir spill threshold (*QSac_RM146_1*).

8.37.1.5 Q_ColusaWeir HistFix
The UDC *Q_ColusaWeir HistFix* sets the flow over the weir to the historical observed value. The UDC has been deactivated.

8.37.1.6 QSac_RM146
QSac_RM146 is a user-defined standard LP variable that represents the flow immediately upstream from the Colusa Weir at Sacramento River RM 146.

8.37.1.7 QSac_RM146 Eqn1
The UDC *QSac_RM146 Eqn1* sets the variable *QSac_RM146* equal to the corresponding flow in the SacWAM schematic.

8.37.1.8 QSac_RM146 Eqn2
The UDC *QSac_RM146 Eqn2* disaggergates the flow *QSac_RM146* into *QSac_RM146_0* and *QSac_RM146_1*, which represent the components of flow below and above the weir threshold flow of 30,000 cfs.

8.37.1.9 QSac_RM146 Eqn3
The UDC *QSacRM146* Eqn3 sets the upper bound of the variable *QSac_RM146_0* to be 1 cfs greater than the spill threshold*.*

8.37.1.10 QSac_RM146 Eqn4
The UDC *QSacRM146 Eqn4* sets the lower bound on the flow component *QSac_RM146_0* depending on whether the weir is spilling (*int_colusa* = 1).

8.37.1.11 QSac_RM146 Eqn5
The UDC *QSacRM146 Eqn5* sets the upper bound on the flow component *QSac_RM146_1* depending on whether the weir is spilling (*int_colusa* = 1).

8.37.1.12 QSac_RM146_0
QSac_RM146_0 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is below the weir spill threshold.

8.37.1.13 QSac_RM146_1
QSac_RM146_1 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the weir spill threshold.

8.37.2 Eastside to Butte Basin

8.37.2.1 Int_eastside
Int_eastside is a user-defined integer (0, 1) variable that determines whether the control structures are spilling or not.

8.37.2.2 Q_Overflow
Q_ColusaWeir is a user-defined standard LP variable that represents the spill over the Colusa Weir.

8.37.2.3 Q_Overflow Eqn1
The UDC *Q_Overflow Eqn1* sets the variable *Q_Overflow* equal to the corresponding flow in the SacWAM schematic.

8.37.2.4 Q_Overflow Eqn2
The UDC *Q_Overflow Eqn2* calculates the spill over the control structures as a linear fraction of the upstream flow that is above the control structure spill threshold (*QSac_RM184_1*).

8.37.2.5 Q_Overflow HistFix
The UDC *Q_Overflow HistFix* sets the flow over the three overflow structures to the historical observed value. The UDC has been deactivated.

8.37.2.6 QSac_RM184
QSac_RM146 is a user-defined standard LP variable that represents the flow upstream from the control structures at Sacramento River RM 184.

8.37.2.7 QSac_RM184 Eqn1
The UDC *QSac_RM184 Eqn1* sets the variable *QSac_RM184* equal to the corresponding flow in the SacWAM schematic.

8.37.2.8 QSac_RM184 Eqn2
The UDC *QSac_RM184 Eqn2* disaggergates the flow *QSac_RM184* into *QSac_RM184_0* and *QSac_RM184_1*, which represent the components of flow below and above the weir threshold flow of 90,000 cfs.

8.37.2.9 QSac_RM184 Eqn3
The UDC *QSacRM184* Eqn3 sets the upper bound of the variable *QSac_RM184_0* to be 1 cfs greater than the spill threshold.

8.37.2.10 QSac_RM184 Eqn4
The UDC *QSacRM184 Eqn4* sets the lower bound on the flow component *QSac_RM184_0* depending on whether the weir is spilling (*int_eastside* = 1).

8.37.2.11 QSac_RM184 Eqn5
The UDC *QSacRM184 Eqn5* sets the upper bound on the flow component *QSac_RM184_1* depending on whether the weir is spilling (*int_eastside* = 1).

8.37.2.12 QSac_RM184_0
QSac_RM184_0 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is below the weir spill threshold.

8.37.2.13 QSac_RM184_1
QSac_RM184_1 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the weir spill threshold.

8.37.3 Fremont Weir

8.37.3.1 Int_Fremont
Int_Fremont is a user-defined integer (0, 1) variable that determines whether the weir is spilling or not.

8.37.3.2 Q_FremontWeir
Q_ColusaWeir is a user-defined standard LP variable that represents the spill over the Colusa Weir.

8.37.3.3 Q_FremontWeir Eqn1
The UDC *Q_FremontWeir Eqn1* sets the variable *Q_FremontWeir* equal to the corresponding flow in the SacWAM schematic.

8.37.3.4 Q_FremontWeir Eqn2
The UDC *Q_FremontWeir Eqn2* calculates the spill over the Fremont Weir as a linear fraction of the upstream flow that is above the weir spill threshold (*QSac_RM82_1*).

8.37.3.5 Q_FremontWeir HistFix
The UDC *Q_FremontWeir HistFix* sets the flow over the weir to the historical observed value. The UDC has been deactivated.

8.37.3.6 QSac_RM82
QSac_RM82 is a user-defined standard LP variable that represents the flow immediately upstream from the Fremont Weir at Sacramento River RM 82.

8.37.3.7 QSac_RM82 Eqn1
The UDC *QSac_RM82 Eqn1* sets the variable *QSac_RM82* equal to the corresponding flow in the SacWAM schematic.

8.37.3.8 QSac_RM82 Eqn2
The UDC *QSac_RM82 Eqn2* disaggergates the flow *QSac_RM82* into *QSac_RM82_0* and *QSac_RM82_1*, which represent the components of flow below and above the weir threshold flow of 43,710 cfs.

8.37.3.9 QSac_RM82 Eqn3
The UDC *QSacRM82* Eqn3 sets the upper bound of the variable *QSac_RM82_0* to be 1 cfs greater than the spill threshold.

8.37.3.10 QSac_RM82 Eqn4
The UDC *QSacRM82 Eqn4* sets the lower bound on the flow component *QSac_RM82_0* depending on whether the weir is spilling (*int_fremont* = 1).

8.37.3.11 QSac_RM82 Eqn5
The UDC *QSacRM82 Eqn5* sets the upper bound on the flow component *QSac_RM82_1* depending on whether the weir is spilling (*int_fremont* = 1).

8.37.3.12 QSac_RM82_0
QSac_RM82_0 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is below the weir spill threshold.

8.37.3.13 QSac_RM82_1
QSac_RM82_1 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the weir spill threshold.

8.37.4 Moulton Weir

8.37.4.1 Int_Moulton
Int_Moulton is a user-defined integer variable (0, 1) that determines whether Moltom Weir is spilling or not.

8.37.4.2 Q_MoultonWeir
Q_MoltonWeir is a user-defined standard LP variable that represents the monthly spill over Moulton Weir.

8.37.4.3 Q_MoultonWeir Eqn1
The UDC *Q_MoultonWeir Eqn1* sets the variable *Q_MoultonWeir* equal to the corresponding flow in the SacWAM schematic.

8.37.4.4 Q_MoultonWeir Eqn2
The UDC *Q_MoultonWeir Eqn2* calculates the spill over the Moulton Weir as a linear fraction of the portion of the upstream flow (*QSac_RM158_1*) that is above the weir spill threshold (60,000 cfs).

8.37.4.5 Q_MoultonWeir HistFix
The UDC *Q_MoultonWeir HistFix* sets the flow over the weir to the historical observed value. The UDC has been deactivated.

8.37.4.6 QSac_RM158
QSac_RM158 is a user-defined standard LP variable that represents the Sacramento River flow immediately upstream from the Moulton Weir at RM 158.

8.37.4.7 QSac_RM158 Eqn1
The UDC *QSac_RM158 Eqn1* sets the variable *QSac_RM158* equal to the corresponding flow in the SacWAM schematic.

8.37.4.8 QSac_RM158 Eqn2
The UDC *QSac_RM146 Eqn2* disaggergates the flow *QSac_RM146* into *QSac_RM146_0* and *QSac_RM146_1*, which represent the components of flow below and above the weir threshold flow of 60,000 cfs.

8.37.4.9 QSac_RM158 Eqn3
The UDC *QSacRM158* Eqn3 sets the upper bound of the variable *QSac_RM158_0* to be 1 cfs greater than the spill threshold.

8.37.4.10 QSac_RM158 Eqn4
The UDC *QSacRM158 Eqn4* sets the lower bound on the flow component *QSac_RM158_0* depending on whether the weir is spilling (*int_moulton* = 1).

8.37.4.11 QSac_RM158 Eqn5
The UDC *QSacRM158 Eqn5* sets the upper bound on the flow component *QSac_RM158_1* depending on whether the weir is spilling (*int_moulton* = 1).

8.37.4.12 QSac_RM158_0
QSac_RM158_0 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is below the weir spill threshold.

8.37.4.13 QSac_RM158_1
QSac_RM158_1 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the weir spill threshold.

8.37.5 Sacramento Weir

8.37.5.1 Int_Sacramento
Int_Sacramento is a user-defined integer (0, 1) variable that determines whether the Sacramento weir is spilling or not.

8.37.5.2 Q_SacWeir
Q_ColusaWeir is a user-defined standard LP variable that represents the spill over the Colusa Weir.

8.37.5.3 Q_SacWeir Eqn1
The UDC *Q_SacramentoWeir Eqn1* sets the variable *Q_SacramentoWeir* equal to the corresponding flow in the SacWAM schematic.

8.37.5.4 Q_SacWeir Eqn2
The UDC *Q_SacWeir Eqn2* calculates the spill over the Sacramento Weir as a linear fraction of the upstream flow that is above the weir spill threshold (*QSac_RM63_1*).

8.37.5.5 Q_SacWeir HistFix
The UDC *Q_SacWeir HistFix* sets the flow over the weir to the historical observed value. The UDC has been deactivated.

8.37.5.6 QSac_RM63
QSac_RM63 is a user-defined standard LP variable that represents the flow immediately upstream from the Sacramento Weir at Sacramento River RM 63.

8.37.5.7 QSac_RM63 Eqn1
The UDC *QSac_RM63 Eqn1* sets the variable *QSac_RM63* equal to the corresponding flow in the SacWAM schematic.

8.37.5.8 QSac_RM63 Eqn2
The UDC *QSac_RM63 Eqn2* disaggergates the flow *QSac_RM63* into *QSac_RM63_0* and *QSac_RM63_1*, which represent the components of flow below and above the weir threshold flow of 73,000 cfs.

8.37.5.9 QSac_RM63 Eqn3
The UDC *QSacRM63* Eqn3 sets the upper bound of the variable *QSac_RM63_0* to be 1 cfs greater than the spill threshold.

8.37.5.10 QSac_RM63 Eqn4
The UDC *QSacRM63 Eqn4* sets the lower bound on the flow component *QSac_RM63_0* depending on whether the weir is spilling (*int_sacramento* = 1).

8.37.5.11 QSac_RM63 Eqn5
The UDC *QSacRM63 Eqn5* sets the upper bound on the flow component *QSac_RM63_1* depending on whether the weir is spilling (*int_sacramento* = 1).

8.37.5.12 QSac_RM63_0
QSac_RM63_0 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is below the weir spill threshold.

8.37.5.13 QSac_RM63_1
QSac_RM63_1 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the weir spill threshold.

8.37.6 Tisdale Weir

8.37.6.1 Int_tisdale1
Int_Tisdale1 is a user-defined integer (0, 1) variable that determines whether the Tisdale weir is spilling or not.

8.37.6.2 Int_tisdale2
Int_Tisdale1 is a user-defined integer (0, 1) variable that determines whether the Tisdale weir is spilling, and the spill is above the threshold of 8,000 cfs.

8.37.6.3 Int_tisdale3
Int_Tisdale1 is a user-defined integer (0, 1) variable that determines whether the Tisdale weir is spilling, and the spill is above the threshold of 8,000 cfs + 5,760 cfs.

8.37.6.4 Q_TisdaleWeir
Q_ColusaWeir is a user-defined standard LP variable that represents the spill over the Colusa Weir.

8.37.6.5 Q_TisdaleWeir Eqn1
The UDC *Q_TisdaleWeir Eqn1* sets the variable *Q_TisdaleWeir* equal to the corresponding flow in the SacWAM schematic.

8.37.6.6 Q_TisdaleWeir Eqn2
The UDC *Q_TisdaleWeir Eqn2* calculates the spill over the Tisdale Weir as a linear fraction of the upstream flow that is above the weir spill threshold (*QSac_RM119_1, QSac_RM119_2, QSac_RM119_3*).

8.37.6.7 Q_TisdaleWeir HistFix
The UDC *Q_TisdaleWeir HistFix* sets the flow over the weir to the historical observed value. The UDC has been deactivated.

8.37.6.8 QSac_RM119
QSac_RM119 is a user-defined standard LP variable that represents the flow immediately upstream from the Tisdale Weir at Sacramento River RM 119.

8.37.6.9 QSac_RM119 Eqn1
The UDC *QSac_RM119 Eqn1* sets the variable *QSac_RM119* equal to the corresponding flow in the SacWAM schematic.

8.37.6.10 QSac_RM119 Eqn2
The UDC *QSac_RM119 Eqn2* disaggregates the flow *QSac_RM119* into *QSac_RM119_0* and *QSac_RM119_1*, which represent the components of flow below and above the weir threshold flow of 10,000 cfs.

8.37.6.11 QSac_RM119 Eqn3
The UDC *QSacRM119* Eqn3 sets the upper bound of the variable *QSac_RM119_0* to be 1 cfs greater than the spill threshold.

8.37.6.12 QSac_RM119 Eqn4
The UDC *QSacRM119 Eqn4* sets the lower bound on the flow component *QSac_RM119_0* depending on whether the weir is spilling (*int_tisdale* = 1).

8.37.6.13 QSac_RM119 Eqn5

The UDC *QSacRM119 Eqn5* sets the upper bound on the flow component *QSac_RM119_1* depending on whether the weir is spilling (*int_tisdale* = 1).

8.37.6.14 QSac_RM119 Eqn6

The UDC *QSacRM119 Eqn5* sets the lower bound on the flow component *QSac_RM119_1* depending on whether the weir is spilling (*int_tisdale* = 2).

8.37.6.15 QSac_RM119 Eqn7

The UDC *QSacRM119 Eqn5* sets the upper bound on the flow component *QSac_RM119_2* depending on whether the weir is spilling (*int_tisdale* = 2).

8.37.6.16 QSac_RM119 Eqn8

The UDC *QSacRM119 Eqn5* sets the lower bound on the flow component *QSac_RM119_2* depending on whether the weir is spilling (*int_tisdale* = 3).

8.37.6.17 QSac_RM119 Eqn9

The UDC *QSacRM119 Eqn5* sets the upper bound on the flow component *QSac_RM119_3* depending on whether the weir is spilling (*int_tisdale* = 3).

8.37.6.18 QSac_RM119_0

QSac_RM119_0 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is below the weir spill threshold of 10,000 cfs.

8.37.6.19 QSac_RM119_1

QSac_RM119_1 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the weir spill threshold, up to the first break point (10,000 cfs + 8,000 cfs).

8.37.6.20 QSac_RM119_2

QSac_RM119_2 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the the first break point but below the second break point (10,000 cfs + 8,000 cfs + 5,760 cfs).

8.37.6.21 QSac_RM119_3

QSac_RM119_3 is a user-defined standard LP variable that represents the portion of the upstream Sacramento River flow that is above the second break point.

8.37.7 Weir Tolerance

This UDC is not defined or used.

8.38 Yuba County WA

Yuba WA's[83] Yuba River Development Project is described in Section 7.9.23. The project includes three separate powerhouses: New Colgate Powerhouse and the New Bullards Bar (minimum instream flow) Powerhouse located at New Bullards Bar Dam and Narrows 2 Powerhouse located at Englebright Dam. Narrows 1 Powerhouse, which is owned by PG&E, supplements Narrows 2 Powerhouse. Both Narrows 1 and 2 powerhouses draw water directly from Englebright Reservoir. Flow through these powerhouses is represented in SacWAM by the diversion arc *Narrows Powerhouse I and II*. The maximum diversion through this arc is 4,120 cfs. An IFR placed on the *Narrows Powerhouse I and II* arc is also set to 4,120 cfs. The IFR priority is set so that it can draw water from New Bullards Bar storage when the storage volume is above buffer storage.

8.38.1 TargetStorageRelease

The UDC *YCWA TargetStorageRelease* curtails discretionary hydropower releases from New Bullards Bar Dam that would result in flows at Englebright Dam in excess of the combined capacity of the Narrows I and II powerhouses. The constraint requires that the flow through *Narrows Powerhouse I and II* be less than the sum of the capacity of New Colgate Powerhouse, the flow requirement below New Bullards Bar Dam, outflows from the Middle and South Yuba, and local (natural) inflow to Englebright Reservoir.

[83] Yuba County Water Agency changed its name to Yuba Water Agency in 2018. The SacWAM data tree has not been revised.

9 Key Assumptions

SacWAM is designed to provide the model user flexibility in simulating system operations by defining a set of model settings or controls known as 'Key Assumptions.' These controls can be accessed in the WEAP Data view under Key Assumptions. This chapter describes each control.

- Key Assumptions
  - Allocation Reduction
  - Climate
  - ClimateDir
  - Constrain GW Pumping
  - ConstrainResStorageToHistoricalAvgMonthly
  - ConstrainResStorageToHistoricalTimeseries
  - Crop Area Reduction
  - PCWA MFP FERC License
  - Reservoir Buffering
  - Simulate Hydrology
  - Simulate Operations
  - Simulate SWRCB IFRs
  - SWRCB_IFR
  - Units
  - Use Baseline Trinity Imports
  - Use Water Board Vernalis Inflow

9.1 Allocation Reduction

Key Assumptions located under *Allocation Reduction* are used as multiplicative factors to reduce CVP and SWP allocations to their contractors beyond the reduction that occurs through the logic described in Sections 7.4.3 and 7.4.8. Ten different allocation types can be adjusted using these factors, as shown below. *Allocation Reduction* factors should have values between 0 and 1.

- Allocation Reduction
  - CVP Ag NOD
  - CVP Ag SOD
  - CVP Exchange
  - CVP MI NOD
  - CVP MI SOD
  - CVP Refuge NOD
  - CVP Refuge SOD
  - CVP Settlement
  - SWP Settlement
  - SWP SOD
  - Allow MI Reduction to 25percent
  - Allow Further SC EX Reductions

Allow MI Reduction to 25percent is a switch that when activated allows CVP M&I reductions of up to 75%. *Allow Further SC EX Reductions* is a switch that when activated allows CVP Settlement and Exchange Contractor allocations to be reduced by more than the 25% and 23% currently imposed in Shasta Critical Years.

9.1.1 CVP Ag NOD

Allocation reduction factor for CVP North of Delta Agriculture allocations, assumed to be 1.

9.1.2 CVP Ag SOD

Allocation reduction factor for CVP South of Delta Agriculture allocations, assumed to be 1.

9.1.3 CVP Exchange

Allocation reduction factor for CVP Exchange allocations, assumed to be 1.

9.1.4 CVP MI NOD

Allocation reduction factor for CVP North of Delta M&I allocations, assumed to be 1.

9.1.5 CVP Refuge NOD

Allocation reduction factor for CVP North of Delta Refuge allocations, assumed to be 1.

9.1.6 CVP Refuge SOD

Allocation reduction factor for CVP South of Delta Refuge allocations, assumed to be 1.

9.1.7 CVP Settlement

Allocation reduction factor for CVP Settlement allocations, monthly values based on whether VA simulation is on.

9.1.8 SWP Settlement

Allocation reduction factor for SWP Settlement allocations (Feather River Service Area), assumed to be 1.

9.1.9 Allow MI Reduction to 25 percent

Switch to allow CVP MI allocations as low as 25 percent, i.e., a 75% reduction.

9.1.10 Allow Further SC EX Reductions

Switch to allow further reductions in Sacramento River Settlement Contractor allocations beyond the 25% reduction specified in CVP contracts and further reductions in ExchangeContractor allocations beyond the 23% reduction specified in CVP contracts.

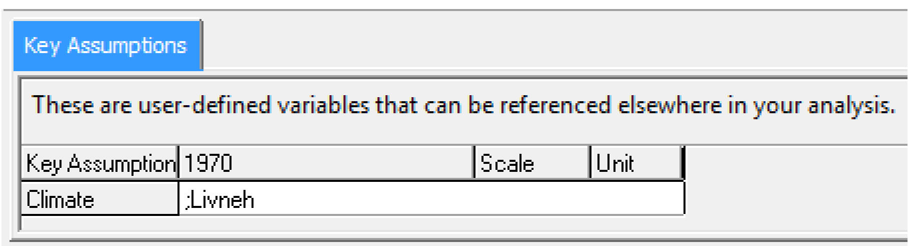
9.2 Climate and ClimateDir

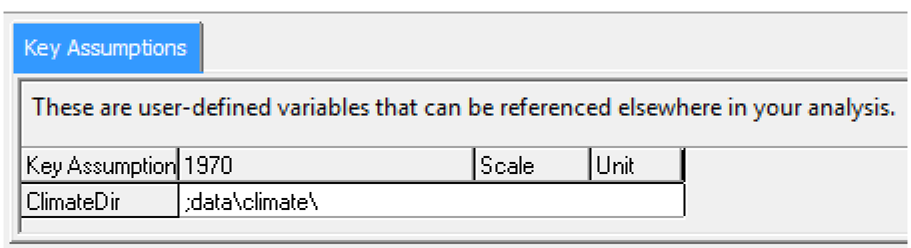
There are two Key Assumptions that specify the climate input data to be used during model simulation. The parameter *Climate* specifies the name of the subdirectory located under 'data\climate' that contains the climate data to be used by WEAP's Soil Moisture Model and MABIA module. Currently, there are 3 possible options, as follows:

- 'Livneh,' which contains historical climate inputs derived from the Livneh et al. (2013) dataset as described in Sections 5.2.1.
- 'PRISM,' which contains historical climate inputs derived from the PRISM Group at Oregon State University as described in Section 5.2.1.
- 'PRISMLivneh2,' which is a combination of datasets: PRISM data for the valley floor and Livneh for the upper watersheds.

If another climate dataset is to be used, the model user must create a new subdirectory within 'data\climate' and enter the name of the new subdirectory into the *Climate* Key Assumption. In specifying the directory and subdirectory, the WEAP software uses a semi-colon (;) to signify a text string.

The *ClimateDir* parameter specifies the location or path of the climate data within the model directory. Currently, this parameter is set at 'data\climate' and likely does not need to be changed by the model user.





9.3 Constrain GW Pumping

The Key Assumption *Constrain GW Pumping* affects model access to groundwater. A value of '1' adds limits the availability of groundwater to meet catchment demands; a value of '0' does not impose groundwater pumping limits in the model. If a value of '1' is entered, constraints are placed on the groundwater transmission links based on information in the file Data\Groundwater\GroundwaterLimits.csv. Typically, this file is used to constrain groundwater pumping in scenarios to amounts simulated during a base run. For more details on model limits to groundwater pumping, refer to the Groundwater Pumping discussion in Section 3.4. The parameter *GW Tolerance* is used as a global multiplicative factor on timeseries data read from GroundwaterLimits.csv.

9.4 ConstrainResStoragetoHistoricalAvgMonthly

The Key Assumption *ConstrainResStoragetoHistoricalAvgMonthly* allows the user to choose between allowing SacWAM to regulate storage in the smaller reservoirs in the upper watersheds based on water allocation priorities, or to constrain reservoir storage to equal average monthly historical values. The latter option is achieved by assigning the Top of Conservation and the Top of Inactive to the same value read from a csv file. *ConstrainResStoragetoHistoricalAvgMonthly* can have a value of 0 or 1. A value of 1 will result in the use of average monthly historical storage levels.

Key Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time-Series Wizard.

Key Assumption	1922	Scale	Unit
FixedUpperResStorage	1; 0 = Set TOC and TOI to single values 1 = Fix TOC and TOI to average monthly storage		

ConstrainResStoragetoHistoricalAvgMonthly affects Top of Conservation and Top of Inactive storage for the following reservoirs:

- Combie Reservoir
- Scotts Flat Reservoir
- Sly Creek Reservoir
- Lake Valley Reservoir
- Little Grass Valley Reservoir
- Englebright Reservoir

9.5 ConstrainResStoragetoHistoricalTimeSeries

The Key Assumption *ConstrainResStoragetoHistoricalTimeSeries* is used to select between constraining upper watershed reservoirs to operate to their historical levels and allowing the model to dynamically simulate reservoir storage driven by downstream demands and reservoir operational requirements (e.g., flood control). *ConstrainResStoragetoHistoricalTimeSeries* can have a value of '0' or '1'. A value of '1' will result in the use of historical storage levels read from a csv file. This parameter was set to '1' during model calibration and validation exercises but should normally be set equal to '0' to allow the model logic to operate the reservoirs.

Key Assumptions

These are user-defined variables that can be referenced elsewhere in your analysis. For monthly variation, use Monthly Time-Series Wizard.

Key Assumption	1922	Scale	Unit
FixedRimResStorage	0; 0 = Operate reservoirs 1 = Fix reservoirs to historical timeseries		

ConstrainResStoragetoHistoricalTimeSeries affects bounds on *Top of Conservation*, *Top of Inactive*, and *Top of Buffer* parameters for the following reservoirs. Reservoir names that are italicized are where only the *Top of Inactive* parameter is constrained. Reservoir names that are bolded are where *Top of Buffer* is constrained also.

- **Antelope Reservoir**
- Black Butte Reservoir
- **Bowman Lake**
- **Bucks Lake**
- **Butt Valley Reservoir**
- Camanche Reservoir
- **Camp Far West Reservoir**
- **Caples Lake**
- **Clear Lake**
- ***CVP San Luis Reservoir***
- East Park Reservoir
- EBMUD Terminal Reservoir
- **Folsom Lake**
- **French Meadows Reservoir**
- **Frenchman Lake**
- **Hell Hole Reservoir**
- **Ice House Reservoir**
- Indian Valley Reservoir
- **Jackson Meadows Reservoir**
- Jenkinson Lake
- Keswick Reservoir
- **Lake Almanor**
- Lake Amador
- Lake Berryessa
- **Lake Davis**
- **Lake Fordyce**
- Lake Natoma
- **Lake Spaulding**
- Lewiston Lake
- **Loon Lake**
- Los Vaqueros Reservoir
- Lower Bear Reservoir
- **Merle Collins Reservoir**
- **Mountain Meadows Res.**
- **New Bullards Bar Reservoir**
- New Hogan Reservoir
- **Oroville Lake**
- Pardee Reservoir
- *Salt Springs Reservoir*
- **Shasta Lake**
- **Silver Lake**
- Stony Gorge Reservoir
- *Stumpy Meadows Reservoir*
- ***SWP San Luis Reservoir***
- Thermalito Afterbay
- Trinity Lake
- **Union Valley Reservoir**
- Whiskeytown Reservoir

9.6 Crop Area Reduction

The Key Assumptions located under *Crop Area Reduction* are used as multiplicative factors to reduce the irrigated crop acreage (ICA). The factors should be assigned values between 0 and 1.

- Crop Area Reduction
  - Bear Ag
  - Cache Creek Ag
  - CVP Ag NOD
  - CVP Refuge NOD
  - CVP Settlement
  - Delta Ag
  - Eastside Ag
  - Feather Ag
  - Minor Creeks
  - Putah Creek Ag
  - Sacramento Ag
  - Stanislaus
  - Stony Creek Ag
  - SWP Settlement
  - Yuba Ag

These factors are applied in the area expressions for the crops in each DU (see below). The factor is multiplied by the area for each crop class except for the Fallow class. For the Fallow class, the value of one minus the factor is multiplied by the total irrigated area of the DU in this class. The combination of these expressions reduces ICA by the factor and increases the fallow area by an equivalent amount, thereby maintaining the same total land area. Different DUs are affected by different reduction factors as shown in Table 9-1.

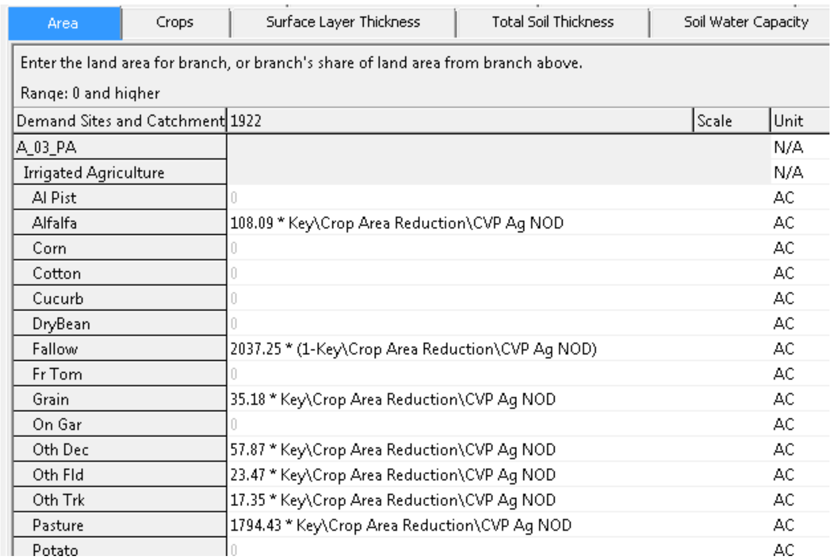


Table 9-1. Demand Unit Crop Area Reduction Factors and Associated Demand Units

Reduction Factor	DU Prefix	Affected Demand Units
Bear Ag	A_	23_NA, 24_NA1, 24_NA2, 24_NA3
Cache Creek Ag	A_	20_25_NA1
CVP Ag NOD	A_	02_PA, 03_PA, 04_06_PA1, 04_06_PA2, 07_PA, 08_PA, 16_PA, 21_PA
CVP Settlement	A_	02_SA, 03_SA, 08_SA1, 08_SA2, 08_SA3, 09_SA1, 09_SA2, 18_19_SA, 21_SA, 22_SA1
Delta Ag	A_	50_NA1, 50_NA2, 50_NA3, 50_NA4, 50_NA5, 50_NA6, 50_NA7
Eastside Ag	A_	60N_NA1, 60N_NA3, 60N_NA4, 60N_NA5, 60S_PA
Feather Ag	A_	12_13_NA
Minor Creeks	A_	02_NA, 03_NA, 04_06_NA, 05_NA, 10_NA
Putah Creek Ag	A_	20_25_NA2, 20_25_PA, SIDSH
Sacramento Ag	A_	08_NA, 09_NA, 11_NA, 16_NA, 17_NA, 18_19_NA, 21_NA, 22_NA
Stanislaus	A_	61N_NA2, 61N_NA3, 61N_PA
Stony Creek Ag	A_	04_06_NA1
SWP Settlement	A_	11_SA1, 11_SA2, 11_SA3, 11_SA4, 12_13_SA, 14_15N_SA, 15S_SA, 16_SA, 17_SA, 22_SA2
Yuba Ag	A_	14_15N_NA2, 14_15N_NA3, 15S_NA
CVP Refuge NOD	R_	None

9.6.1 Bear Ag

Crop reduction factor assumed to be 1.

9.6.2 Cache Creek Ag

Crop reduction factor assumed to be 1.

9.6.3 CVP Ag NOD

Crop reduction factor assumed to be 1.

9.6.4 CVP Refuge NOD

Crop reduction factor assumed to be 1.

9.6.5 CVP Settlement

Crop reduction factor based on monthly pattern depending on whether VA is simulated.

9.6.6 Delta Ag

Crop reduction factor assumed to be 1.

9.6.7 Eastside Ag

Crop reduction factor assumed to be 1.

9.6.8 Feather Ag

Crop reduction factor assumed to be 1.

9.6.9 Minor Creeks

Crop reduction factor assumed to be 1.

9.6.10 Putah Creek Ag

Crop reduction factor assumed to be 1.

9.6.11 Sacramento Ag

Crop reduction factor assumed to be 1.

9.6.12 Stanislaus

Crop reduction factor assumed to be 1.

9.6.13 Stony Creek Ag

Crop reduction factor assumed to be 1.

9.6.14 SWP Settlement

Crop reduction factor based on monthly pattern depending on whether VA is simulated.

9.6.15 Yuba Ag

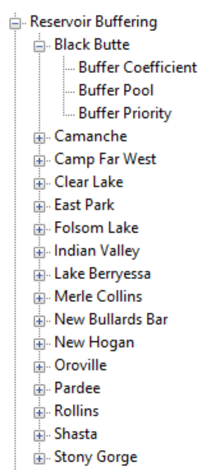
Crop reduction factor assumed to be 1.

9.7 PCWA MFP FERC License

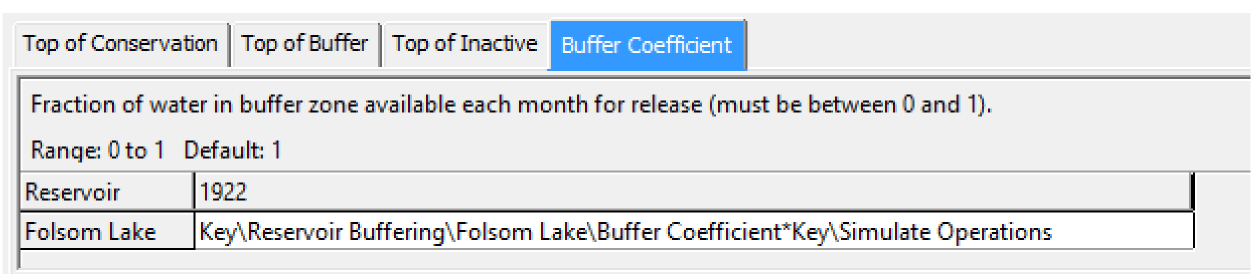
The Key Assumption, *PCWA MFP FERC* license, allows the user to choose between simulating MFP operations under the original FERC license, issued in 1963, or to simulate the requirements of the new license issued in 2020. For an assigned value of '0' (the default setting), SacWAM simulates the original license conditions.

9.8 Reservoir Buffering

The Key Assumptions under *Reservoir Buffering* can be used to set the buffer pool volume and buffer coefficient for selected reservoirs. These Key Assumptions were provided to simplify the specification of buffering parameters for reservoirs of interest to the State Water Board.



These Key Assumptions are, in turn, read into the expressions for *Top of Buffer*, *Buffer Coefficient*, and *Buffer Priority* parameters in the reservoir interface, as shown in the example below.



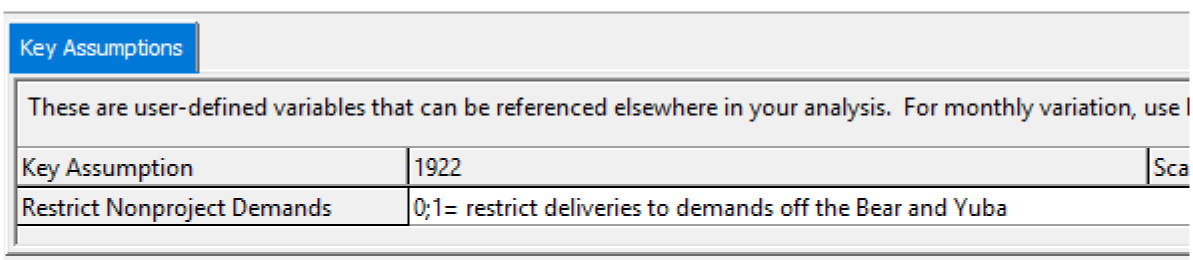
Recent model development refined local reservoir operations, and in many cases the buffering option was replaced with more precise logic. Table 9.2 presents buffer coefficients, buffer pool levels and buffer priority for reservoirs represented in SacWAM.

Table 9-2. Reservoir Buffer Coefficients, Buffer Pools, and Buffer Priorities

Reservoir	Buffer Coefficient	Buffer Pool (TAF)	Buffer Priority
Berryessa	1.00	0.10*Storage Capacity	0
Black Butter	1.00	0.20*Storage Capacity	0
Camanche	1.00	145	34
Camp Far West	0.15	45	0
Clear Lake	1.00	0.8*Storage Capacity	0
East Park	0.00	0	0
Folsom	1.00	0.31*Storage Capacity	66
Indian Valley	0.00	0	0
Merle Collins	0.00	0	15
New Bullards Bar	1.00	Historical Timeseries	0
New Hogan	1.00	0.10*Storage Capacity	0
Oroville	1.00	300+MonthlyValues(Oct, 1074, Nov, 1000, Dec, 1136, Jan, 1266, Feb, 1475, Mar, 1711, Apr, 1922, May, 2016, Jun, 1862, Jul, 1510, Aug, 1230, Sep, 1088)	99
Pardee	1.00	0.10*Storage Capacity	0
Rollins	0.00	0	15
Shasta	1.00	300+MonthlyValues(Oct, 1222, Nov, 1209, Dec, 1530, Jan, 1752, Feb, 2080, Mar, 2422, Apr, 2629, May, 2556, Jun, 2219, Jul, 1735, Aug, 1388, Sep, 1200)	99
Stony Gorge	1.00	0.10*Storage Capacity	33

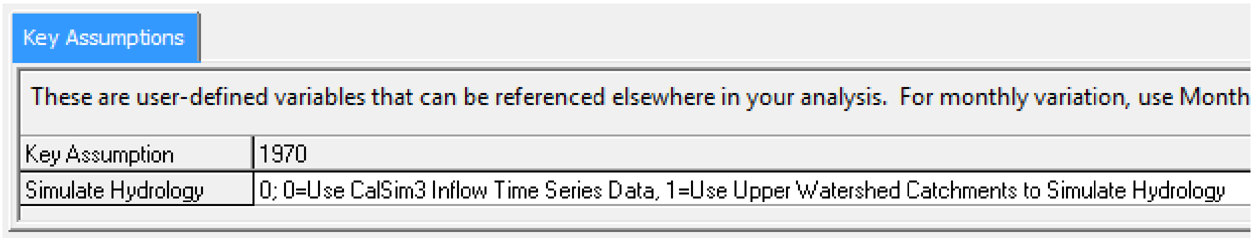
9.9 Restrict Nonproject Demands

The Key Assumption *Restrict Nonproject Demands* is used in State Water Board scenarios to constrain surface water deliveries to the values found in Data\Trans_link_fractionXX.csv, where XX refers to the unimpaired flow scenario. These restrictions are only applied in the Bear River and Yuba River basins. This parameter is not used in the Current Accounts and Existing scenario.



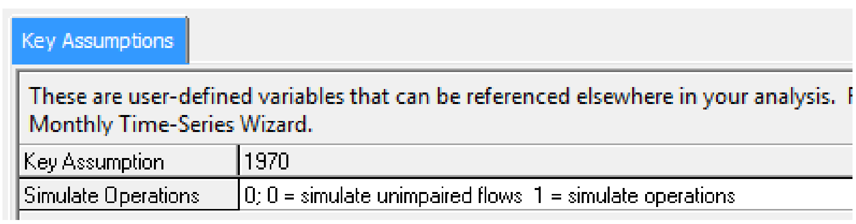
9.10 Simulate Hydrology

The Key Assumption *Simulate Hydrology* is used to select between preprocessed inflow time series data and model simulation of hydrological processes using WEAP catchment objects in the upper watersheds. *Simulate Hydrology* can be assigned a value of ‘0’ (default setting) or ‘1’. A value of ‘1’ activates WEAP’s catchment objects in SacWAM.[84] Hydrologic processes in the valley floor are always dynamically simulated. Currently, this Key Assumption cannot be altered; it is always set to use the preprocessed inflow time series data.



9.11 Simulate Operations

The Key Assumption *Simulate Operations* is used to select between two different simulation modes. For a parameter setting of ‘0’, SacWAM simulates unimpaired flows by ‘switching off’ or deactivating all reservoirs, diversions, IFRs, and transmission links. This option is provided so that the model can be used to generate unimpaired flow time series data for the creation of State Water Board proposed IFRs (see Section 9.12). If this variable is set to ‘1’ (default setting) then all operations/facilities are simulated.



9.12 Simulate SWRCB IFRs

A set of WEAP IFR objects were created in SacWAM to allow the State Water Board to study the effects of alternative flow requirements based on unimpaired flows. IFR objects were placed downstream from the major foothill reservoirs, on tributaries to the Sacramento River at their confluence with the Sacramento River, and at USGS and DWR gauge locations on the Sacramento River.

As described in Section 9.11, SacWAM was designed to run in an ‘unimpaired’ mode to generate time series data of unimpaired flows that can subsequently be used to create and evaluate new State Water Board flow requirements. In the unimpaired mode, all reservoirs, diversions, flow requirements, and transmission links are inactive. To implement an unimpaired model run and generate unimpaired monthly time series data for future use, the following steps should be followed:

1. Simulate Existing Conditions for full period.
2. Export groundwater pumping favorite to CSV file.
3. Copy (update) groundwater pumping limits CSV file to:

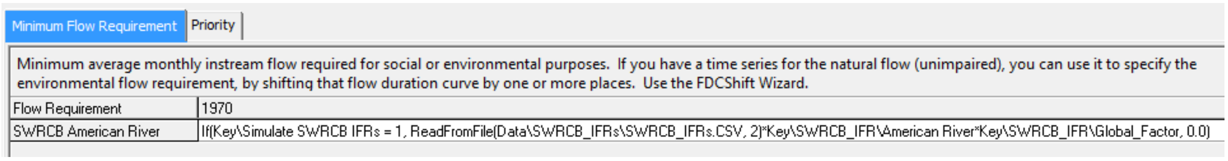
[84] Currently, several aspects of SacWAM operational logic are linked to the preprocessed time series data. Several model updates are required before SacWAM can completely use simulated hydrology in the upper watersheds.

/Data/Groundwater/GroundwaterLimits.csv

4. Make the following changes to Key Assumptions in Current Accounts:
   a. Key/Simulate Operations = 0
   b. Key/constrain GW Pumping = 1
5. Increase initial GW storage to 80 MAF for all GW basins.
6. Check Vernalis Headflow. If you do not want unimpaired Vernalis flows, change read from file expression.
7. Change Clear Lake reservoir parameters:
   a. Change Top of Conservation →Blank
   b. Change Top of Buffer →Blank
   c. Change Top of Inactive →842 TAF
   d. Change Storage Capacity →842
   e. Change Initial Storage →842
8. Turn off all User Defined Constraints.
9. Turn back on the following User Defined Constraints:
   a. Knights Landing Ridge Cut
   b. Weirs (you need to click on each weir)
   c. Delta Cross Channel
      i. GeorgeSlough
      ii. GeorgeSlough Eqn
      iii. QSacWG
      iv. Set GeorgeSlough
      v. Set C400
10. Check and adjust period of simulation.

Once steps 1 through 10 are complete, it will be possible to run SacWAM with operations and the SWRCB IFRs active and explore the impacts of new IFRs. To do so, set *Simulate Operations* and *Simulate SWRCB IFRs* to a value of '1' and reactivate UDCs. At runtime, SacWAM will now read time series data in the file 'SWRCB_IFRs.csv' and use this data to determine IFRs. The model user has the option of multiplying the time series values by a parameter found in *Key Assumptions\SWRCB_IFR*, which can be used to scale the unimpaired flow by a time-varying amount. For example, the time series data read from SWRCB_IFRs.csv by the IFR object located on the American River at its confluence with the

Sacramento River can be scaled by the parameter *Key Assumptions\SWRCB_IFR\American River*. Additionally, these IFRs can be scaled globally by *Key Assumptions\SWRCB_IFR\Global_Factor*.



9.13 SWRCB_IFR

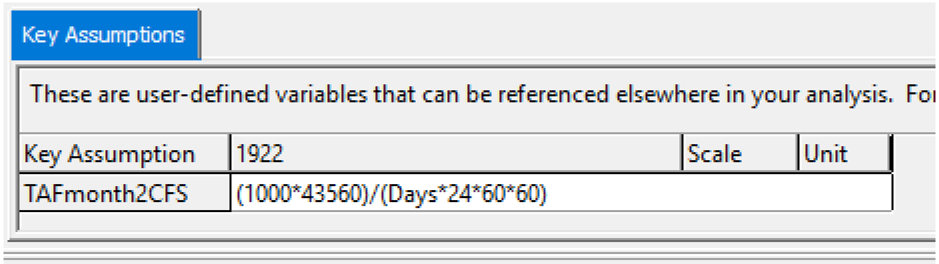
Table 9.3 lists streams and locations found in the data tree under SWRCB_IFR.

Table 9-3. SWRCB IFR Parameters

Parameter	Parameter Value	Parameter	Parameter Value
American River	1	M Yuba Inflow	1
Antelope Creek	1	Mill Creek	1
Battle Creek	1	Mokelumne River	1
Bear River	1	New Bullards Bar Inflow	1
Big Chico Creek	1	New Bullards Bar Outflow	1
Black Butte Inflow	1	New Hogan Outflow	1
Black Butte Outflow	1	Oroville Inflow	1
Butte Creek	1	Oroville Outflow	1
Cache Creek	1	Pardee Inflow	1
Calaveras River	1	Putah Creek	1
Camanche Inflow	1	S Yuba Inflow	1
Camanche Outflow	1	Sac ab Bend Bridge	1
Camp Far West Inflow	1	Sac at Butte City	1
Camp Far West Outflow	1	Sac at Colusa	1
Clear Creek	1	Sac at Freeport	1
Clear Creek Outflow	1	Sac at Hamilton	1
Consumnes River	1	Sac at Knights Landing	1
Cottonwood Creek	1	Sac at Ord Ferry	1
Cow Creek	1	Sac at Rio Vista	1
Deer Creek	1	Sac at Verona	1
Delta	1	Sac at Vina	1
Engelbright Inflow	1	Sac at Wilkins Slough	1
Engelbright Outflow	1	Shasta Outflow	1
Feather River	1	Stony Creek	1
Folsom Inflow	1	Thomes Creek	1
Folsom Outflow	1	Trinity Outflow	1
Global_Factor	1	Yuba River	1
Lake Berryessa Outflow	1		

9.14 TAFmonth2CFS

The parameter *TAFmonth2CFS* is a unit conversion factor to convert values that are in thousands of acre-feet per month to cubic feet per second.



9.15 Units

Different data sources use different units. The Key Assumptions under *Units* contain additional conversion factors.

9.15.1 cfs2m3

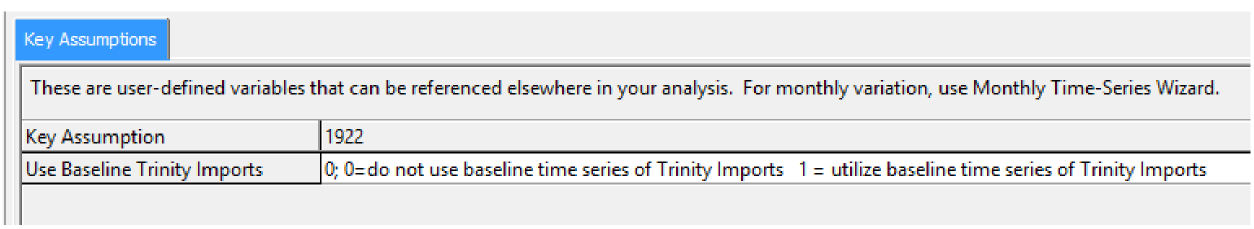
Conversion factor from cfs to cubic meters per month.

9.15.2 in2mm

Conversion factor from inches to millimeters.

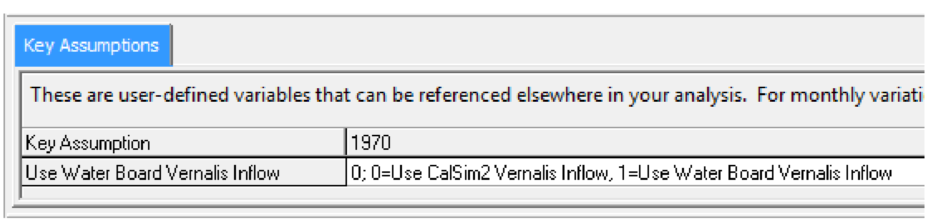
9.16 Use Baseline Trinity Imports

The *Use Baseline Trinity Imports* Key Assumption is used to specify whether the model should use a baseline time series of Trinity River imports through the Clear Creek Tunnel or dynamically determine these imports based on storage conditions in Trinity and Shasta reservoirs. If a value of ‘1’ is entered, a monthly time series of flows through the Clear Creek Tunnel will be read from Data\Diversions\SACVAL_ClearCreekTunnel_DiversionFlows.csv. If a value of ‘0’ is entered, the model will simulate Clear Creek Tunnel flows using the logic described in Section 7.4.9.



9.17 Use Water Board Vernalis Inflow

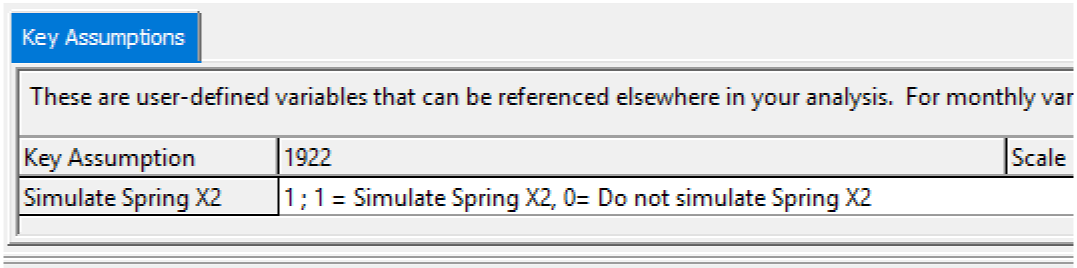
The Key Assumption *Use Water Board Vernalis Inflow* is used to select between two different sets of time series data for representing boundary inflows for the San Joaquin River at Vernalis. If a value of ‘0’



is selected, time series data derived from CalSim II/CalSim 3 is used. If a value of ‘1’ is selected, time series data developed during the State Water Board Phase 1 process is used.

9.18 Simulate Spring X2

The Key Assumption *Simulate Spring X2* is used to enable the simulation of the spring X2 flow requirement.



9.19 Simulate Fall X2

The Key Assumption *Simulate Fall X2* is used to enable the simulation of the fall X2 flow requirement.

9.20 Voluntary Agreement (VA)

The Key Assumption branch *VA* contains switches related to simulation of the elements of the proposed Voluntary Agreement (VA). The default setting for all switches is ‘0’, which indicates the VA elment is not simulated.

9.20.1 American VA

American VA is a switch to activate Voluntary Agreement requirements in the American River watershed.

9.20.2 Ann Blinding

ANN Blinding, when set to a value of ‘1’, prevents the CVP and SWP benefiting from Delta water quality improvements associated with increased Delta outdflow.

9.20.3 Export Reduction VA

Export Reduction VA is a switch to cut south-of-Delta exports to increase Net Delta outflow.

9.20.4 Feather VA

Feather VA is a switch to activate Voluntary Agreement requirements in the Feather River watershed.

9.20.5 Friant VA

Friant VA is a switch to activate Voluntary Agreement requirements in the San Joaquin River watershed associated with recapture of San Joaquin River Restoration flows.

9.20.6 Minimize Project Trib Reoperation

Minimize Project Trib Reoperation is a switch associated with simulation of the VAs. When this switch is set to a value of '1', a series of dummy networks are used to minimize any reoperation of CVP and SWP reservoirs caused by the VA.

9.20.7 Mokelumne VA

Mokelumne VA is a switch to activate Voluntary Agreement requirements in the lower Mokelumne River watershed.

9.20.8 Putah VA

Putah VA is a switch to activate Voluntary Agreement requirements in the Putah Creek watershed.

9.20.9 Sacramento VA

Sacramento VA is a switch to activate Voluntary Agreement requirements in the Sacramento River watershed. It is currently unused, and is overridden by the value of *Simulate VA*.

9.20.10 Simulate VA

Simulate VA is a switch to activate Voluntary Agreement requirements.

9.20.11 Tisdale Weir VA

Tisdale Weir VA is a switch to simulate the proposed Tisdale Weir notch. The parameter affects the simulation of spill over the Tisdale Weir.

9.20.12 Yuba Water Agency (YCWA)

9.20.12.1 YCWA Allocation
Assumed 0 (1 for YWA FERC relicensing allocations).

9.20.12.2 Schedule 6 GW Substitution
Schedule 6 GW Substitution is a switch to allow groundwater substitution (1 for On, 0 for Off).

9.20.12.3 GW Substitution
GW Substitution is a switch to allow GW substitutionin addition to Schedule 6.

9.20.12.4 SetGWSubstitutionHistorical
SetGWSubstitutionHistorical is a switch to simulate historical-based groundwater substitutions.

9.21 SFWPA

The Key Assumption SFWPA establishes flow requirements downstream from Lost Creek Diversion Dam and downstream from Forbestown Diversion Dam. These two facilities are part of the South Feather Water and Power Project, FERC No. 2088. When SFWPA is set to a value of 1, flow requirements are based on the 2018 Water Quality Cretification for the South Feather Water and Power Project. When SFWPA is set to a value of 0, flow requirements are from the existing FERC license.

9.22 RiceWinterFlooding

The maximum depth and target ponding depth for rice cultivation and for winter habitat and rice straw decomposition varies throughout the year. The Key Assumption RiceWinterFlooding allows different depths to be set depending on hydrologic conditions. Currently, the same depths are used for wet/normal years and dry/critical years.

9.23 CFS2TAF_NonLeap

Twelve conversion factors from cfs to TAF for different months of the year. The February conversion factor is based on 28 days in the month.

9.24 Putah Creek

9.24.1 BSM Assumptions

The BSM Assumptions switch was created during discussions with Solano ID regarding modeling of Putah Creek. The parameter may be set to a value of 0 or 1 and controls the following aspects of Putah Creek operations:

- Groundwater inflow to the reach of the stream below Lower Putah Diversion Dam
- Stream seepage losses in the reach below Lower Putah Diversion Dam
- Instream flow requirement below Lower Putah Diversion Dam
- Instream flow requirement below Interstate 80 Road Bridge
- Instream flow requirement below at outfall to Toe Drain

9.25 BiOp2019_ITP2020

A series of switches control which parts of the SWP Incidental Take Permit (ITP) are to be included in model simulation.

9.25.1 SMSCG_Fall

Fall operations of SMSCG are simulated for a parameter value of 1.

9.25.2 SMSCG_Summer

Summer operations of SMSCG are simulated for a parameter value of 1.

9.25.3 FallX2

Fall X2 simulated for a parameter value of 1.

9.25.4 HORB

Simulation of flow through from the San Joaquin River into the Head of the Old River is described in Section 7.5.2. The flow split is determined by a linear regression equation and the upstream San Joaquin River flow. The coeffcients of the equation are set according to whether the barrier at the Head of the Old River is installed. When the Key Assumption HORB is set to a value of 1, the Old River Barrier is assumed to be installed each spring.

9.25.5 FMS

American River FMS is simulated for a parameter value of 1.

9.25.6 OMR

OMR actions are simulated for a parameter value of 1.

9.25.7 SummerAction_100TAF

Additional SWP outflow is simulated for a parameter value of 1.

9.25.8 SJIE

SWP and CVP export constraints based on the San Joaquin River E:I ratio are described in Section 8.8.4. This export constraint is simulated when the Key Assumption SJIE is assigned a value of 1.

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10 Model Calibration and Validation

SacWAM was calibrated in a multi-step process that covered the upper watersheds, the Sacramento Valley floor, CVP/SWP project operations, and local agency project operations. These steps are as follows:

1. Calibration of the rainfall-runoff processes in the upper catchments located upstream from the valley floor because these calculations are independent of all other model processes.

    a. The Soil Moisture method hydrological parameters for these catchments were adjusted until simulated and observed historical flows matched within the design tolerance.[85]

2. Calibration of hydrologic processes occurring on the Sacramento Valley floor. The valley floor calibration is described in Appendix A.

    b. Simulated evapotranspiration values were calibrated to match values from DWR's CUP model.

    c. Simulated diversions for 2000-2009 were compared to historical observations and irrigation management parameters were adjusted as needed.

    d. Stream-aquifer interaction parameters were defined based on information from a C2VSim run.

    e. Valley floor runoff was calibrated to observed valley floor accretions at the Freeport gauge.

3. Operational logic under *Other Assumptions* and *User-Defined LP Constraints* were refined so that SacWAM simulated CVP and SWP operations reasonably match those simulated by the CalSim II model for water years 1922-2003.

4. Operational logic under *Other Assumptions* and *User-Defined LP Constraints* were refined so that SacWAM simulated local agency operations reasonably match observed reservoir storage and streamflow data for water years 1990-2009.

[85] The SacWAM peer review panel did not review the upper watershed calibration, because the use of the catchment objects has not been the focus of the model development.

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11 Model Use and Limitations

Over the last decade, computer simulation models have been widely used in California to support a diverse range of policy and regulatory decisions, planning processes, and environmental review. With expanding use of these models, it becomes increasingly important to identify the purpose for which the model has been developed, appropriate model use, and model limitations. This chapter briefly reviews these aspects of SacWAM.

11.1 Model Objective

SacWAM has been developed by the State Water Board to support an update of the 2006 Bay-Delta Plan. The model may be used to inform the following types of analyses as part of the agency's assessment of potential alternative regulatory requirements:

- Estimates of flow conditions under a range of alternative regulatory requirements.
- Estimates of changes in water diversions for use in an evaluation of the impacts of alternative regulatory requirements on agricultural resources, water suppliers, and groundwater.
- Estimates of changes in reservoir storage for use in an analysis of the impacts of alternative regulatory requirements on hydropower generation, recreation, and fisheries.
- To inform other analyses or models, such as Delta hydrodynamics, Delta water quality, water temperature, economic, and fisheries benefits models.

It is intended that SacWAM is transparent, easy to use, and freely available. The WEAP software and its interactive GUI were designed to facilitate a shared model vision. However, the SacWAM application is complex, highly detailed, and requires the model user to be familiar with both system operations modeling and California water. Additionally, SacWAM requires a significant investment of time to become familiar with the schematic, properties of objects, and user-defined variables and constraints. This imposes barriers to widespread model use.

The WEAP software is freely available to California water agencies. Before the development of SacWAM, all WEAP applications used a free MILP solver. However, given the unprecedented size and complexity of SacWAM, it was necessary to substitute the free solver with a commercial product (XA) to decrease run time and eliminate failures to solve. [86] To overcome the barriers to using SacWAM, the State Water Board has worked with the owners of the XA solver, Sunset Software Technology, to package the solver in the freely downloadable version of WEAP.

11.2 Appropriate Use of Model

SacWAM should be used in a comparative manner where model results for an alternative are compared to a base simulation. In the comparative analysis, differences in certain factors, such as deliveries or

[86] Solution time for a 10-year simulation period with the free solver is approximately 3 hours. In a test run, the free solver was forced to relax constraints in 14 months over the 10 years to find a feasible solution. Model run time with the XA solver for an 88-year period of simulation is less than 1.5 hours with no relaxation of constraints.

reservoir storage levels, are analyzed to determine the impact of the alternative. SacWAM should not be used in an absolute, stand-alone analysis in which model results are used to predict an outcome.

SacWAM results are believed to be more dependable in a comparative study than an absolute study. All assumptions are the same for baseline and alternative model runs, except the action itself, and the focus of the analysis is the differences in the results. Model errors, introduced through necessary simplification of the real world and which render absolute results unreliable, are assumed to be independent of the scenario being considered, so that these errors will largely cancel out in a comparative analysis.

11.3 Model Run Time Instructions

There are CSV files that are stored in SacWAM that contain results from a previous model run. These files are used to make forecasts for certain parameters in SacWAM, and therefore must be updated after the model is run. These files include the following:

- ReadFromFile(Data\Delta\SACWAM_Depletions.csv)
- ReadFromFile(Data\Diversions\SACVAL_ClearCreekTunnel_DiversionFlows.csv)
- ReadFromFile(Data\Groundwater\GroundwaterLimits.csv)
- ReadFromFile(Data\SWRCB_IFRs\SWRCB_IFRs.csv)
- ReadFromFile(Data\WYT\IFII.csv)
- ReadFromFile(Data\BiasCorrection\BiasCorrection.csv)
- ReadFromFile(Data\Weirs\SimulatedWeirFlows.csv)
- ReadFromFile(Data\WYT\FeatherInflow.csv)

11.4 Interpretation of Model Results

SacWAM is a long-term planning model developed for planning analysis. It is not intended to be used to support real-time reservoir operations and water delivery decisions. Although SacWAM uses historical hydrology to represent a reasonable range of water supply conditions, SacWAM does not simulate historical water operations. Simulated results for a particular year will not correspond to historical storage and flows and do not provide information about historical events. Model results are best interpreted using various statistical measures such as long-term or year-type averages.

11.4.1 Temporal Resolution

SacWAM uses a monthly time step for all operational decisions and for routing water through the SacWAM schematic. Operational requirements that affect daily management of water infrastructure are not included in the model, such as hourly flow ramping rate criteria. Average monthly flows may not accurately represent operations that respond to daily variability in water conditions, such as reservoir flood control operations. Therefore, disaggregation of monthly model results to finer time scales should be undertaken with caution and may not be an appropriate use of the model.

11.4.2 Spatial Resolution

SacWAM is built on a detailed spatial representation of the water supply network in the Sacramento Valley and Delta. However, the model necessarily simplifies the depiction of streamflows by aggregating surface water diversions, return flows, surface runoff, and groundwater inflows to the stream network. Only downstream from these points of aggregation will SacWAM accurately simulate streamflows.

11.4.3 Drought Conditions

SacWAM operational decisions are based on a set of predefined rules that represent existing regulations, contract agreements, and obligations. The model has no capability to dynamically adjust these rules based on extreme hydrologic events such as prolonged drought. For example, the model does not represent the Temporary Urgency Change Petitions (TUCP) that were submitted by DWR and Reclamation to the State Water Board in 2014, 2015, and 2021. The TUCPs resulted in temporary changes to Delta Cross Channel operations, Delta outflow requirements, and Delta export limits. Similarly, in 2014, drought conditions resulted in Reclamation meeting San Joaquin River exchange contractor water demands with a mix of Delta and San Joaquin River sources. Currently, SacWAM does not represent this type of operational change from a standard procedure. Under drought conditions, this model simplification results in challenges in operating CVP and SWP reservoirs and excessive reservoir draw down in particular years. Model results for drought conditions should be presented in terms of water year type averages, and extreme dry year operations, such as 1924, 1977, 1991, 2014 and 2015, should not be the focus of the analysis.

11.4.4 Time Horizon

The SacWAM simulation represents existing conditions, or approximately 2010/2015, for land use, population, and infrastructure, and 2020 regulatory environment. Currently, no model version has been developed for future (No Project/No Action) conditions, as may be required for environmental review and documentation.

11.5 Computational Methods

11.5.1 Objective Function

WEAP uses a MILP solver (XA) to solve a series of equations that seek to maximize an objective function that will best allocate water resources according to a user-defined set of delivery, flow, and storage priorities (weights). This set of equations also includes physical and operational constraints of the system as defined by the user.

The WEAP solution algorithm facilitates the development of the objective function by using a hierarchy of priorities, which are met sequentially. However, this approach prevents trade-offs between high priority objectives and those of lower priorities. It also limits model functionality and flexibility. For example, the model user cannot use negative weights to discourage certain actions.

11.5.2 Iterative Solution Technique

In SacWAM, the MILP solver does not optimize across multiple time steps or across multiple objectives. Rather, the MILP solver runs iteratively within each time step to allocate current water resources within the system, priority by priority. Successive solution of priorities and preferences are known as allocation orders. The WEAP algorithm moves sequentially through priority levels 1 through priority 99[87] before moving to the next time step and through supply preferences within a priority. Objectives achieved for a given allocation order are enforced as allocation constraints in all successive priorities and solutions.

Considerable time during model development was spent eliminating 'relaxation of constraint' errors caused by numerical rounding and the iterative WEAP solution technique. These problems were resolved using two approaches. The first approach was to slightly relax allocation constraints in cases where the constraint caused numerical instability. The second was to allow injection of small amounts of water to overcome model infeasibilities. The amounts injected are typically much less than 1 cfs, but in all new simulations the model user must check that amounts injected are not significant. The user can do this by checking the file WaterInjections.csv that is located in the WEAP Areas directory. Every instance in which WEAP injects additional water to overcome model infeasibilities is recorded as a row in the .csv file. Thus, the user can check that the values under the 'Volume Added [cfs]' column in this file are not significant.

11.5.3 Flexibility

WEAP has no ability to refer to values of decision variables established in previous allocation orders within the same time step. Regulations that require layering of requirements based on the previous state of the system (within the same time step) cannot easily be modeled. For example, simulation of SWP use of unused Federal share of water under COA requires model 'tricks' that make model operations less transparent. These tricks are described in Section 3.17.[88]

Typically, UDCs are active through all allocation orders.[89] Additionally, priorities are only active in one allocation order. For example, storage in a reservoir is only valued in one allocation order. Results from individual allocation orders prior to the final solution may not be meaningful.

11.5.4 Robustness

Model development has focused on the base simulation of existing conditions. Less effort has been focused on assessing the model over a wide range of alternative scenarios or conducting a sensitivity analysis to check that the model correctly responds to different changes in regulatory requirements. However, the State Water Board has worked with DWR staff to validate SacWAM using a comparative

[87] Beginning with WEAP version 2018.0105, the upper limit on the demand priority has been expanded from the default of 99 to 999,999,999.

[88] Beginning with WEAP version Version 2019.0007, the user may refer to values of LP variables from previous priorities in a user-defined LP constraint.

[89] SacWAM makes limited use of priority-based constraints, a relatively new feature in the WEAP software. Refer to Section 8.28.

analysis of a 50 percent unimpaired flow alternative to existing conditions. Additionally, State Water Board staff have carefully reviewed results from unimpaired flow scenarios.

11.6 Model Calibration and Validation

SacWAM is a monthly accounting tool. Some of the model's routines are physically based and can be calibrated to observed data, e.g., the MABIA root-zone daily soil moisture simulation. However, many aspects of SacWAM are not physically based, being simplifications of complex operating criteria and regulations. These management aspects of the model cannot be calibrated. Instead, SacWAM simulation has been validated through comparison with CalSim II, a management or planning model for the CVP and SWP.

11.7 Climate Change

Climate change is a key consideration in planning for the State's water management. California's aging water infrastructure was designed and built based on an analysis of historical hydrology. Past weather patterns have long been assumed to be representative of future conditions. However, as climate change continues to affect California, past hydrology is no longer a good guide to the future.

SacWAM uses a historical sequence of 94-years inflow hydrology and historical climate data to simulate both water supply and water demands. Currently, no climate change scenarios have been developed for the model. Additionally, no adaptive management actions or model code has been developed to help offset climate change effects. For example, reservoir flood space reservations could be adjusted in response to changing seasonal inflow patterns.

SacWAM offers two modes of simulation with respect to the upper watersheds: use of historical unimpaired inflows that are inputs to the model; and climate-driven runoff that is dynamically simulated using WEAP's catchment objects. Historical streamflow records are usually incomplete and unimpaired inflows input into the model are often derived using statistical techniques. Inflows have been developed assuming stationarity over the historical period and assuming that statistical relationships between (unimpaired) streamflows are constant. However, this assumption of stationarity is not appropriate when there has been significant land use change in the upper watersheds and may not be appropriate for the high elevation watersheds where global warming has affected the timing of snowmelt runoff. The effects of climate change can be simulated using the WEAP catchment objects as this effectively switches model inputs from streamflows to meteorological data such as precipitation, temperature, wind speed, and humidity.

The historical trace of natural hydrology and meteorology by itself, without modifications, may not be adequate for reliable modeling and reliable planning of nearterm conditions. Modeling of 'existing conditions' should be driven by reliable input hydrology reflecting current and near future conditions to produce modeling results representative of current conditions performance. Amongst the modeling community, there is a desire to continue to model baseline and climate change future projections as time series representations that broadly follow the historical sequence of events (i.e., allowing users to simulate a 1976–1977 drought under current/future conditions). However, as hydrology is now considered non-stationary, a more reliable representation of current conditions may require modification, or detrending, of observed runoff to account for global warming that has already occured, changes in the timing of runoff, and increased volatility of annual runoff volumes.

11.8 Sea-Level Rise

Sea levels have increased steadily over the past century and are projected to continue to increase throughout this century. Sea level rise will affect the eastward movement of salt into the Delta, requiring additional freshwater Delta outflow to repel salinity and meet existing Delta water quality standards. SacWAM uses an ANN embedded within the model to translate water quality standards to a Delta outflow requirement. The ANN was developed by DWR for use in its planning studies and seeks to emulate flow-salinity relationships derived from DWR's one-dimensional hydrodynamic and water quality model, DSM2. DWR has developed different versions of ANN that are appropriate for representing existing conditions, 2040, and 2070 conditions.

Currently, SacWAM has only been linked to the ANN for existing conditions. Additionally, no operational logic has been developed for potential adaptive management actions to address future Delta conditions affected by sea-level rise. The California Ocean Protection Council's (OPC) guidance, updated in 2018, gives the likely range (66% chance) of sea level rise by 2040 as 0.5 feet to 0.8 feet.

The ANN's have been 'trained' using CalSim II, CalSim 3, and DSM2 simulations for a broad range of Delta conditions. However, differences between SacWAM and CalSim hydrology may decrease the performance of the ANN for determining flow-salinity relationships and net Delta outflow for salinity control.

11.9 Model Limitations

This section discusses limitations of various aspects of SacWAM.

11.9.1 Watershed Hydrology

WEAP uses a one-dimensional lumped parameter hydrologic model to estimate monthly runoff, baseflow, ET, groundwater recharge, and soil water storage. The SacWAM domain is divided into upper watersheds and the valley floor. The upper watersheds are further divided into sub-catchments based on elevation so that the model can simulate snow accumulation and snowmelt processes. However, elevation bands are coarse (500 meters). Refinement of these elevation bands and additional calibration would improve simulated flows derived from input climate data (precipitation and temperature) or the upper watersheds. Currently, the model uses pre-processed inflow time series in the upper watersheds.

11.9.2 Land Use

SacWAM assumes that the irrigated area remains constant over the period of simulation and is independent of water supply. The modeled irrigated area is based on the observed irrigated area for the 10-year period 1998-2007. In reality, land dedicated to annual crops may be fallowed in drought years when surface water supplies are limited. Land fallowing and groundwater substitution may support north-of-Delta to south-of-Delta water transfers. These types of transfers are not simulated in SacWAM.

11.9.3 Water Supply Forecasts

SacWAM uses a mix of perfect foresight and forecasts to estimate water supply conditions. For example, water supply indices and water year types that determine many regulatory flow requirements may either be set equal to historical values or be dynamically forecasted based on simulated winter snowpack and regression analysis that associates snowpack within each of the watersheds to projected runoff. CVP and SWP contract allocations are based on current month reservoir levels and future inflows determined using 90 percent or 99 percent exceedance forecasts. However, SacWAM's simulation of local agency operations is typically based on perfect foresight of water supply conditions.

11.9.4 Upstream Watershed Operations

SacWAM implements a very simple approach in simulating most of the high elevation reservoirs in the upper watersheds of the Sierra Nevada mountain range. Typically, the top of buffer is defined based on historical observed storage under various hydrologic conditions. Above this level, reservoirs may make discretionary releases for hydropower. Below this level, reservoirs make only non-discretionary releases. Further refinement is needed to better simulate hydropower operations and simulate multi-purpose reservoirs that are operated for both hydropower and water supply.

11.9.5 Sacramento - San Joaquin Delta

The complexity of Delta channel flows and Delta salinity cannot be included in a flow-based accounting model, such as SacWAM. SacWAM does not dynamically simulate Delta water quality conditions that drives operation of Contra Costa WD's Los Vaqueros Project. Water quality at the district's Delta intakes is an input to the model.

In the default set-up, SacWAM uses values of Delta channel accretions and depletions that were developed by DWR for use in their planning models. While this maintains consistency with past analysis, there are inconsistencies between how NDOI is calculated for operations and real-time compliance and how channel depletions are represented in planning models.

11.9.6 San Joaquin River at Vernalis

San Joaquin River flows at the Airport Way bridge near Vernalis and associated water quality are inputs to SacWAM and must be derived from other modeling activities. SacWAM contains no dynamic links between San Joaquin River conditions at the Delta boundary and other parts of the model. San Joaquin River flows and salinity are treated as being independent of CVP and SWP water deliveries to the San Joaquin Valley, which are dynamically determined at run-time.

11.9.7 Groundwater

Ten groundwater basins are simulated in SacWAM using WEAP groundwater objects. Parameters governing the stream-groundwater interaction were calibrated to match results from DWR's distributed groundwater model of the Central Valley, C2VSim. Stream-groundwater interaction is simulated as a linear function of streamflow and may fluctuate in direction but is independent of groundwater levels. Thus, stream gains and losses are independent of the state of the underlying aquifer.

Simulation of groundwater storage in SacWAM may not be realistic as there is no feedback mechanism to limit groundwater outflow to the stream system as elevations fall (or conversely as elevations rise). SacWAM does not simulate subsurface lateral flows between groundwater basins.

11.9.8 Hydropower Operations

SacWAM does not simulate hydropower operations or power generation. Reservoirs with associated hydropower facilities are either simulated using a fixed rule curve, or for multi-purpose reservoirs it is assumed that hydropower generation is secondary to water supply objectives.

11.9.9 Water Temperature Objectives

CVP and SWP operations are often dictated by water temperature considerations. For example, the NMFS 2009 BiOp specifies actions to protect fall-, winter-, and spring-run chinook through cold water pool management of Shasta Lake. The BiOp establishes water temperature and compliance points at various locations on the Sacramento River above Bend Bridge and on Clear Creek (Action Suite 1.2). The 2009 BiOp also establishes objectives for end-of-September carryover storage in Shasta Lake. Long-term performance measures are specified in terms of exceedance.

SacWAM contains no specific actions to meet the requirements of Action Suite 1.2 contained in the NMFS 2009 BiOp. SacWAM cannot operate to meet exceedance-based performance criteria. SacWAM has no ability to translate water temperature-based objectives in to flow equivalents. The model specifies flow requirements below Keswick based on Reclamation modeling of CVPIA 3406(b)2 actions undertaken for the 2008 OCAP for the CVP and SWP. Post-processing of SacWAM results is required to assess exceedance-based metrics. Additional analysis using a water temperature model is required to assess water temperatures resulting from SacWAM actions. In the future, this type of analysis may result in refinement of current flow schedules implemented in SacWAM.

11.9.10 Biological Objectives

Regulatory requirements that were established to protect threatened and endangered fish species and their habitats are often triggered by metrics other than flow and storage. For example, the 2008 USFWS RPAs may be triggered by water temperatures, turbidity, spawning, migration, salvage, and results of fish surveys. These triggers cannot be dynamically implemented in SacWAM, and the model must use either flow surrogates or preset schedules of actions. For example, OMR reverse flow criteria, as simulated in SacWAM, will only approximate real-time decisions made by fishery management agencies.

11.9.11 CVPIA (b)(2)

SacWAM does not explicitly represent the Central Valley Project Improvement Act (CVPIA) 3406(b)(2) water allocation, management, and related actions. SacWAM does not simulate (b)(2) water but does implement pre-determined USFWS BiOp upstream fish objectives for Clear Creek, Sacramento River below Keswick Dam, and American River below Nimbus Dam, based on DWR and Reclamation assumptions for the CalSim II model.

11.9.12 Water Rights

Currently, the SacWAM portrayal of direct diversion and diversion to storage water rights is limited to major water agencies and water districts that divert from the Sacramento River and its major tributaries.

In general, the model assumes that agricultural growers hold water rights that are sufficient to irrigate the historical irrigated area.

The Sacramento River Settlement Contractors hold senior water rights for diversion of Sacramento River water. In a series of settlement contracts with Reclamation, these senior water right holders agreed to limit diversions of Sacramento River water in return for CVP water that is made available from April through October. Outside of this irrigation season, the contractors may divert under their own water rights. However, many of the water rights for diversion of winter water are junior to those of the CVP and SWP and may be curtailed by Term 91 (described below). SacWAM does not impose any limits on the diversion of winter water other than beneficial use.

Term 91 is a standard condition included in post-1965 water right permits and licenses that curtails these water right holder diversions when the Delta is in balanced conditions (i.e., the CVP and SWP are being operated to meet water quality standards in the Delta) and the CVP/SWP are releasing supplemental project water to meet in-basin entitlements. Supplemental project water is defined as water imported to the basin by the CVP/SWP and water released from CVP/SWP storage, which combined is in excess of project exports plus carriage water requirements. Term 91 is typically triggered in the late spring or summer and lifted in the fall or early winter. Term 91 has been triggered each year since 2012, except for 2017 when there were no curtailments. SacWAM does not represent Term 91.

11.9.13 Contract Allocations

The procedures used in SacWAM to compute allocations for CVP and SWP include lookup tables that estimate the amount of the available water supply that can be used for delivery and/or carryover storage. These lookup tables are referred to as the WSI-DI curves. The curves are developed through an iterative process wherein they are updated with each successive model run until the model can deliver the allotted allocation with no delivery deficits. The WSI-DI relationship depends on three key features of the modeled system: hydrology; water supply infrastructure; and the regulatory environment. If significant changes are applied to any of these three model elements, then new WSI-DI curves should be developed to prevent over or under allocation to CVP and SWP contractors. Currently, SacWAM has no automated procedures to develop new WSI:DI curves.

11.9.14 Water Transfers

Short-term water transfers are currently not simulated in SacWAM. Additionally, the lower Yuba water transfer program is not represented in SacWAM. Neither is the additional 500 cfs of regulatory capacity at Banks Pumping Plant represented in the model.[90] SacWAM does not represent the transfer of available CVP contract water from one group of users (e.g., Sacramento River Settlement contractors) to another group (e.g., agricultural water service contractors).

[90] The USACE permit for Clifton Court Forebay intake allows a maximum 3-day average diversion rate of 6,680 cfs, with additional diversion possible depending on Vernalis flows from December 15 to March 15. Additional capacity of 500 cfs (i.e., pumping limit of 7,180 cfs) is permitted (but not represented in SacWAM) to reduce the impact of NMFS BiOp Action 4.2.1 on the SWP, and transfer 'Component 1' water made available as part of the lower Yuba River Accord.

11.9.15 Model Output

User-defined variables associated with COA accounting, sharing of meeting in-basin use, and sharing available water in the Delta must be taken from intermediate solutions. Constraints that dictate the values of these variables are deactivated in priorities following Priority 83.

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Appendix A. Sacramento Valley Floor and Delta Calibration and Validation

A.1 Introduction

This appendix briefly describes calibration of SacWAM's internal hydrology routines for the valley floor domain and subsequent validation of the model through comparison with other simulation models (C2VSim, CalSim II) and historical observed data. Finally, results from a sensitivity analysis are presented.

A.1.1 Model Calibration

This appendix contains a description of the procedure used in the calibration of the simulated hydrological processes for every portion of the model downstream of the upper watersheds described in Appendix A. This applies to all catchment nodes, or DUs, that start with an "A_," "R_," or "U_." These objects utilize the MABIA module for hydrological calculations. During the calibration, the model was considered in parts in order to simplify the process and to isolate particular sections of the model. The process employed the following steps:

1. Evapotranspiration calibration
2. Irrigation management parameter calibration
3. Rainfall runoff calibration
4. Stream-aquifer interaction calibration

The first step was the calibration of the potential crop evapotranspiration (ET) processes. This process is independent of all other aspects of the model. ET input parameters were adjusted so that potential ETc matched target values. The focus was on agricultural crops as they dominate the land area on the valley floor.

Following the ET calibration the parameters that control the management of irrigation operations were specified. In effect, these parameters control the routing of water through the irrigation delivery and return flow management system and determine the irrigation efficiency and the relative amounts of water that go to deep percolation and surface runoff. These parameters include evaporation and seepage losses, tailwater fractions, operational spills, and reuse. For more details on these factors see Section 4.4 in the SacWAM model documentation. During the calibration these parameters were obtained from DWR. The final adjustment in this step was to adjust the flow through parameter on rice fields. This was done to bring simulated and observed deliveries into agreement.

The calibration of rainfall runoff and stream aquifer interactions were considered jointly as these processes are not independent from the other. Initially, stream-aquifer interactions were specified based on information derived from DWR's C2VSim model. Rainfall-runoff was then calibrated to historical observations of valley floor accretions during winter months. Additional analysis revealed the need for reexamination of the inflow hydrology from the upper watersheds during high-flow events. The final calibration target was Sacramento River flow at Freeport and total Delta inflows.

A.1.2 Model Validation

Following the discussion of the model calibration, this appendix presents a validation of simulated operations and water management of the CVP and SWP operations, as follows:

- SacWAM simulated operations of the CVP and SWP, referred to here as "project operations" are compared to CalSim II data for water years 1922-2003 (Section B.6), and are compared to historical data for water years 2010-2015 (Section B.7). This recent 6-year period reviews CVP and SWP operations rules following the release of biological opinions in 2008 and 2009 for the long-term operation of the two projects. The comparison includes flows in the American, Feather, and Sacramento Rivers that are dominated by project operations.
- SacWAM simulated operations of local district and agency operations, referred to as "non-project," are compared to historical observed streamflows (Section B.8) and reservoir storage (Section B.9). The period of comparison is water years 1996-2015. This comparison includes streamflows in the Mokelumne, Calaveras, Cosumnes, Bear, and Yuba rivers, and Stony, Cache, Putah, and Butte creeks. It also includes a comparison of inflows to Lake Folsom and Lake Oroville.

A.1.3 Sensitivity Analysis

The final section (B.10) in the appendix is a sensitivity analysis of evapotranspiration rates and the specified inflows at Vernalis on the San Joaquin River. This analysis provides an assessment of model sensitivity to assumptions made during the ET calibration. The Vernalis inflow analysis provides information about the sensitivity of Delta operations to the assumption of flow at this model boundary.

A.2 Evapotranspiration Calibration

A.2.1 Calibration to Basin Study ET values

Calibration of crop ET in SacWAM was conducted using crop ET rates derived from DWR's Consumptive Use Program (CUP) during the Sacramento – San Joaquin Basin Study. This source was chosen because it utilized a recently updated set of crop coefficients and crop season information (Reclamation, 2016).

The CUP model performs a single coefficient ET calculation:

ET = ETo x Kc

where:

ET – crop evapotranspiration

ETo – reference evapotranspiration

Kc – crop coefficient

The reference evapotranspiration is the ET rate for the reference crop, a well irrigated cool season grass, 4-6 inches in height. The crop coefficient is dependent on crop type and growth stage and reflects both the plant transpiration and bare soil evaporation. The CUP model uses a daily time step and representative crop coefficients and crop season length information compiled by DWR. In the calibration of SacWAM, ET rates were compared to values calculated using CUP during the Sacramento-San Joaquin Basin Study. The target ET rates were calculated for water year 2005 for the Davis region using reference ET values (ETo) obtained from the California Irrigation Management Information System (CIMIS) station located in Davis. These values are provided in Table A-1

In SacWAM, crop ET is calculated using the dual crop coefficient approach described in FAO 56 (Allen et al., 1998):

ET = ETo x (Kcb + Ke)

where:

ET – crop evapotranspiration

ETo – reference evapotranspiration

Kcb – basal crop coefficient

In the dual crop coefficient approach, the plant transpiration and bare soil evaporation are calculated separately. This approach allows for a more accurate accounting of bare soil evaporation as it explicitly takes into account the frequency and duration of rainfall and irrigation events which wet the soil. In SacWAM, this calculation is performed daily in the MABIA module. For the calibration, CUP derived monthly ET rates and seasonal ET (April to September) were compared to values derived from the demand unit A_20_25_NA1 which contains the Davis area. The objective was to adjust the basal crop coefficients until the bias in seasonal ET was less than +/- 5% (Table A-2). The resulting crop specific basal crop coefficients are found in the **crop library** (General>Crop Library). The data used in the calibration are in the **ET calibration** spreadsheet.

Table A-1. Water Year 2005 CUP Monthly Crop ET for Davis (inches)

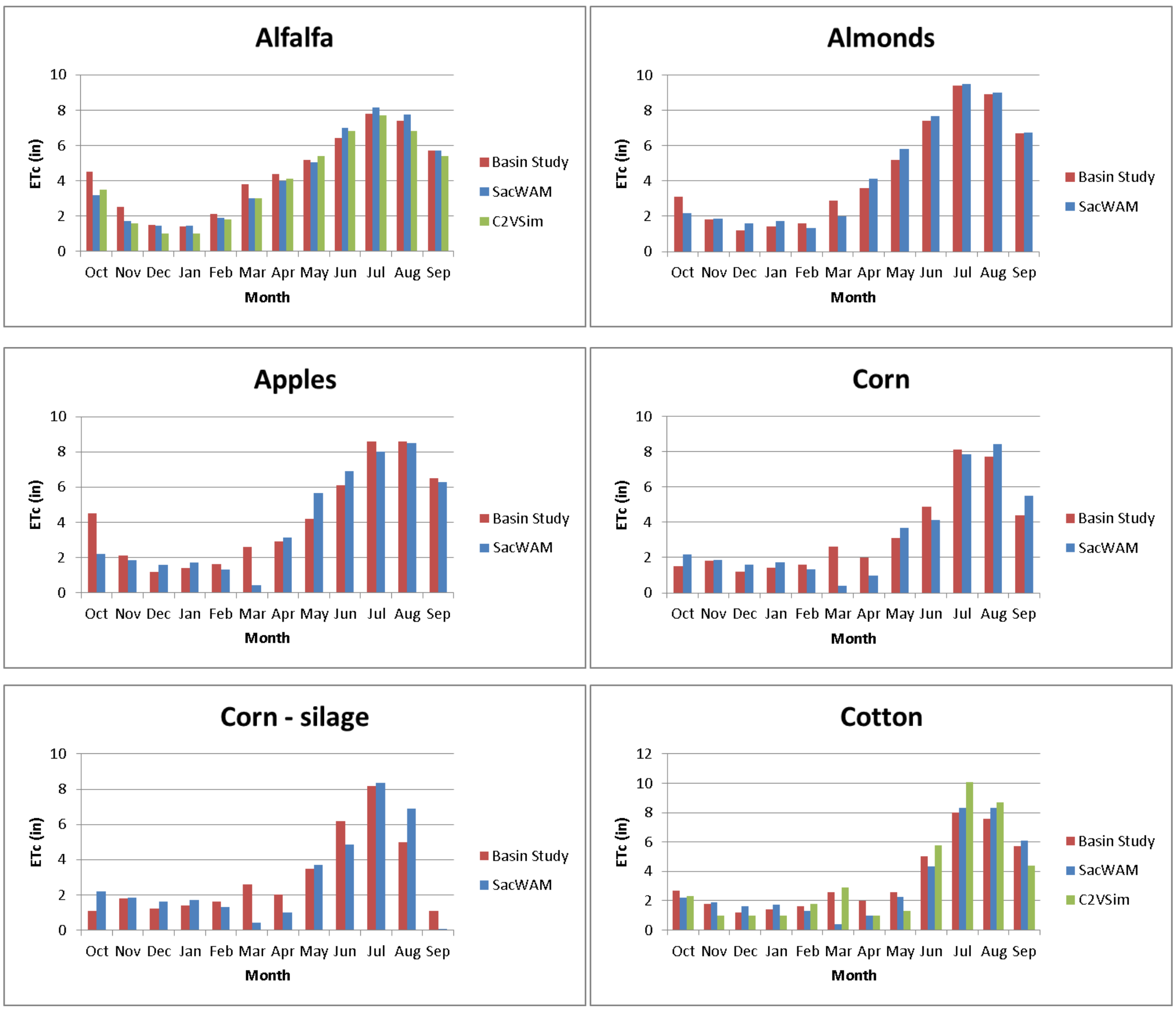
Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ann. Total	Apr-Sep
Alfalfa	4.5	2.5	1.5	1.4	2.1	3.8	4.4	5.2	6.4	7.8	7.4	5.7	52.7	36.9
Almonds	3.1	1.8	1.2	1.4	1.6	2.9	3.6	5.2	7.4	9.4	8.9	6.7	53.4	41.2
Other Deciduous/Apples	4.5	2.1	1.2	1.4	1.6	2.6	2.9	4.2	6.1	8.6	8.6	6.5	50.3	36.9
Corn	1.5	1.8	1.2	1.4	1.6	2.6	2	3.1	4.9	8.1	7.7	4.4	40.3	30.2
Other Field/Corn silage	1.1	1.8	1.2	1.4	1.6	2.6	2	3.5	6.2	8.2	5	1.1	35.6	26
Cotton	2.7	1.8	1.2	1.4	1.6	2.6	2	2.6	5	8	7.6	5.7	42.3	30.9
Other Truck	0.9	1.5	1	1.1	1.5	2.1	1.7	2.9	4.8	6.4	5.6	1.4	30.8	22.8
Dry Beans	1.5	1.8	1.2	1.4	1.6	2.6	2	2.1	2.3	5.8	8.1	5.1	35.5	25.4
Cucurbits/Melons	0.9	1.5	1	1.1	1.5	2.1	1.7	2.8	4.4	6.6	6.3	2.9	32.9	24.7
Onions	1.6	1.8	1.2	1.4	1.6	3	3.8	5.8	7.7	9.4	7.8	4.1	49.2	38.6
Subtropical/Oranges	4.5	2.5	1.5	1.4	2.1	3.8	4.4	5.2	6.4	7.8	7.4	5.7	52.7	36.9
Pasture	4.2	2.4	1.4	1.4	2	3.6	4.2	5	6.1	7.4	7.1	5.5	50.3	35.3
Potatoes	1.1	1.8	1.2	1.4	1.6	2.6	2.9	4.5	7.2	8.5	3.7	1.1	37.6	27.9
Rice	1.5	1.8	1.2	1.4	1.6	2.6	2	4.8	7.6	8.2	7.8	5.5	46	35.9
Safflower	1.1	1.8	1.2	1.4	1.6	2.6	2.9	5	6.8	5.5	2	0.9	32.7	23.1
Sugar Beets	1.5	1.8	1.2	1.4	1.6	2.8	3.3	5	7.3	9	8.5	5.9	49.3	39
Tomatoes	1.1	1.8	1.2	1.4	1.6	2.6	2	2.9	7	9.4	6.6	1.6	39.1	29.5
Vines	2.2	1.9	1.2	1.4	1.6	2.6	2.7	4	5.1	6.2	5.9	4.2	39	28.1
Wheat	0.9	2	1.2	1.1	1.9	3.2	3.9	2.7	1.5	1	0.7	0.5	20.6	10.3

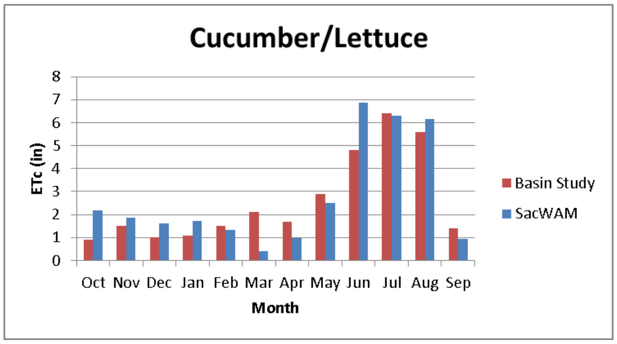
Source: Basin Study

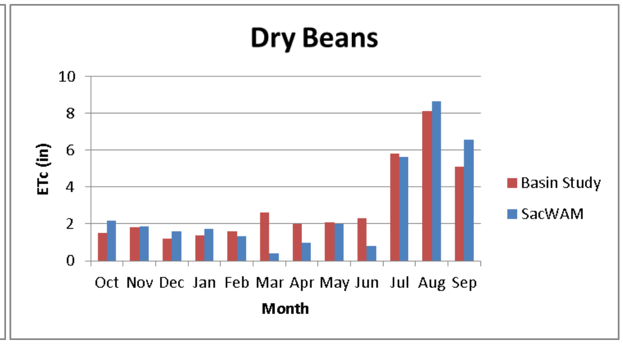
Table A-2. Water Year 2005 SacWAM Monthly Crop ET for DU A_20_25_NA1 (inches) and Seasonal Bias in Comparison to Basin Study Values

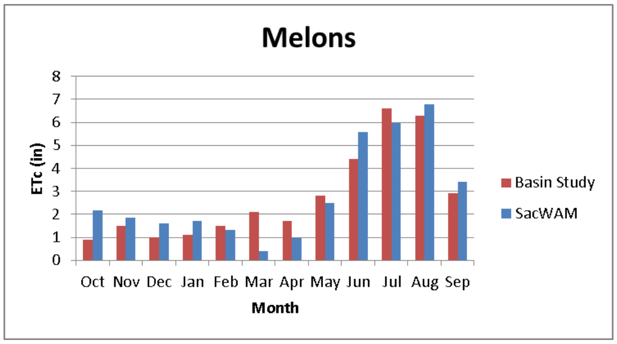
Crop	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Ann. Total	Apr-Sep	Apr-Sep Bias (%)
Alfalfa	3.18	1.70	1.46	1.45	1.91	3.00	3.97	5.03	7.01	8.17	7.76	5.72	50.36	37.66	2.1
Almonds	2.18	1.86	1.60	1.72	1.32	1.98	4.14	5.79	7.69	9.50	9.00	6.74	53.52	42.87	4.1
Other Deciduous/Apples	2.18	1.86	1.60	1.72	1.32	0.41	3.12	5.65	6.89	8.03	8.48	6.29	47.54	38.47	4.2
Corn	2.18	1.86	1.60	1.72	1.32	0.41	0.98	3.67	4.11	7.84	8.43	5.49	39.61	30.53	1.1
Other Field/Corn silage	2.18	1.86	1.60	1.72	1.32	0.41	0.98	3.71	4.87	8.36	6.88	0.01	33.88	24.80	-4.6
Cotton	2.18	1.86	1.60	1.72	1.32	0.41	0.98	2.28	4.36	8.31	8.34	6.07	39.40	30.32	-1.9
Other Truck	2.18	1.86	1.60	1.72	1.32	0.41	0.98	2.52	6.87	6.29	6.15	0.95	32.83	23.75	4.2
Dry Beans	2.18	1.86	1.60	1.72	1.32	0.41	0.98	1.99	0.80	5.63	8.67	6.59	33.74	24.66	-2.9
Cucurbits/Melons	2.18	1.86	1.60	1.72	1.32	0.41	0.98	2.49	5.57	5.98	6.78	3.41	34.29	25.21	2.1
Onions	2.18	1.86	1.60	1.72	1.32	2.38	4.37	5.97	7.84	9.10	8.16	4.03	50.53	39.47	2.3
Subtropical/Oranges	3.84	2.23	1.93	1.91	2.41	3.28	4.55	6.15	6.77	7.29	6.56	5.41	52.33	36.72	-0.5
Pasture	3.00	1.61	1.38	1.37	1.80	2.84	3.76	4.75	6.56	7.67	7.28	5.36	47.38	35.38	0.2
Potatoes	2.18	1.86	1.60	1.72	1.32	0.41	1.21	5.51	7.01	8.61	6.01	0.01	37.43	28.35	1.6
Rice	2.49	2.25	1.94	1.91	2.47	3.11	0.99	3.28	8.18	9.00	8.67	6.61	50.90	36.72	2.3
Safflower	2.18	1.86	1.60	1.72	1.32	0.41	2.13	4.87	6.92	7.21	1.38	0.01	31.60	22.52	-2.5
Sugar Beets	2.18	1.86	1.60	1.72	1.32	0.60	2.55	4.44	7.12	8.93	8.63	6.30	47.23	37.96	-2.7
Tomatoes	2.18	1.86	1.60	1.72	1.32	0.41	2.73	5.25	5.81	7.86	7.26	2.04	40.02	30.94	4.9
Vines	2.18	1.86	1.60	1.72	1.32	0.41	1.87	4.44	6.02	6.14	5.94	4.23	37.73	28.65	2.0
Wheat	2.18	2.14	1.91	1.85	2.08	2.68	4.09	4.78	1.06	0.03	0.01	0.01	22.80	9.96	-3.3

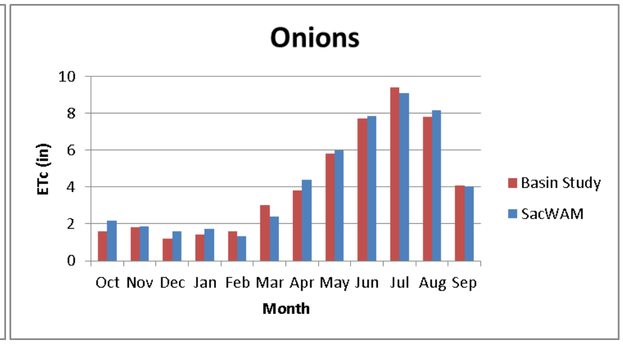
Plots of monthly crop ET rates for water year 2005 as calculated by CUP and SacWAM are provided in Figure A.2.1. Generally, the monthly patterns of crop ET are similar between the two models which is to be expected since they use the same planting date and season length information. The most notable differences are in the winter months and at the start and end of the growing season. Differences during the winter months can be attributed to the fact that the single coefficient approach used in CUP utilizes an average crop coefficient during the winter period that represents typical soil wetting patterns caused by rainfall. In the dual crop coefficient approach, the actual daily pattern of wetting and drying of the soil surface is simulated resulting in a more refined representation of the ET rate. Differences in the ET rates of months at the start and end of the growing season (e.g., October for many crops, March and April for safflower and potatoes, all months for wheat) are likely caused by the difference in the assumed average ET rate inherent in the single crop coefficient and the dual crop coefficient approach which accounts for the soil wetting pattern specific to this simulation. During months in which the crop canopy covers a large portion of the soil, the ET rates are similar.

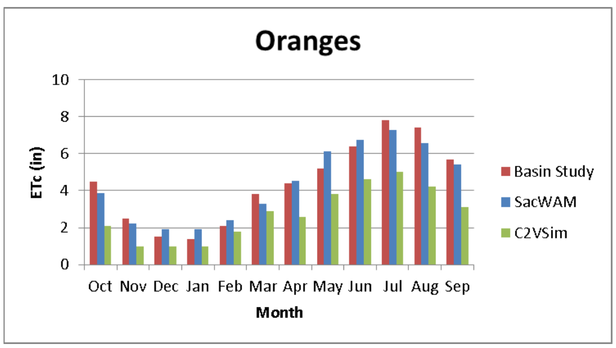


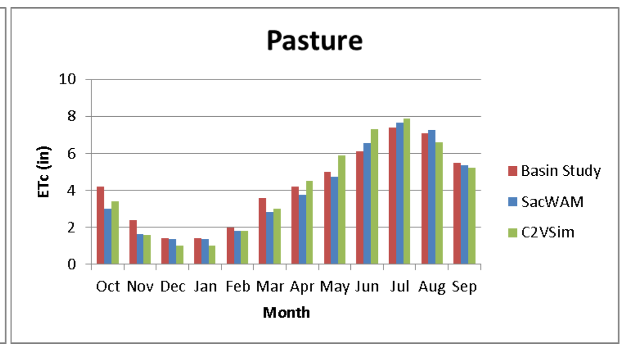

Cucumber/Lettuce
ETc (in)
0 1 2 3 4 5 6 7 8
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM

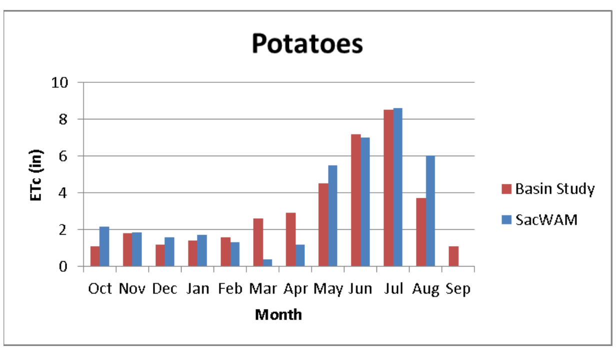

Dry Beans
ETc (in)
0 2 4 6 8 10
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM

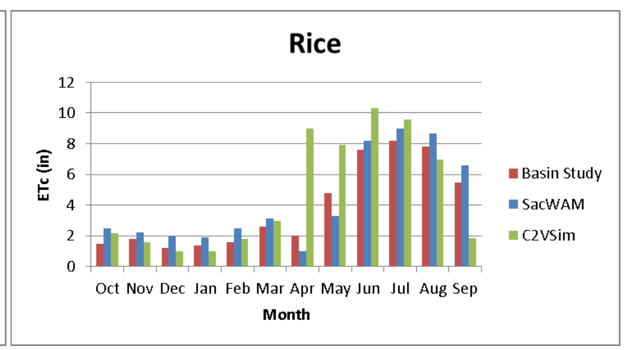

Melons
ETc (in)
0 1 2 3 4 5 6 7 8
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM


Onions
ETc (in)
0 2 4 6 8 10
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM


Oranges
ETc (in)
0 2 4 6 8 10
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM
C2VSim


Pasture
ETc (in)
0 2 4 6 8 10
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM
C2VSim


Potatoes
ETc (in)
0 2 4 6 8 10
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM


Rice
ETc (in)
0 2 4 6 8 10 12
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
Month
Basin Study
SacWAM
C2VSim

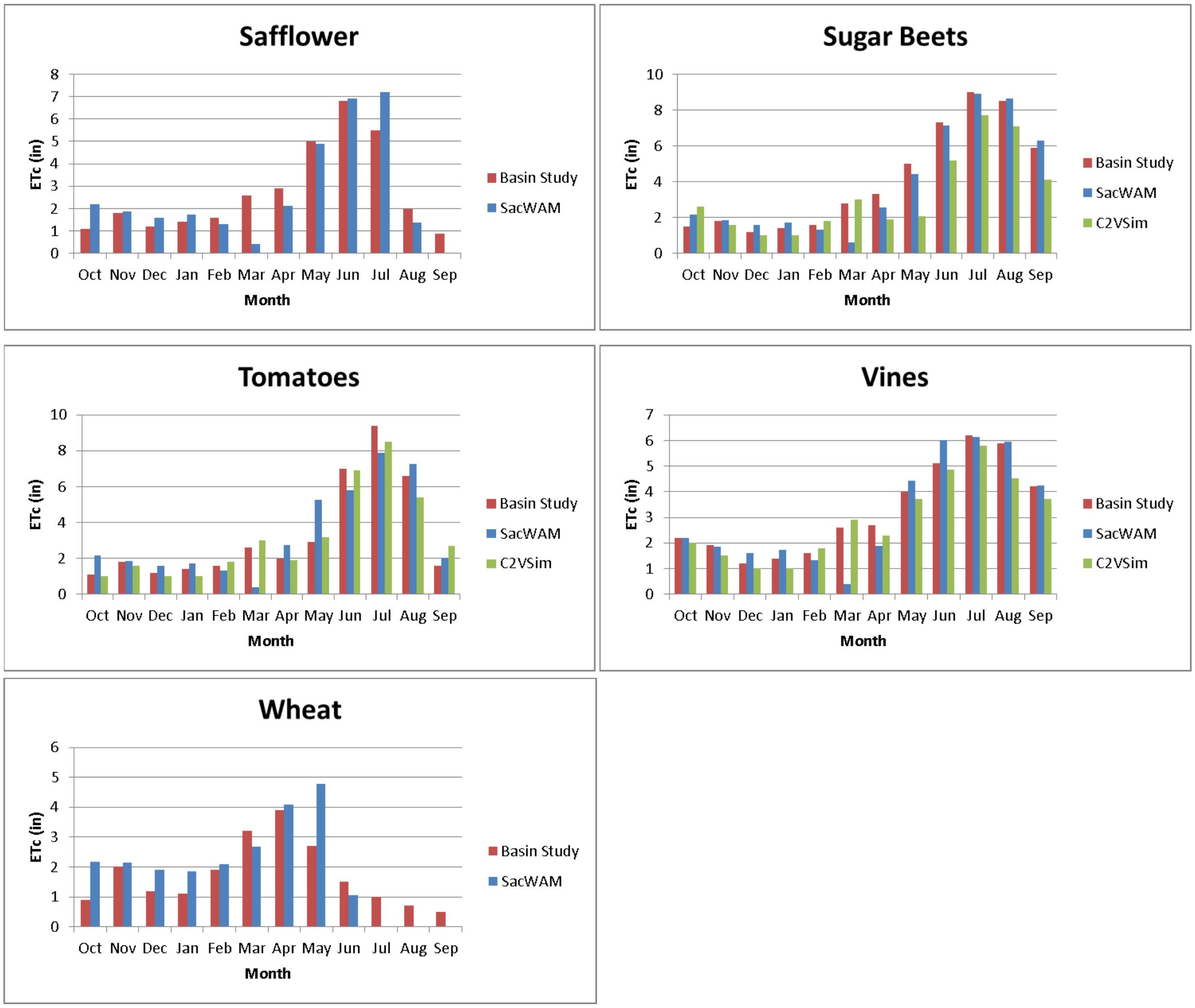


Figure A.2.1a. Monthly Crop ET Rates from CUP, SacWAM, and C2VSim

A.2.2 Comparison with Other ET Estimates

In order to give the reader a point of comparison for the crop ET rates used in SacWAM, crop ET values from C2VSim (version R374) and DWR's county level ET data for the Davis region are provided. The monthly C2VSim crop ET rates are shown on Figure A.2.1 for the crops in which a match could be made. In Figure A.2.2 seasonal total ET rates from SacWAM are compared to rates obtained from DWR's land and water use web page (http://www.water.ca.gov/landwateruse/anlwuest.cfm). In general, both the monthly and seasonal rates compare reasonably well, however, there are some crops which have very different values. In several of these cases it was not possible to determine precisely which crop is represented in the C2VSim and DWR data (e.g., subtropical, cucurbits, other deciduous). It is likely that different representative crops, with different planting dates and season lengths, were selected for these crop categories. For other crops, (e.g., onion/garlic, rice, vines) it appears that different assumptions were made regarding crop coefficients. Since the origin of the parameters in SacWAM are known and represent the best estimate of those values at the time of the Basin Study, we chose to use them.

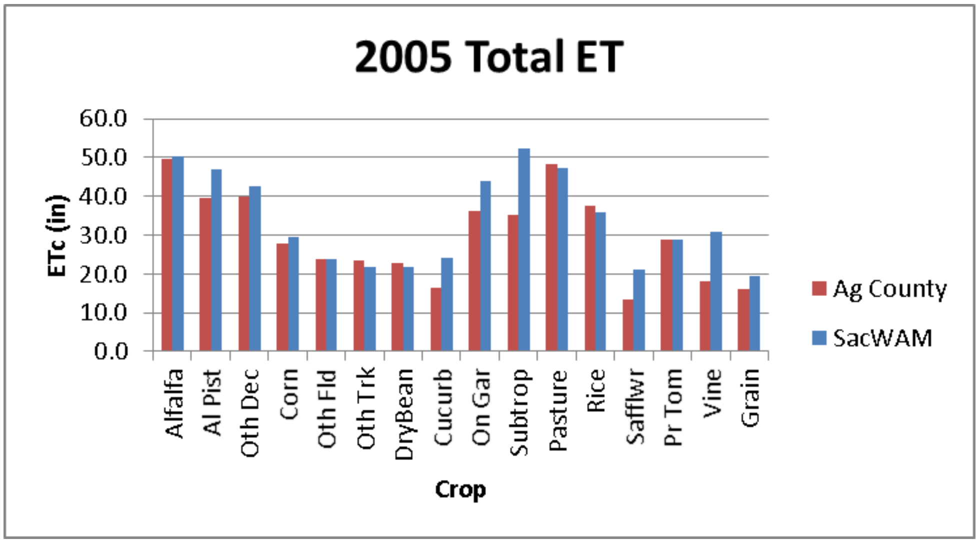


Figure A.2.2a. Comparison of Growing Season ET Rates from SacWAM and DWR County Level Data

In a final point of comparison, reference ET rates for water year 2005 are compared to CIMIS data for six locations throughout the model domain (Figure A.2.3). The graphs show generally good agreement with annual bias ranging from -6% to 11%. Reasons for these discrepancies could include are likely due differences in the meteorological inputs between SacWAM and the CIMIS stations.

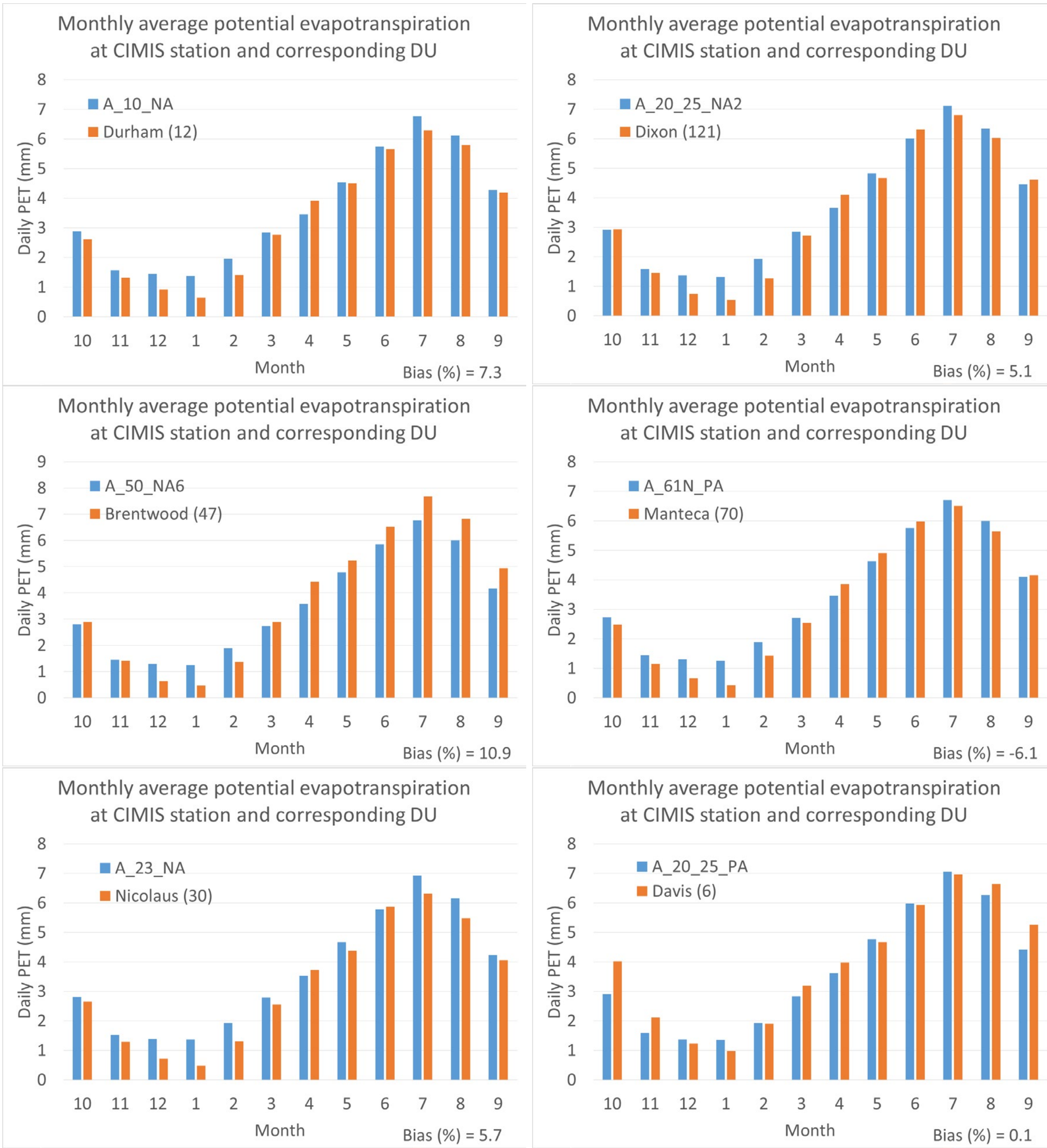


Figure A.2.2a. Comparison of Monthly Reference ET Rates from SacWAM and CIMIS Stations for Water Year 2005

A.3 Water Diversion Calibration

Following the calibration of the ET parameters, surface water diversion and associated irrigation parameters were calibrated for 15 of the largest diversions in the Sacramento Valley, which represent 80 percent of the total volume of surface water diversions simulated by SacWAM.

Initial parameter values for *Seepage Loss Factor*, *Evaporative Loss Factor*, *Operational Spill Factor*, and *Lateral Flow Factor* were based on work undertaken by DWR. The Tailwater Factor was set to 0.1 for all crops other than rice. Since rice is a dominant crop in many regions of the valley and an intensive user of water, calibration efforts were mostly focused on the adjustment of rice irrigation parameters.

Parameters for rice fields were then set based on information reported for Sacramento Valley rice fields. The *Maximum Percolation Rate* was set to 0.635 mm/d. This value resulted in 88 mm of deep percolation over the course of the 139-day rice growing season. This corresponds to a value of 0.29 feet (74 mm) of deep percolation observed by Bruce Linquist (UC Davis Extension) and others in rice field water balances (https://youtu.be/ytY-6U1TarM?list=PLLjlfxpbNglYQxsSCr0TFtk2hUr_p1LDv). Diversions to rice dominated DUs were further adjusted by scaling the *Release Requirement* parameter. This parameter sets the amount of "flow through" that occurs in the rice field. This water is circulated through the fields to maintain acceptable salinity levels. No other parameters were adjusted during model calibration.

The sections below compare observed and simulated diversions for water years 2000-2015. Land use in SacWAM represents the average of 1998-2007 conditions. SacWAM M&I demands are determined from 2006-2010 production data. Calibration of model parameters was completed for 2000-2009; 2010-2015 is a validation period. The comparisons are presented in decreasing size of diversion. A positive reported bias indicates an over-estimate of diversions by SacWAM compared to historical.

A.3.1 Sacramento River Diversions – Glenn-Colusa Canal

The Glenn-Colusa Canal is the primary conveyance channel for Glenn-Colusa ID. The canal intake and pumping station are located on the Sacramento River at river mile (RM) 207 within an oxbow lake, just north of Hamilton City. Downstream from the pumping station the canal stretches 65 miles, generally along the western border of the district's service area, to the canal's terminus at Davis Weir where excess flows are discharged into the Colusa Basin Drain. The canal delivers water to approximately 175,000 acres of agricultural land, and to three national wildlife refuges (Sacramento NWR, Delevan NWR, and Colusa NWR). In model simulation, canal water is predominately used to irrigate rice fields in DUs A_08_SA2 (Glenn Colusa ID) and A_08_PA (Colusa Drain MWC). Additional water is delivered to R_08_PR. Observed data are available for 12 months of the year. The calibration period average annual bias for 2000-2009 is -1.8%. During calibration the *Release Requirement* was set to 2 mm/d. SacWAM underestimates the deliveries in the month of April and over-estimates deliveries during May-July. The reason for these discrepancies is likely due to local rice management practices that differ from those assumed in SacWAM. The bias during the validation period was 3.5%.

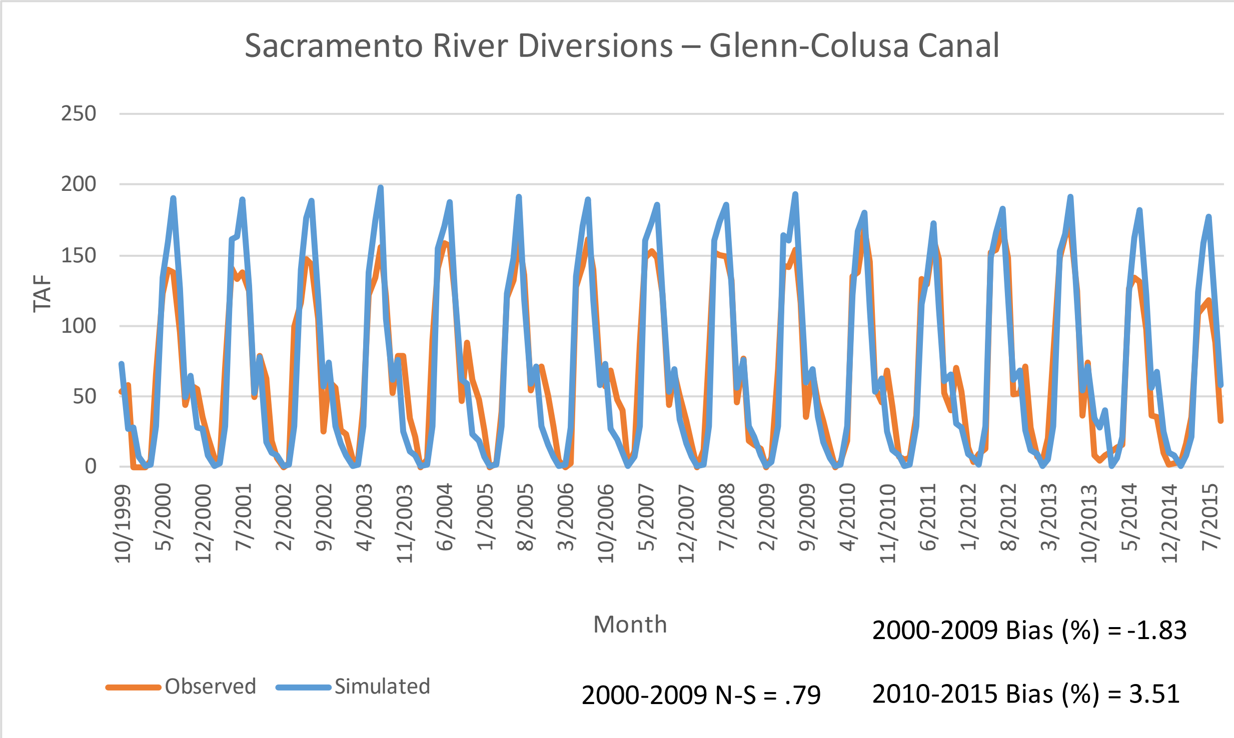


Figure A.3.1a. Sacramento River Diversions – Glenn-Colusa Canal, Monthly 2000 to 2015

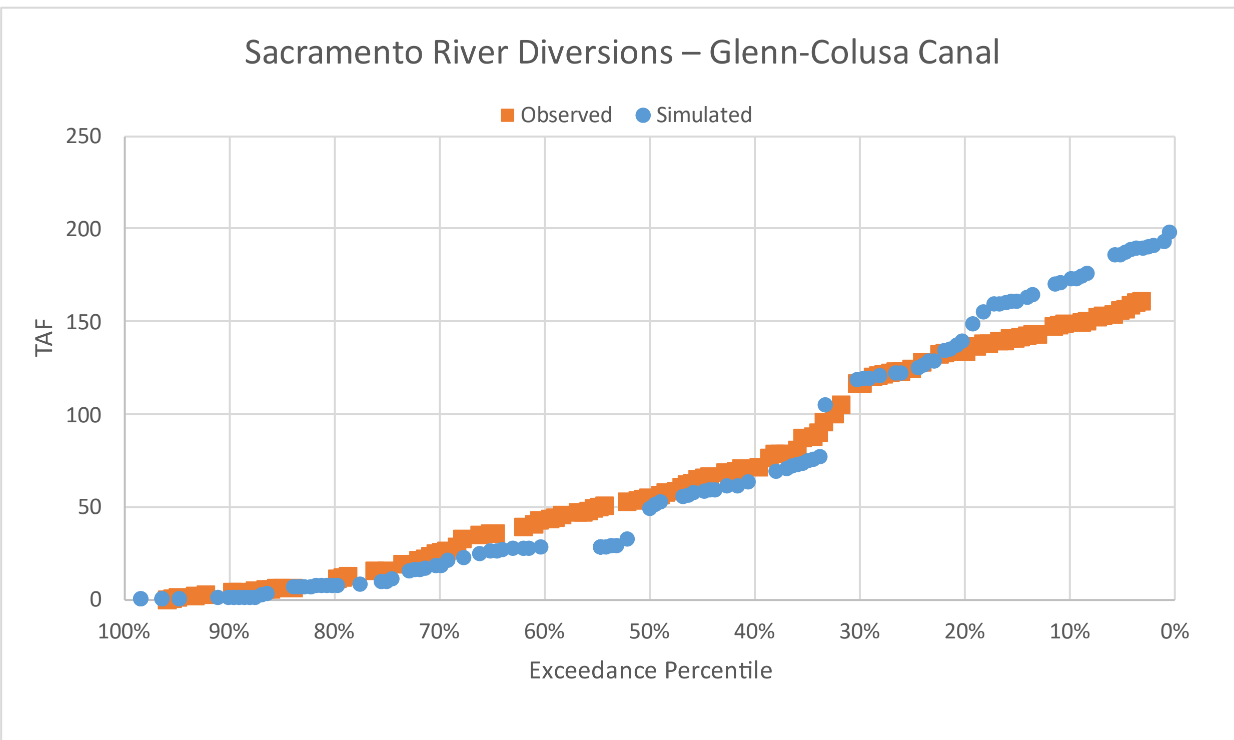


Figure A.3.1b. Sacramento River Diversions – Glenn-Colusa Canal, Exceedance

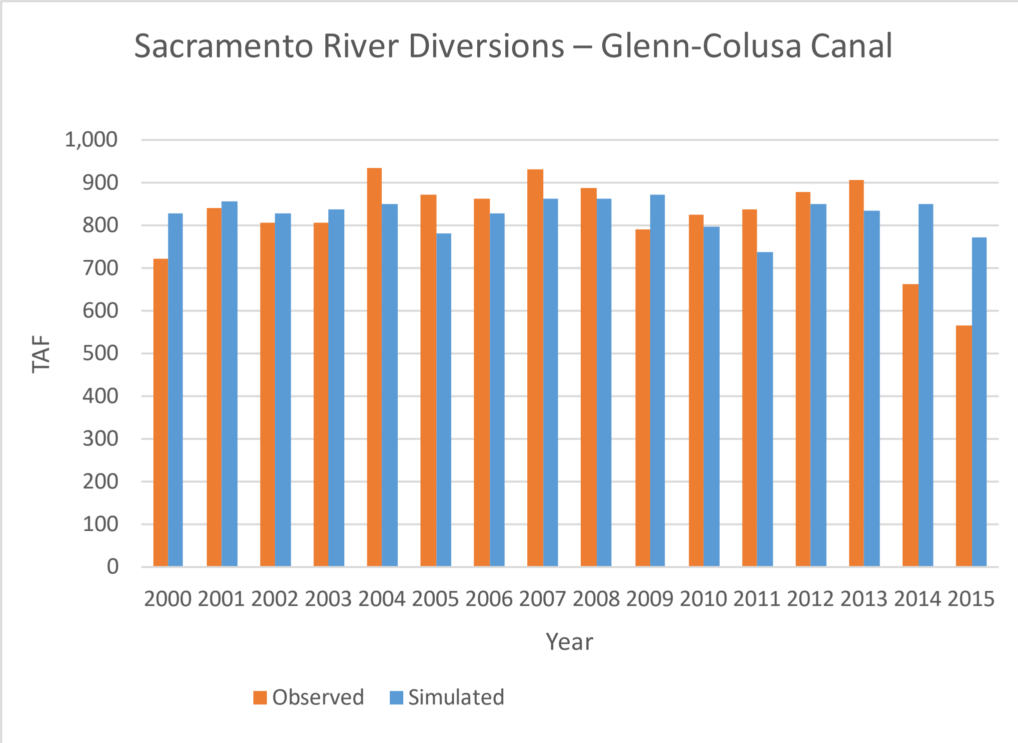


Figure A.3.1c. Sacramento River Diversions – Glenn-Colusa Canal, Annual 2000 to 2015

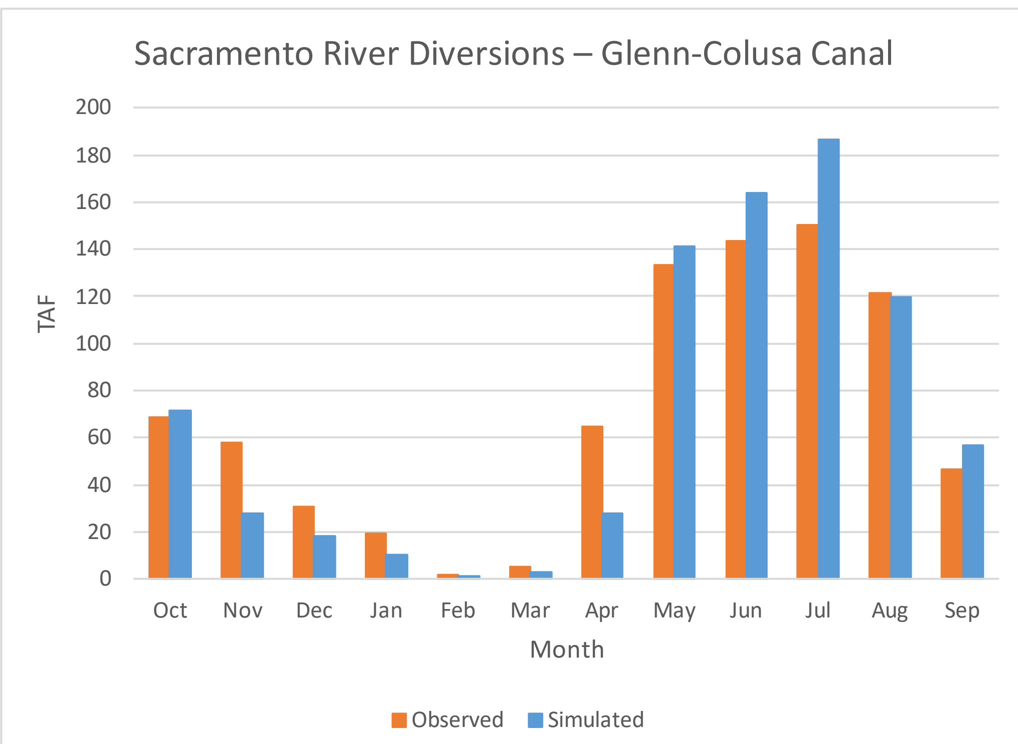


Figure A.3.1d. Sacramento River Diversions – Glenn-Colusa Canal, Average Monthly

A.3.2 Thermalito Afterbay Diversions – Western Canal Water District

The diversions from the Thermalito Afterbay into the Western Canal serve DU A_11_SA1 and are largely used to irrigate rice. Additional water is delivered to R_11_PR, which represents the Upper Butte Basin Wildlife Area. Observed data are available for 12 months of the year. The calibration period average annual bias is -8.9%. During calibration the *Release Requirement* was set to 3 mm/d. Bias on the diversions during the validation period were -18.0%.

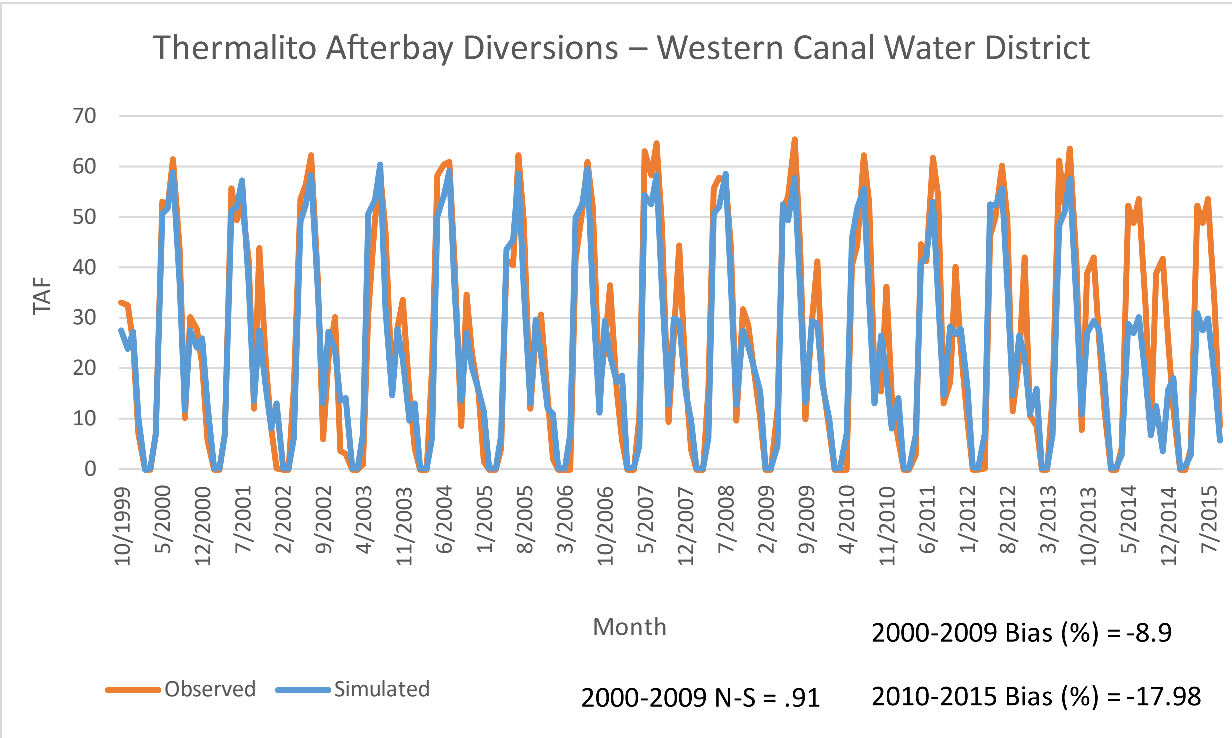


Figure A.3.2a. Thermalito Afterbay Diversions – Western Canal Water District, Monthly 2000 to 2015

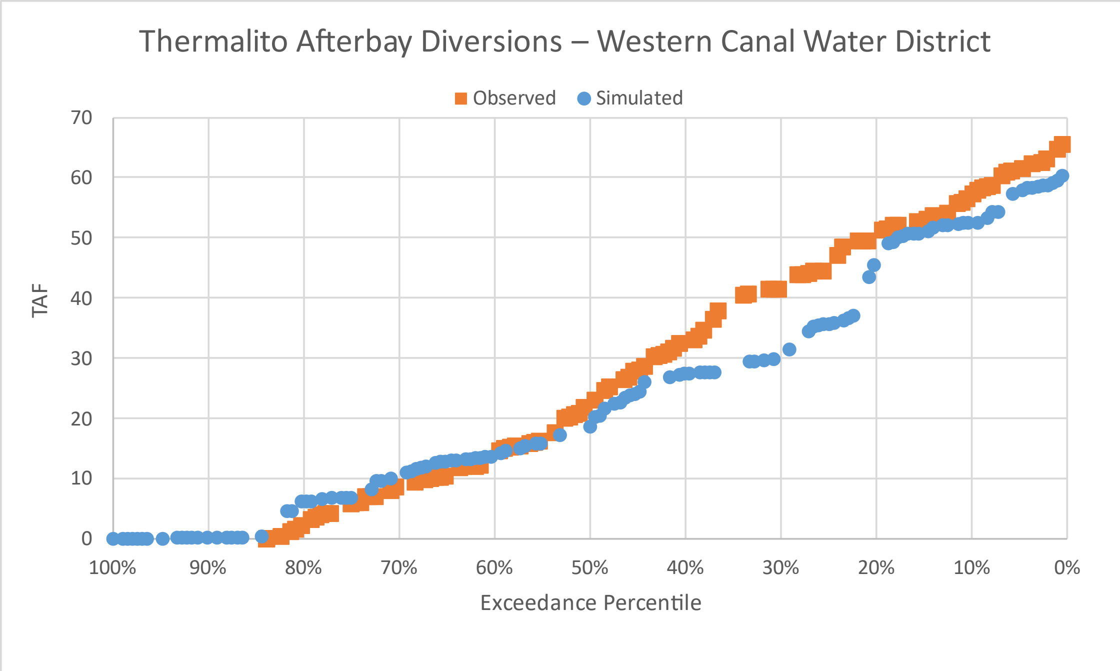


Figure A.3.2b. Thermalito Afterbay Diversions – Western Canal Water District, Exceedance

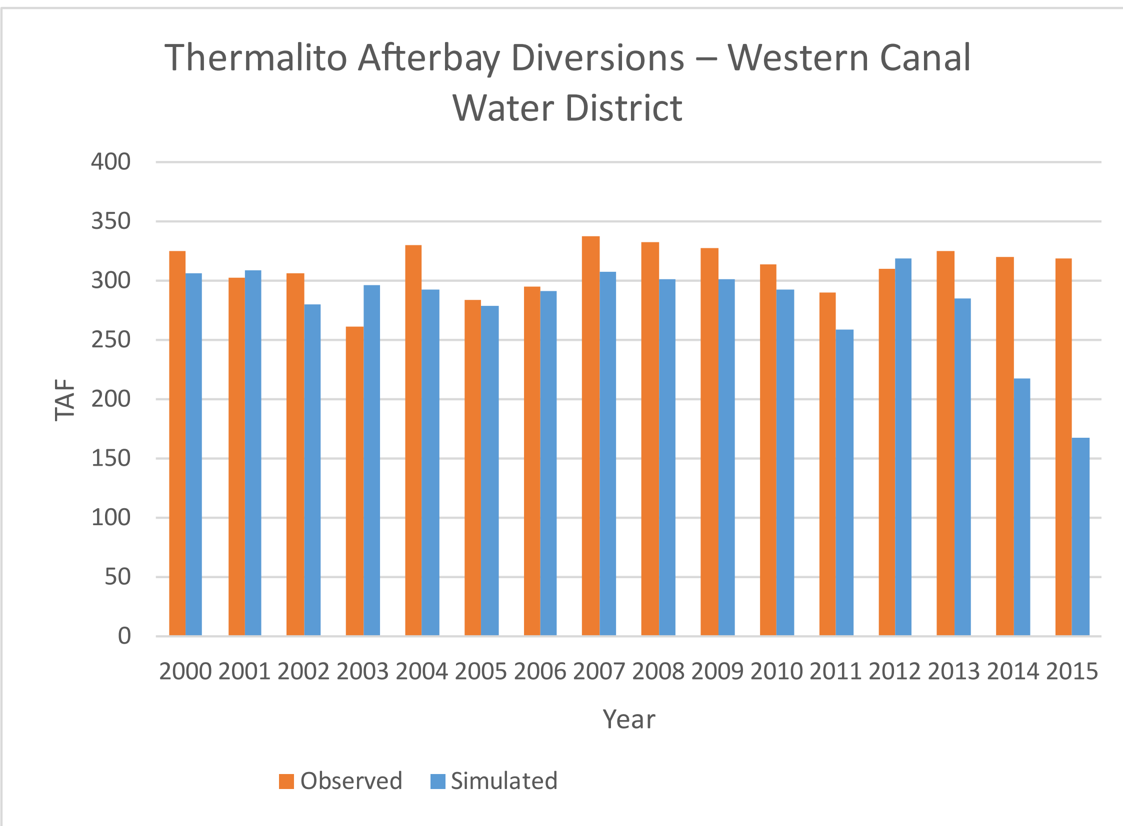


Figure A.3.2c. Thermalito Afterbay Diversions – Western Canal Water District, Annual 2000 to 2015

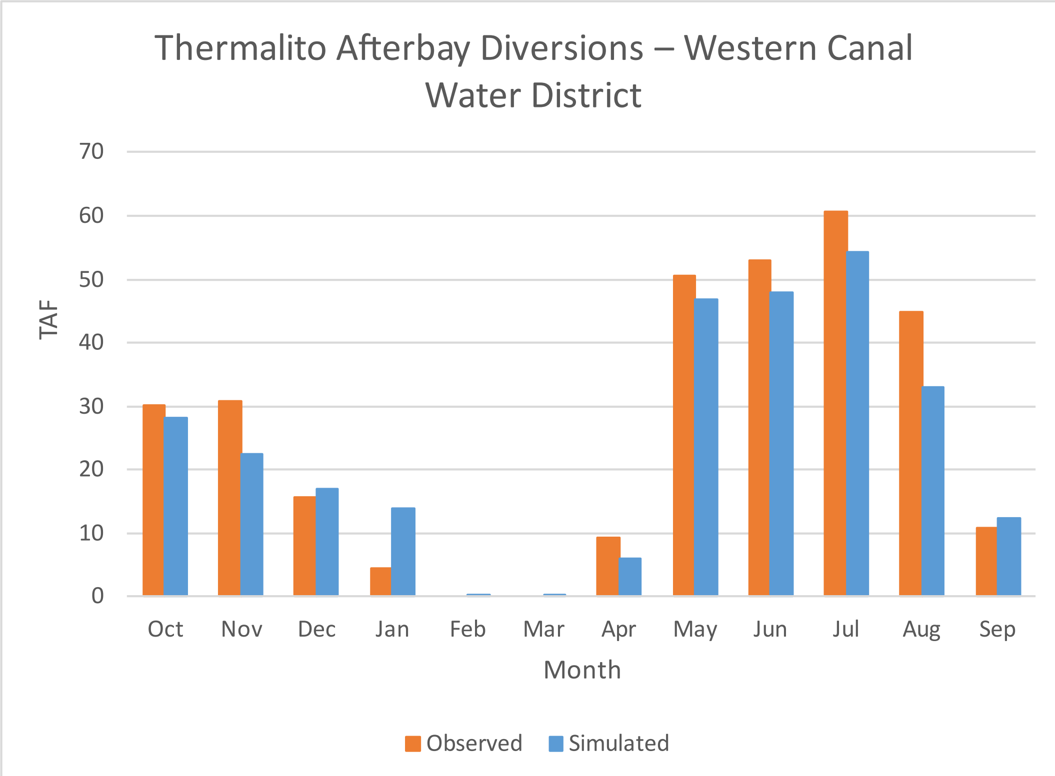


Figure A.3.2d. Thermalito Afterbay Diversions – Western Canal Water District, Average Monthly

A.3.3 Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps

Richvale ID is located around the agricultural community of Richvale, west of Highway 99 and the City of Oroville. The district covers approximately 35,000 acres, primarily agricultural land. Almost all cultivated land is farmed for rice. Water is conveyed from the Thermalito Afterbay to the district through the Richvale Canal and the Joint Board Canal. The district also diverts water from Little Dry Creek. The diversions into the Richvale and Joint Board Canals and Sunset Pumps from the Feather River largely irrigate rice fields in DUs A_11_SA2, A_11_SA3, and A_11_SA4. Additional water is delivered to R_11_PR, R_17_PR1, and R_17_PR2, which represent the Upper Butte Basin Wildlife Area, Gray Lodge Wildlife Area, and Sutter NWR. Observed data are available for 12 months of the year. The calibration period average annual bias is -14.9%. During calibration the *Release Requirement* parameter was set to 3 mm/d for the agricultural DUs served by these diversions. SacWAM underestimates the deliveries in the month of April and over-estimates during November. The reason for these discrepancies is likely due to local rice management practices that differ from those assumed in SacWAM. During the validation period the bias was -7.2%

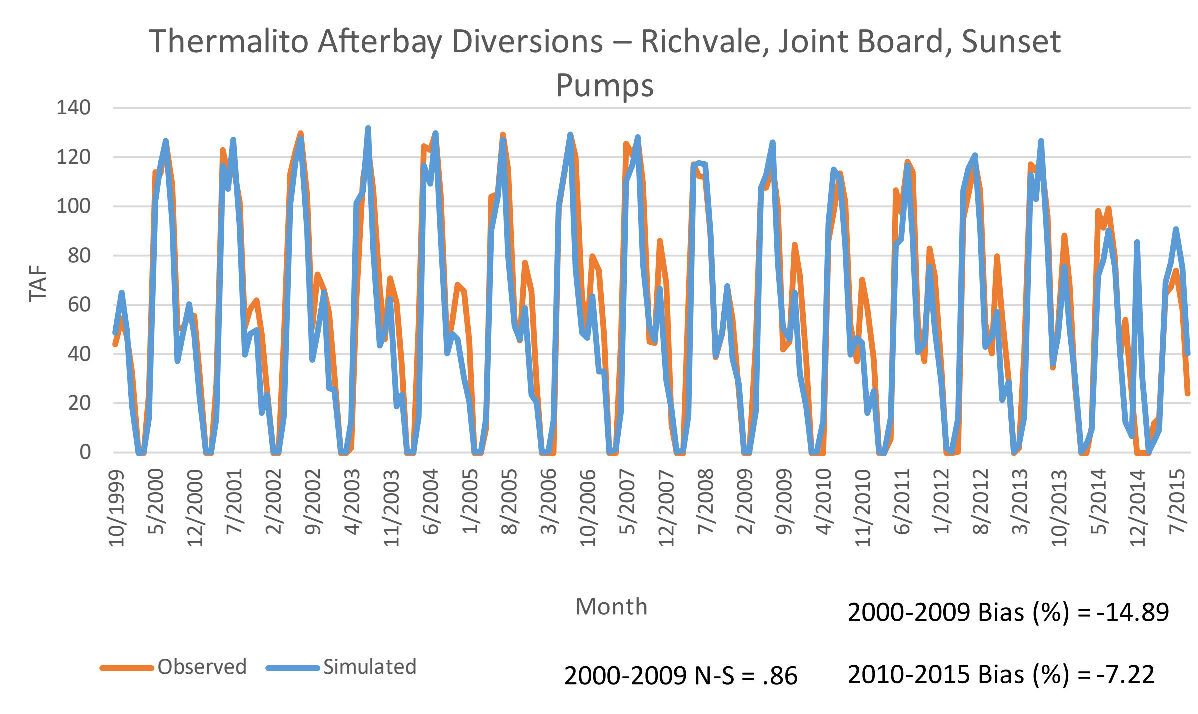


Figure A.3.3a. Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Monthly 2000 to 2015

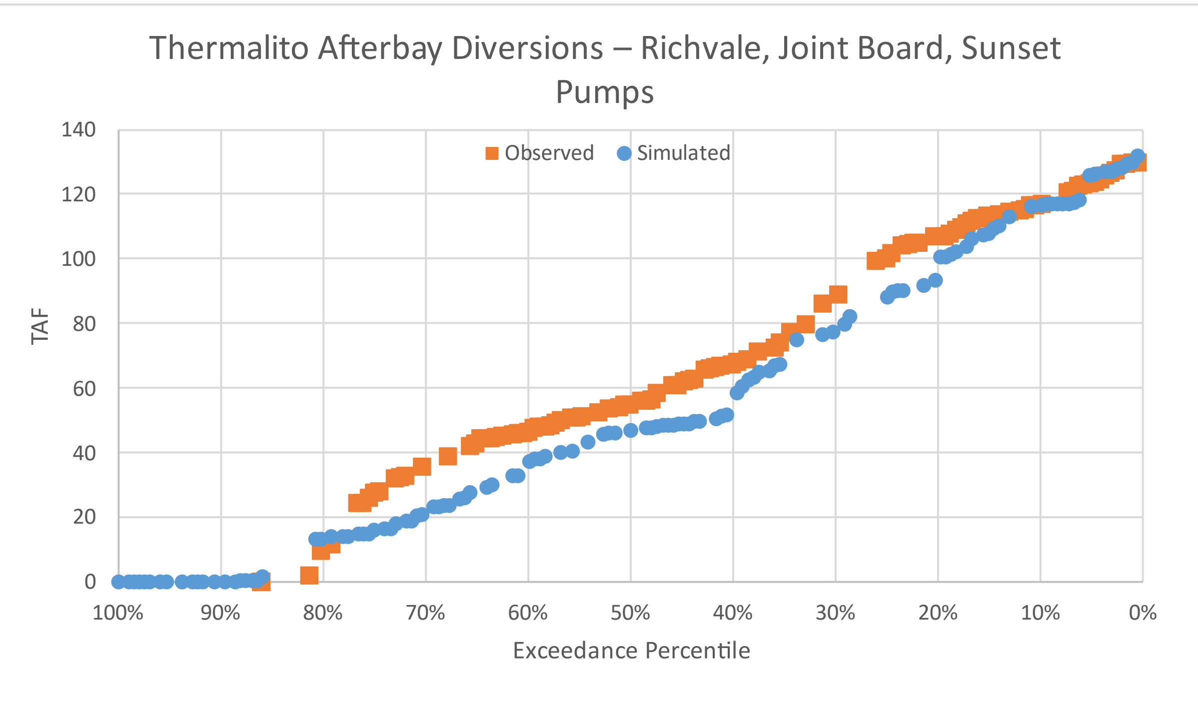


Figure A.3.3b. Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Exceedance

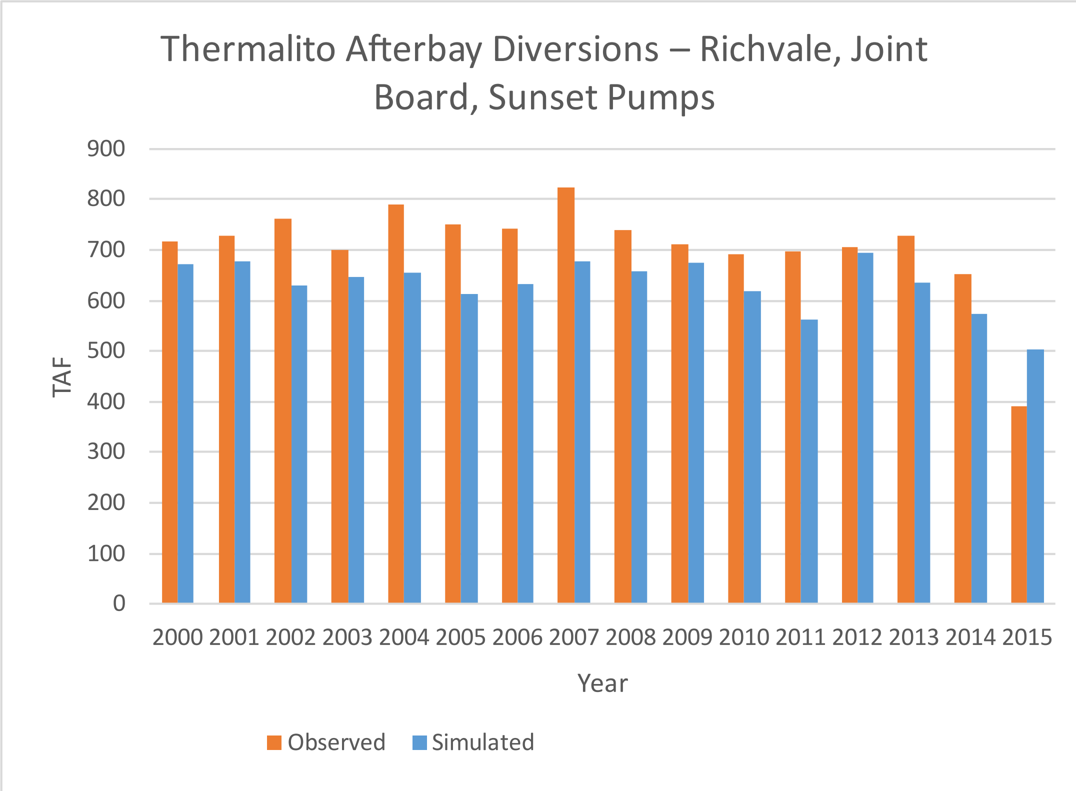


Figure A.3.3c. Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Annual 2000 to 2015

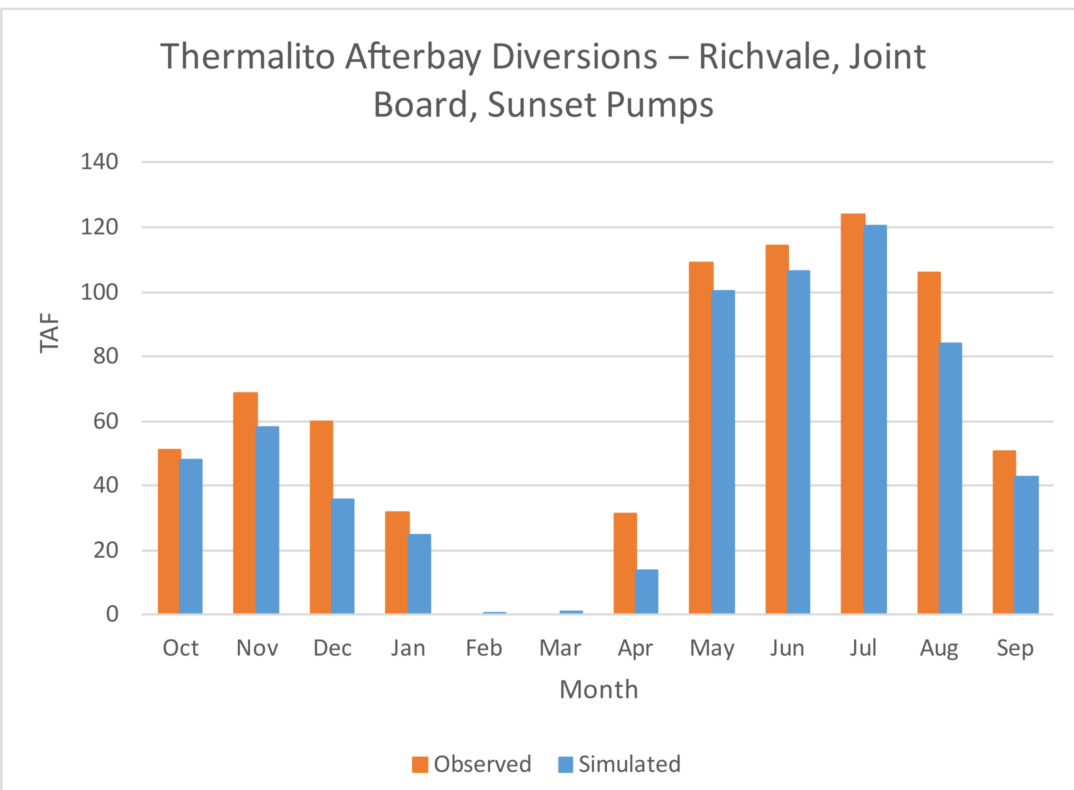


Figure A.3.3d. Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Average Monthly

A.3.4 Lower Yuba River – Yuba County Water Agency Right Bank

The diversion from the right bank of the lower Yuba River to Yuba County WA Member Units and Browns Valley ID serves DUs A_14_15N_NA2 and A_14_15N_NA3. The diversions are principally used to irrigate rice and pasture. Observed data are available for 12 months of the year. The calibration period average annual bias is 4.2%. During calibration the *Release Requirement* was set to 4.5 mm/d. The validation period bias was 10.3%.

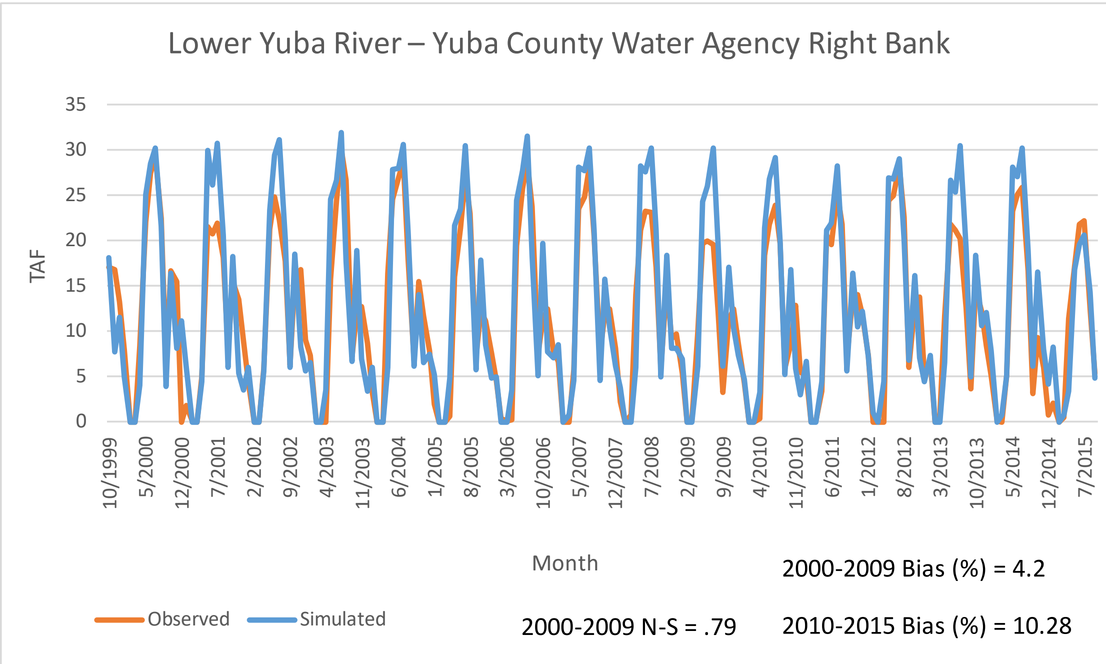


Figure A.3.4a. Lower Yuba River – Yuba County Water Agency Right Bank, Monthly 2000 to 2015

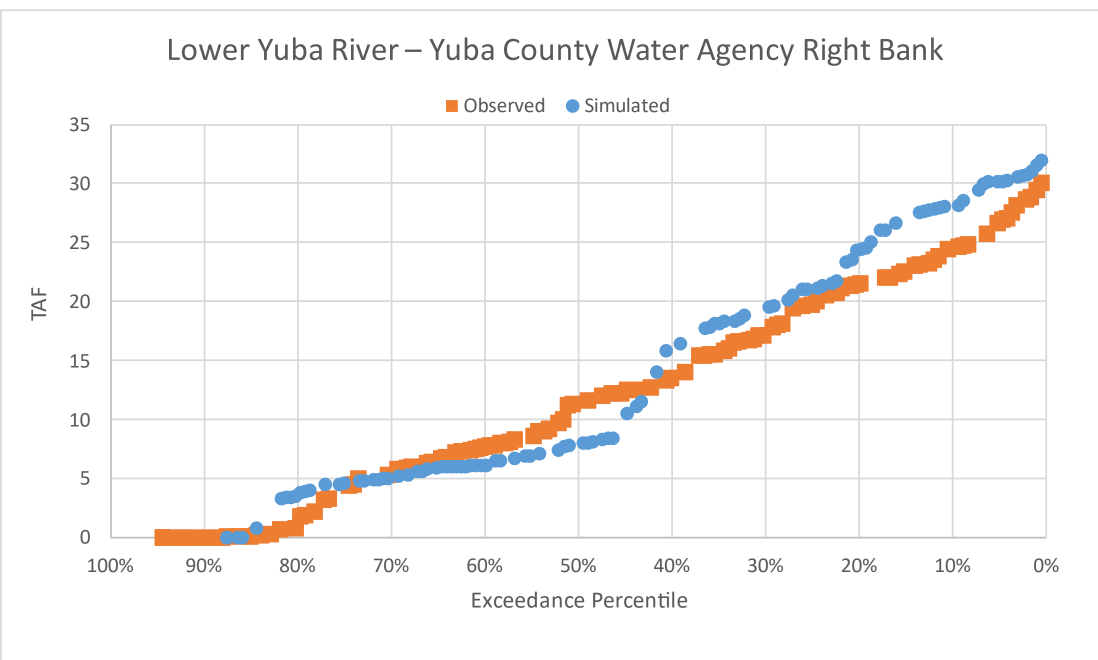


Figure A.3.4b. Lower Yuba River – Yuba County Water Agency Right Bank, Exceedance

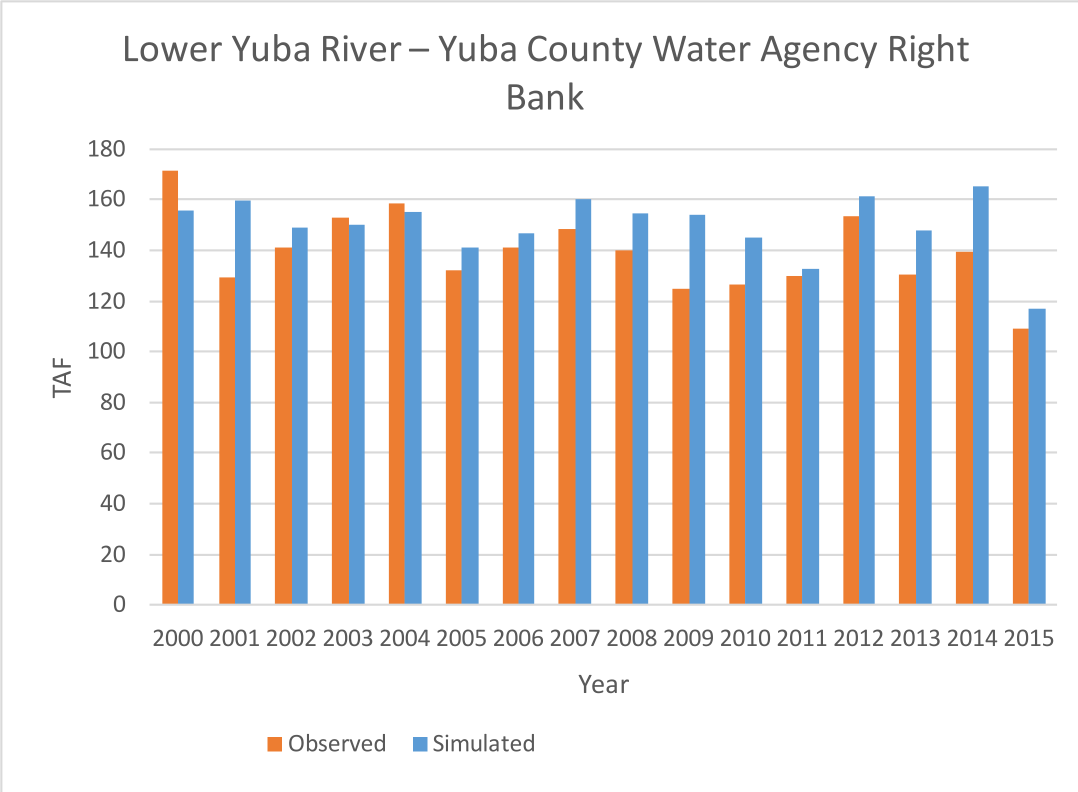


Figure A.3.4c. Lower Yuba River – Yuba County Water Agency Right Bank, Annual 2000 to 2015

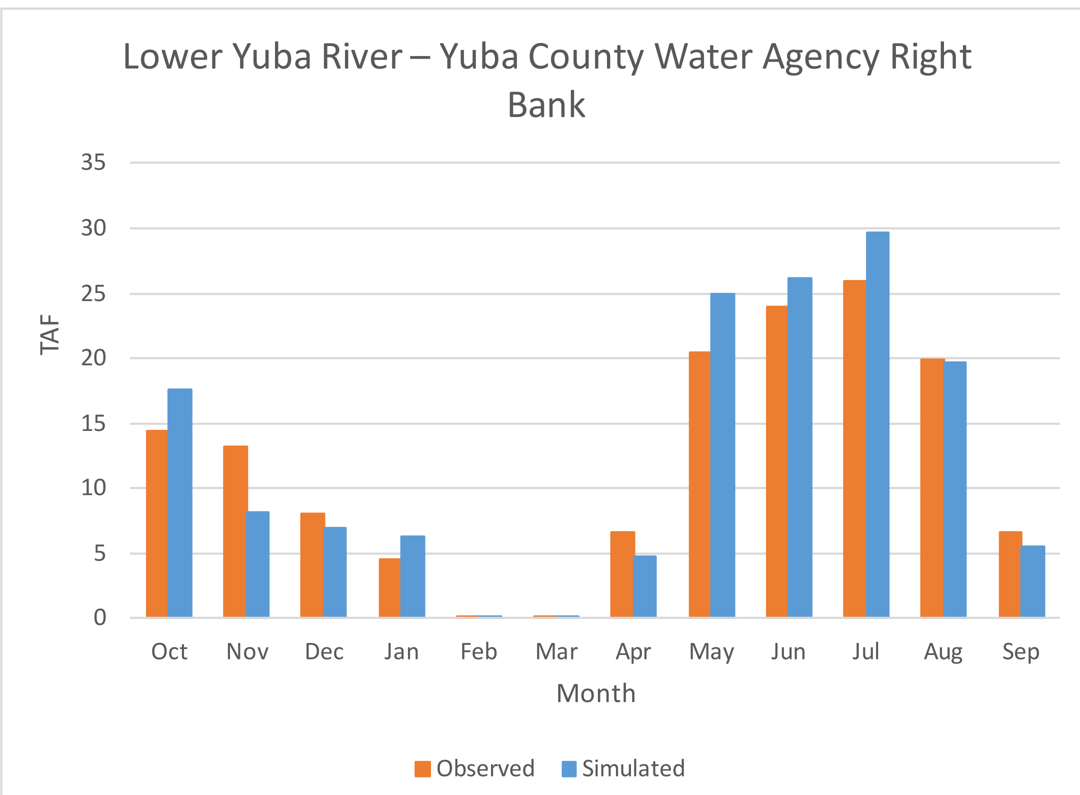


Figure A.3.4d. Lower Yuba River – Yuba County Water Agency Right Bank, Average Monthly

A.3.5 Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District

Princeton-Cordora-Glenn ID is located in Glenn and Colusa counties on the right bank of the Sacramento River. The Colusa Basin Drain forms the western boundary of most of the district. Before 2000, the district owned and operated two diversion facilities on the Sacramento River: the Sidds Landing Pumping Station (at RM178) and the Schaad Pump Station. In 2000, the Sidds Landing Pumping Station was replaced with a new facility which is jointly operated with Provident ID. The Schaad Pump Station was abandoned. Princeton-Cordora-Glenn ID supplements Sacramento River water with diversions from the Colusa Basin Drain.

The sum of diversions from RM 178 and 159 to A_08_SA1 is multiplied by a factor of (67.810/126.259). These are total diversions by agricultural settlement contractors on the right bank of the Sacramento River from the Tehama-Colusa county line, approximately 6 miles upstream from Hamilton City, to the Hamilton Bend, which is located approximately 8 miles upstream from the City of Colusa. The factor is the ratio of Princeton-Cordora-Glenn ID's annual settlement contract to the total settlement contract amount for 7 settlement contractors diverting along this reach of the river. Other diverters include Provident ID, which is located to the north and west of Princeton-Cordora-Glenn ID and west of the Colusa Basin Drain.

Princeton-Cordora-Glenn ID diversion data from April through October is from CVO. Reclamation does not measure data outside of the irrigation season.

The diversion from the Sacramento River to the Princeton-Codora-Glenn ID serves A_08_SA1. The diversions are predominantly used to irrigate rice. The calibration period average annual bias for Apr-Oct is 14.3%. During calibration the *Release Requirement* was set to 2 mm/d. The simulated values are somewhat large. This is probably due to uncertainty in the amount of water that is diverted from the Colusa Basin Drain to the regions served by these diversions. It is likely the model is not diverting as much from the Drain as is done in reality. During the validation period the Apr-Oct bias was 31.4%.

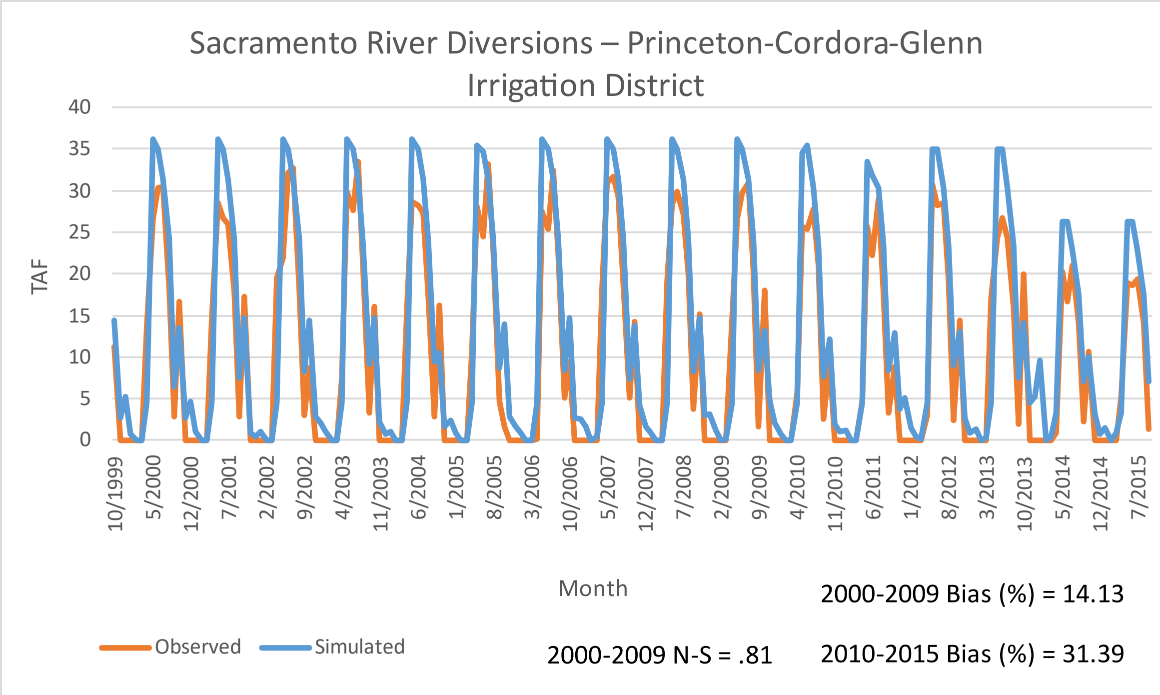


Figure A.3.5a. Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Monthly 2000 to 2015

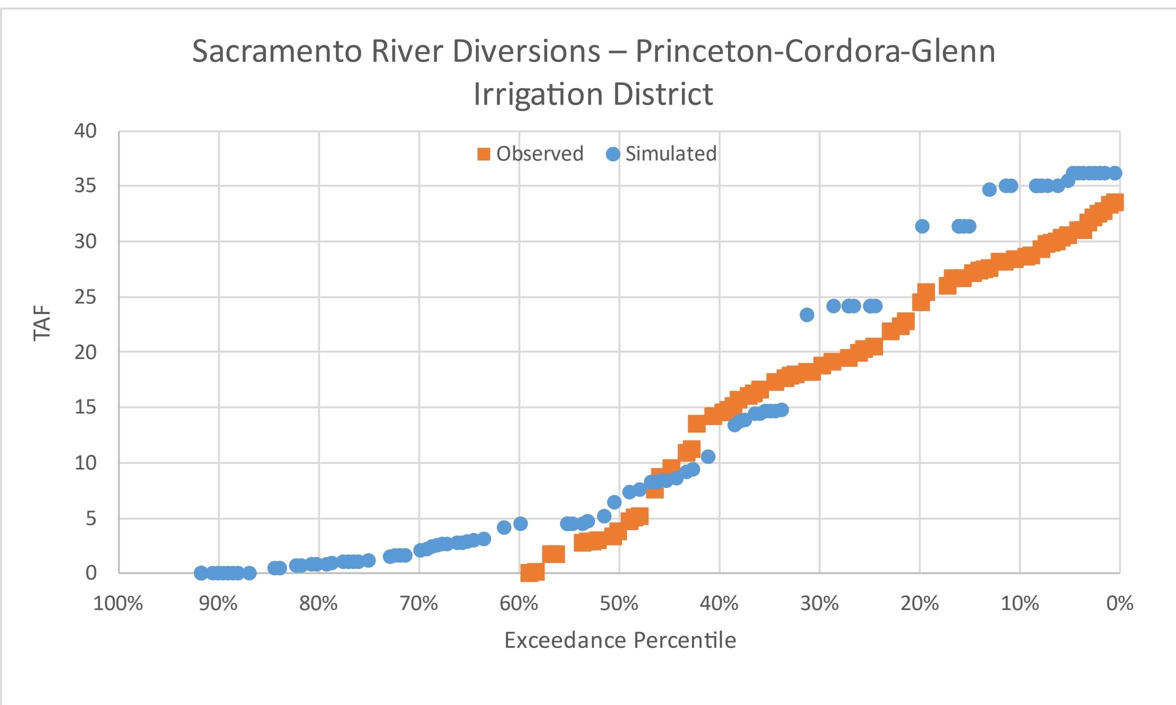


Figure A.3.5b. Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Exceedance

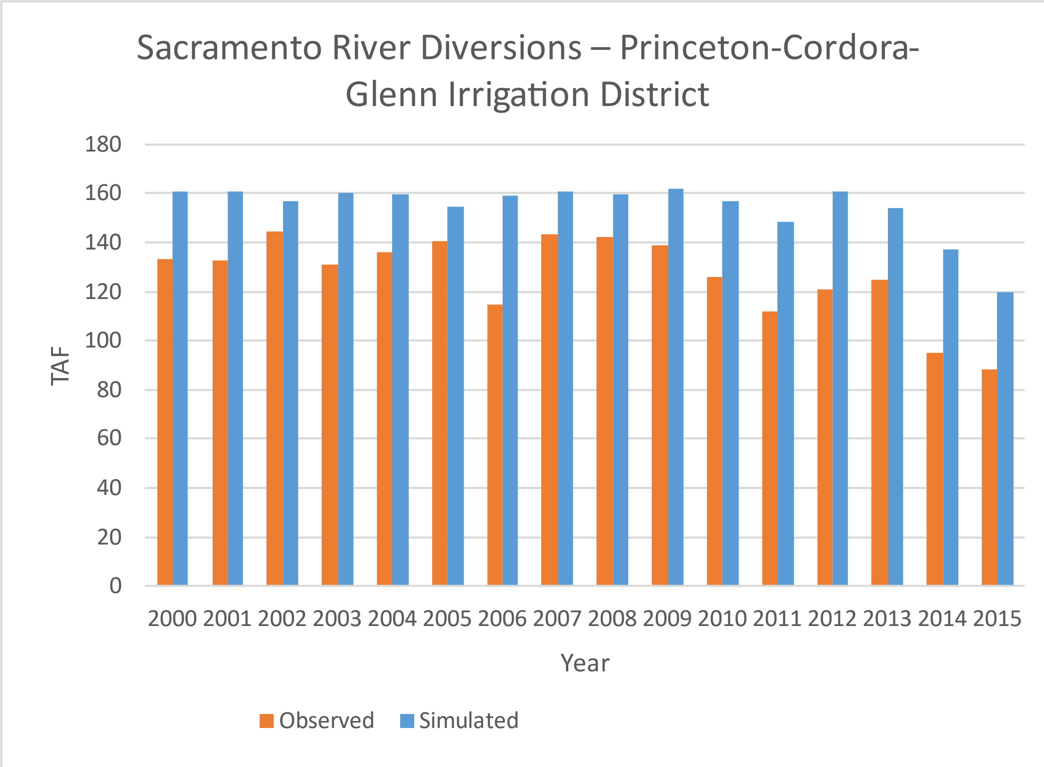


Figure A.3.5c. Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Annual 2000 to 2015

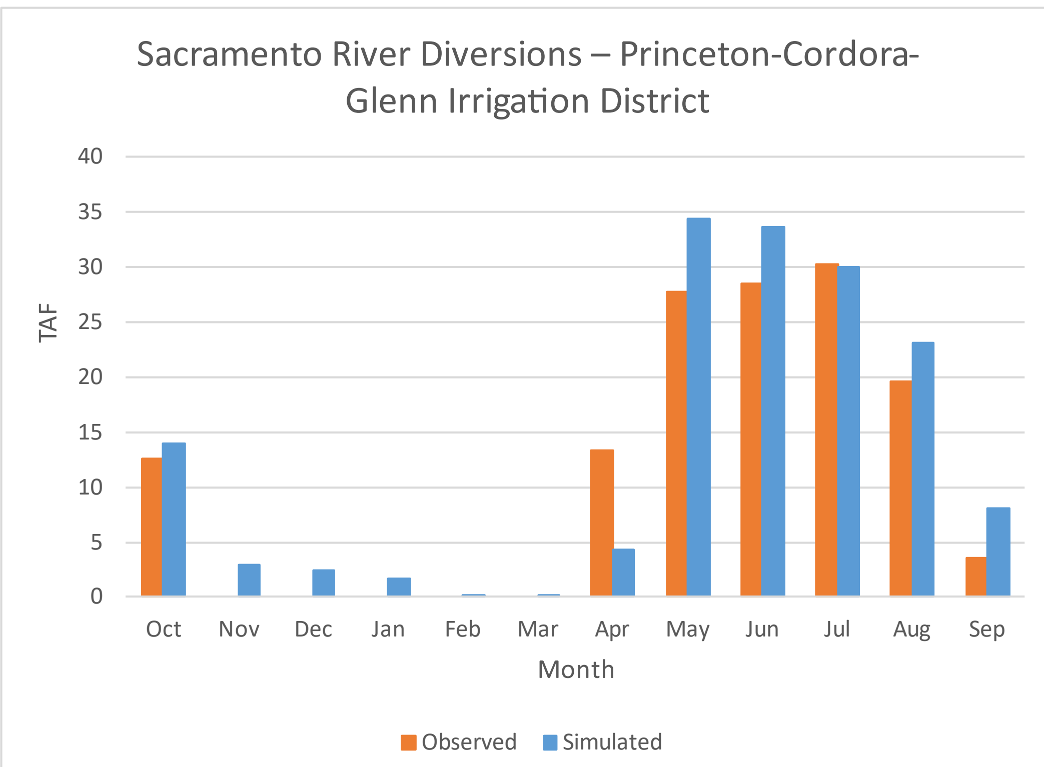


Figure A.3.5d. Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Average Monthly

A.3.6 Sacramento River Diversions – Tehama and Corning Canals

The Tehama-Colusa Canal is part of the CVP Sacramento River Division. Completed in 1980, the canal is owned by Reclamation but operated and maintained by the Tehama-Colusa Canal Authority. The canal stretches 111 miles from the intake adjacent to the Red Bluff Diversion Dam to its terminus in Yolo County, near the town of Dunnigan. The Corning Canal diverts water from the Tehama-Colusa Canal, about 1 half-mile below the headworks. Historically, environmental and regulatory requirements restricted Red Bluff Diversion Dam (RBDD) operations and gravity diversions from the Sacramento River to the period from May 15 through September 15. Outside of this period, Sacramento River water was pumped into the canal, or water is diverted from Stony Creek. The canal consists of 26 pools, which are operated so as to be kept full and to meet target water elevations for each pool. The Tehama-Canal and Corning Canal systems supply water to over 140,000 acres of farmland across 14 water districts.

Diversion data for the Tehama-Colusa Canal is from Reclamations Central Valley Operations office (CVO). However, recent historical diversions may not be a good indicator of existing operations.

Historically, lowering the RBDD gates allowed up to 2,530 cfs to be diverted by gravity into the Tehama-Colusa and Corning canals. However, since 1988 regulations have restricted the period in which the RBDD gates could be in place. Under the 1993 Biological Opinion (BO) for winter-run Chinook salmon, the gates could be in place from mid-May to mid-September. This period was later restricted by the 2009 BO for operation of the CVP to mid-June to the end of August. As an interim measure to maintain water supplies, CVP water stored in Black Butte Reservoir was released to Stony Creek for subsequent rediversion to the Tehama-Colusa Canal through a constant head orifice, located on the canal at the Stony Creek canal siphon. Since 1994, rediversions from Stony Creek have only occurred during gates-out intervals to extend the period of delivery to water districts. Other short-term measures included use of a temporary pumping plant on the Sacramento River and a Research Pumping Plant. In 2012, as part of the Fish Passage Improvement Project, a permanent pumping plant was completed to replace the need for the RBDD.

The diversions into the Tehama-Colusa and Corning Canals from the Sacramento River serve DUs A_04_06_PA1, A_04_06_PA2, and A_07_PA. The diversions are used to mostly irrigate orchards and pasture. Observed data are available for 12 months of the year. The calibration period average annual bias is -6.1%. During the validation period the bias was -3.8%. The discrepancy is caused by differences in simulated and historical CVP allocations to its water service contractors.

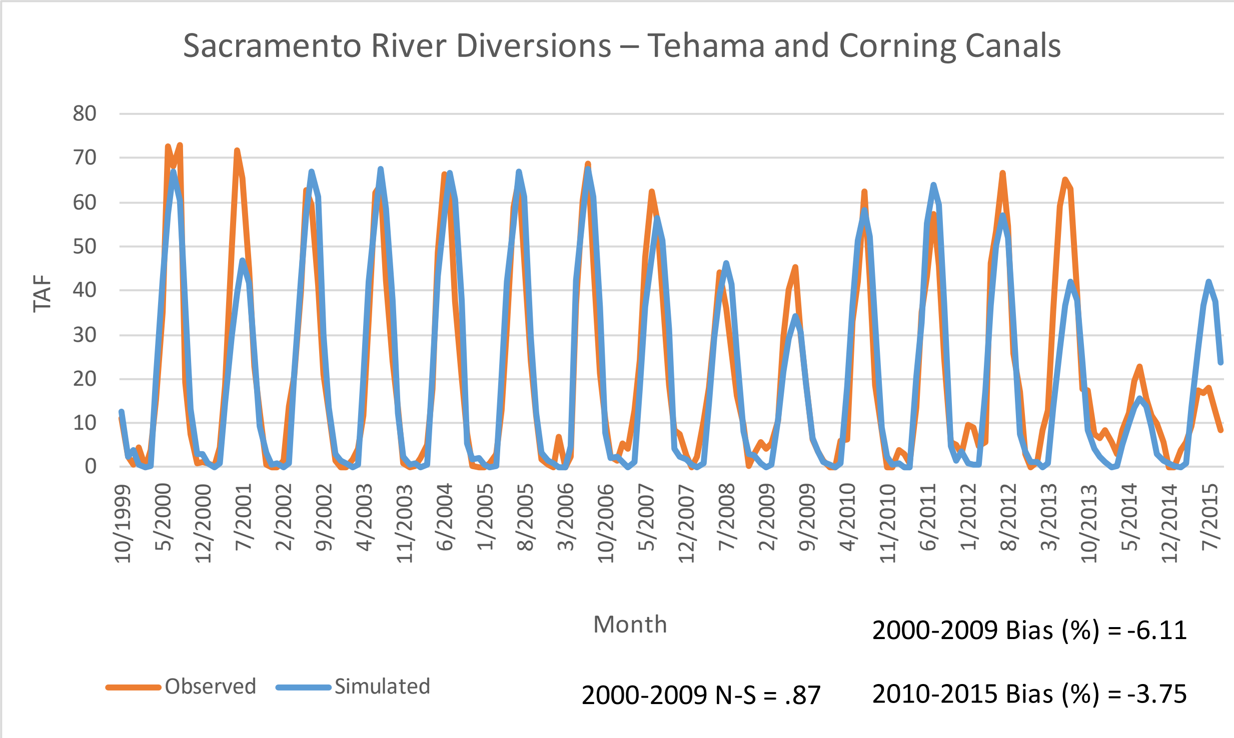


Figure A.3.6a. Sacramento River Diversions – Tehama and Corning Canals, Monthly 2000 to 2015

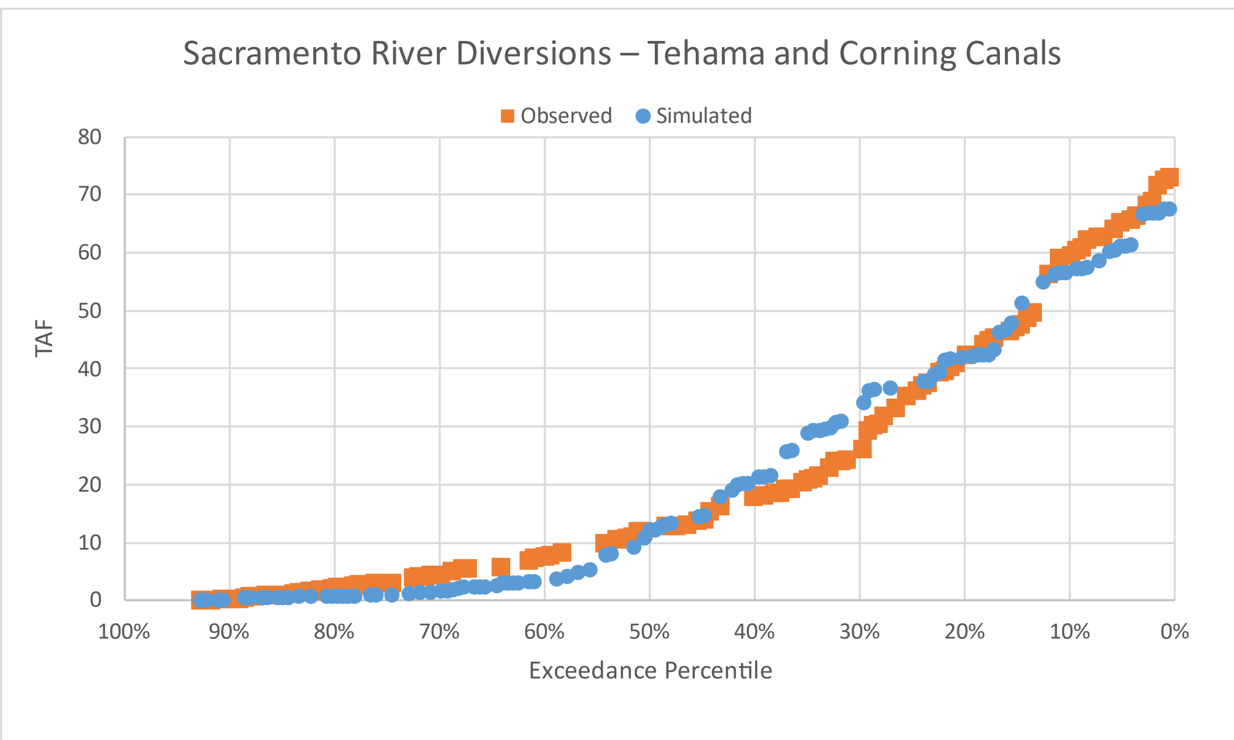


Figure A.3.6b. Sacramento River Diversions – Tehama and Corning Canals, Exceedance

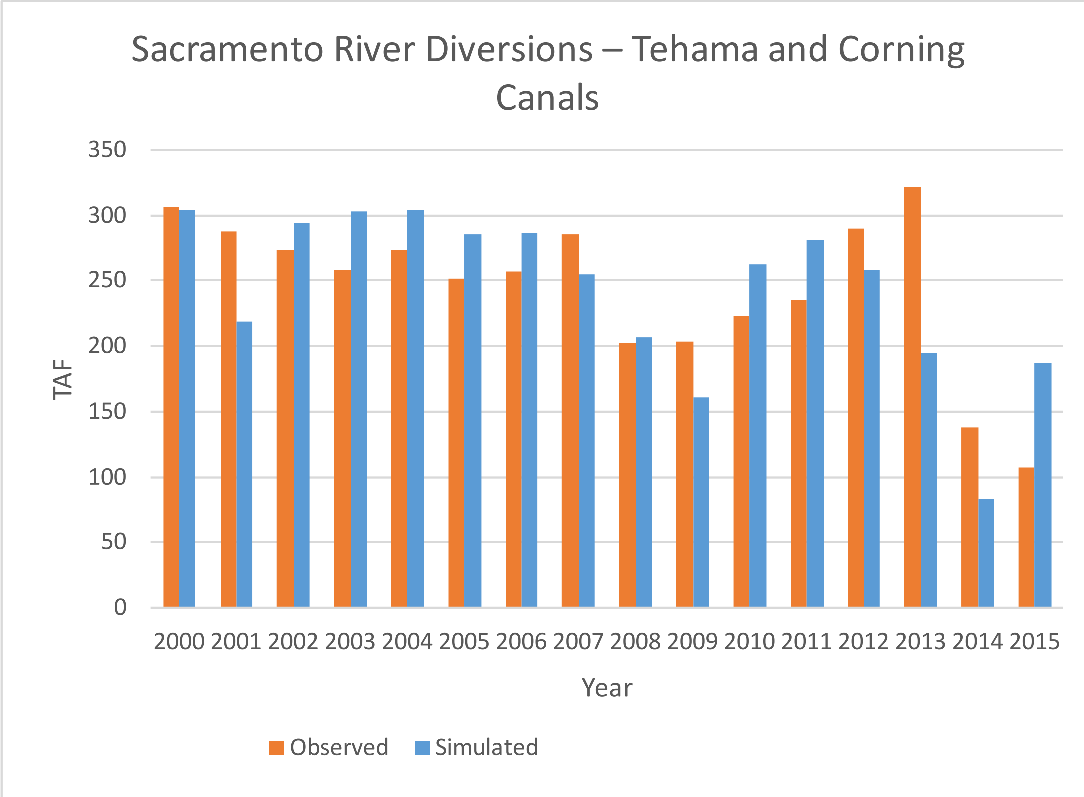


Figure A.3.6c. Sacramento River Diversions – Tehama and Corning Canals, Annual 2000 to 2015

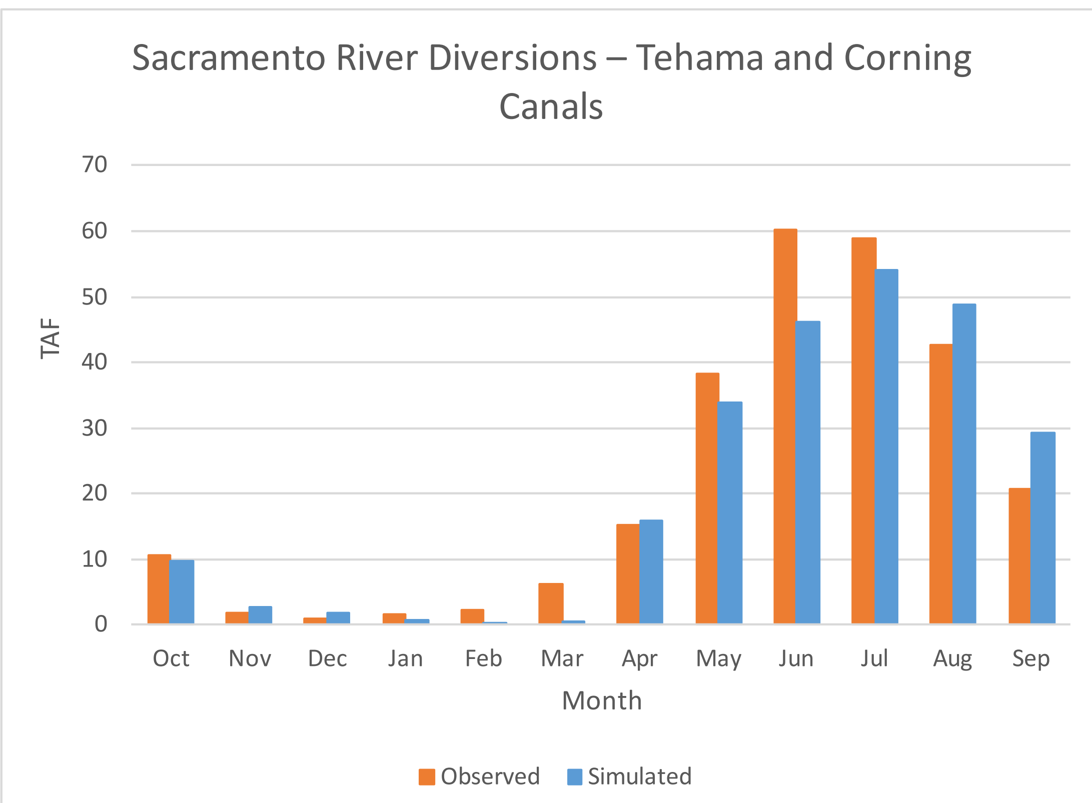


Figure A.3.6d. Sacramento River Diversions – Tehama and Corning Canals, Average Monthly

A.3.7 Sacramento River Diversions – Sutter Mutual Water Company

Sutter MWC is located on the left bank of the Sacramento River in Sutter County between the river and the Sutter Bypass. The majority of the water company is located south of the Tisdale Bypass. Surface water is diverted at the Tisdale, State Ranch Bend, and Portuguese pumping plants.

Diversion data for Sutter MWC from April through October is from CVO. Reclamation does not measure data outside of the irrigation season.

The diversion from the Sacramento River to the Sutter MWC serves DU A_18_19_SA. The diversions are used to irrigate numerous crops including rice, tomatoes, and safflower. Observed data are available for April-October. The calibration period average annual bias for April to October is 3.1%. The simulated delivery pattern largely matches the observed pattern. The validation period bias is 24.7%

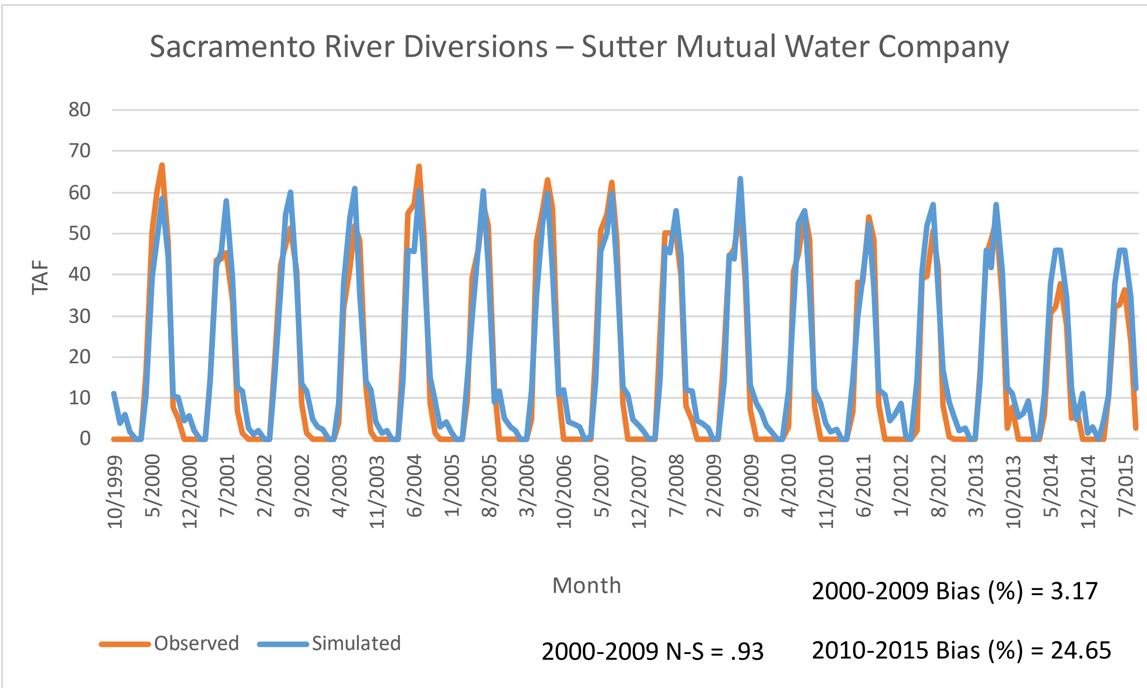


Figure A.3.7a. Sacramento River Diversions – Sutter Mutual Water Company, Monthly 2000 to 2015

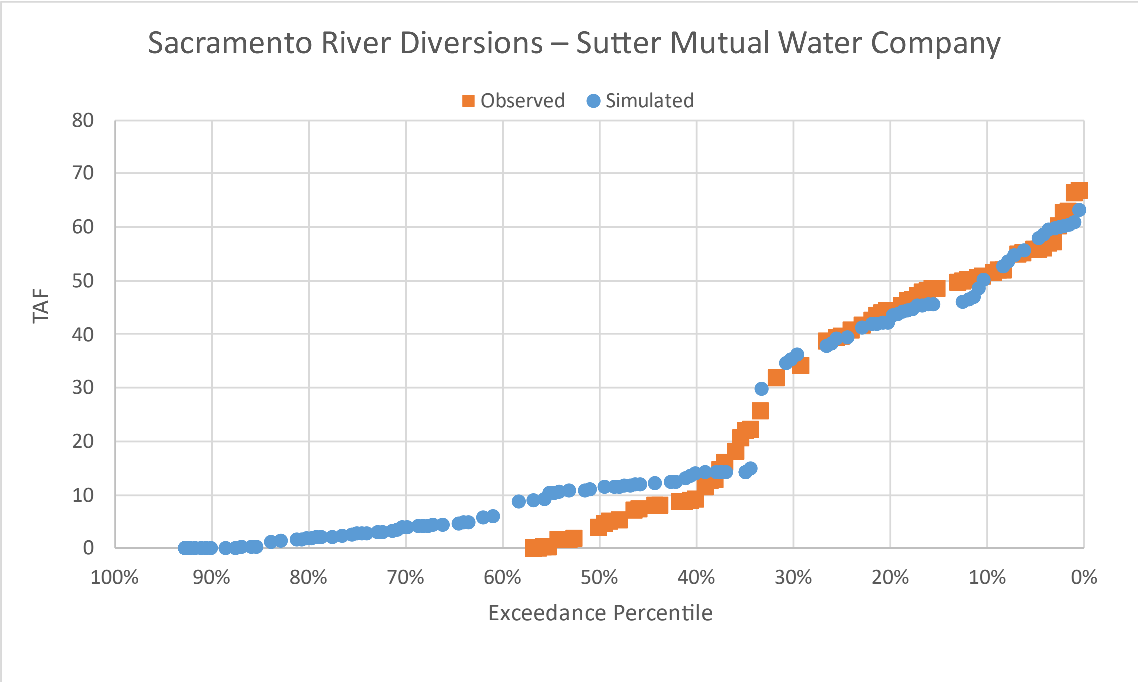


Figure A.3.7b. Sacramento River Diversions – Sutter Mutual Water Company, Exceedance

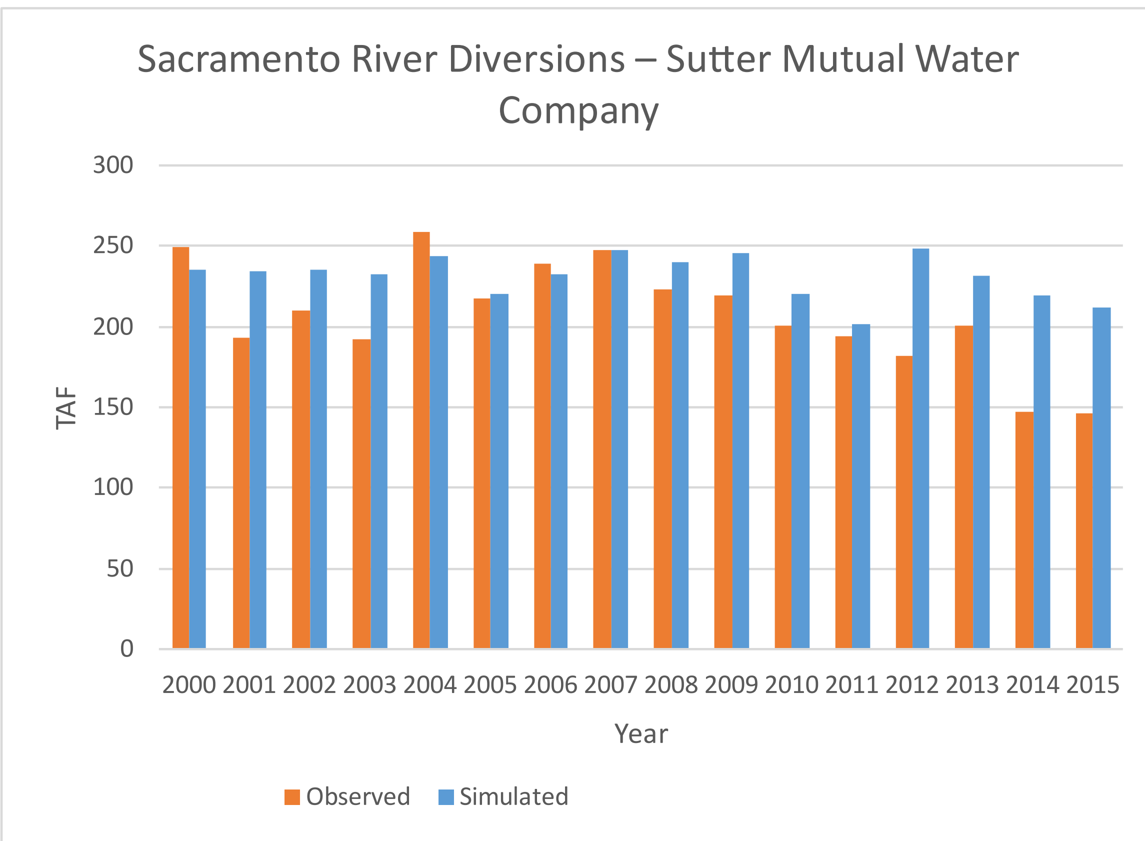


Figure A.3.7c. Sacramento River Diversions – Sutter Mutual Water Company, Annual 2000 to 2015

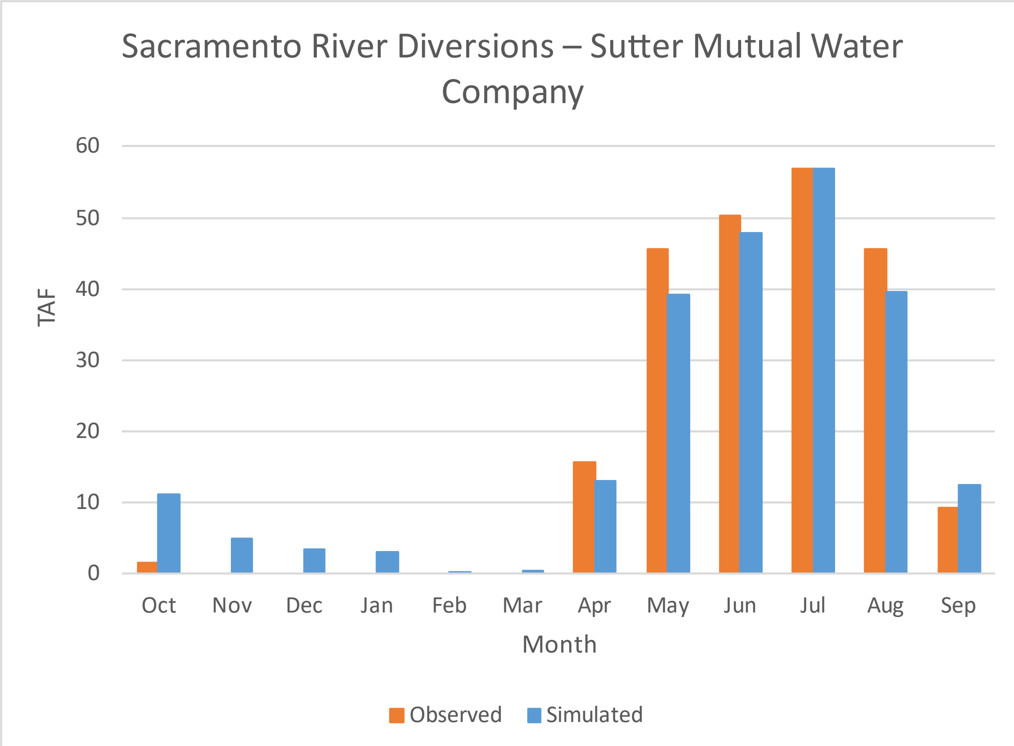


Figure A.3.7d. Sacramento River Diversions – Sutter Mutual Water Company, Average Monthly

A.3.8 Lower Putah Creek – Putah South Canal

The Solano Project was constructed by Reclamation to provide irrigation water to approximately 96,000 acres of land located in Solano County. The project also furnishes M&I water to the major cities of Solano County. Project facilities include Lake Berryessa and Monticello Dam, Putah Diversion Dam, Putah South Canal, a small terminal reservoir, and canal distribution system. Water released from Monticello Dam is diverted at the Putah Diversion Dam located approximately 6 miles downstream. Water is subsequently conveyed to its end users via the Putah South Canal. Agricultural water users served by the canal include Solano ID, Maine-Prairie WD, and the UC Davis Experimental Farm. Part of Solano ID are located outside of the Sacramento River Hydrologic Region.

The demands within the Sacramento River Hydrologic Region are represented in DUs A_20_25_PA and U_20_25_PU. The demands located outside of the Region are represented using a historical average monthly value and therefore do not vary in time. They consist of urban areas located in Solano County. The calibration period average annual bias is 5.6%. The verification period bias was 5.1%.

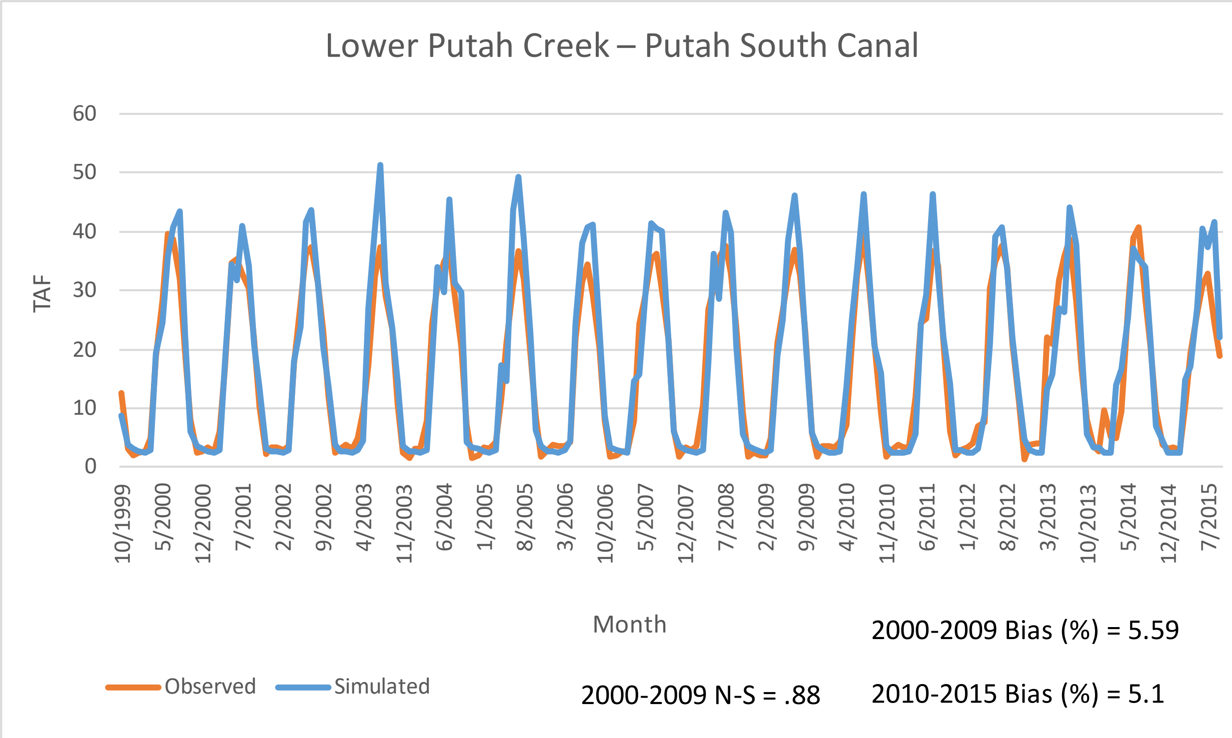


Figure A.3.8a. Lower Putah Creek – Putah South Canal, Monthly 2000 to 2015

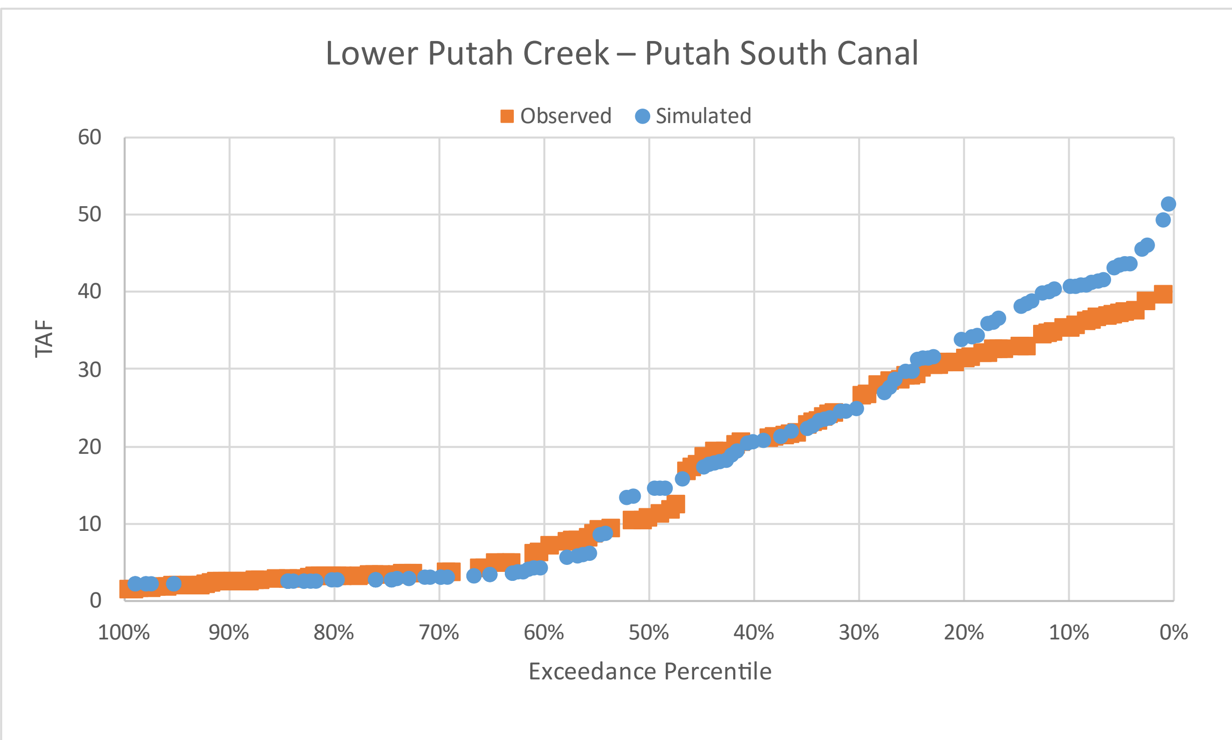


Figure A.3.8b. Lower Putah Creek – Putah South Canal, Exceedance

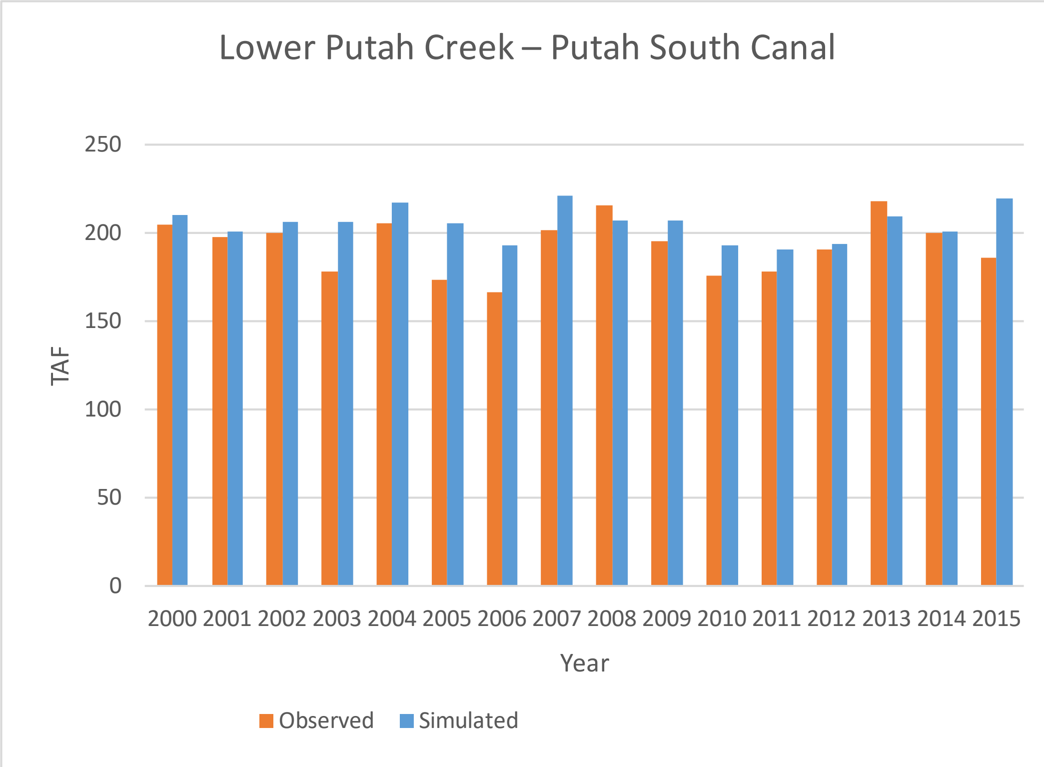


Figure A.3.8c. Lower Putah Creek – Putah South Canal, Annual 2000 to 2015

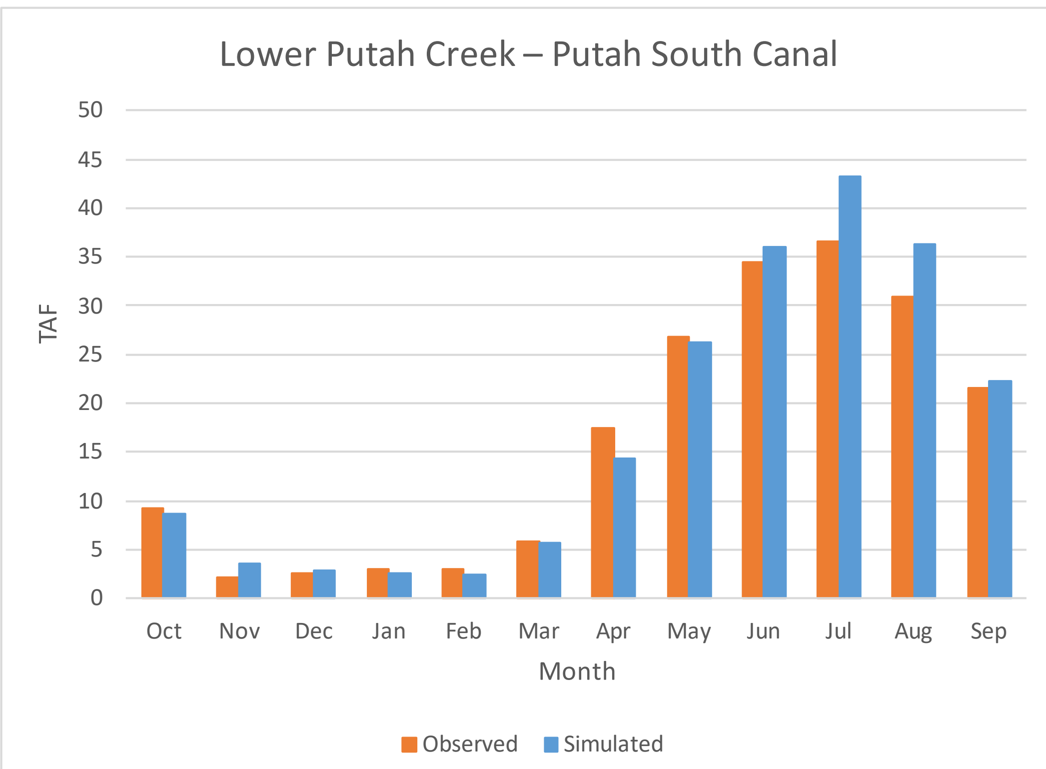


Figure A.3.8d. Lower Putah Creek – Putah South Canal, Average Monthly

A.3.9 Lower Cache Creek – Capay Valley and Capay Diversion Dam

The diversion from Cache Creek serves the agricultural lands in Capay Valley and the irrigated area of the Yolo County FC&WCD. Water released from Clear Lake and Indian Valley Reservoir are diverted into the YCFCWCD canal system at the Capay Diversion Dam. This water is used to irrigate numerous crops including almonds, tomatoes, and corn. These demands are represented in DU A_20_25_NA1. The calibration period average annual bias is -16.2%. Much of the under-prediction occurs during March and October. Precisely mimicking actual operations was difficult due to the variability in the duration of the irrigation season. The validation period bias is -13.1%.

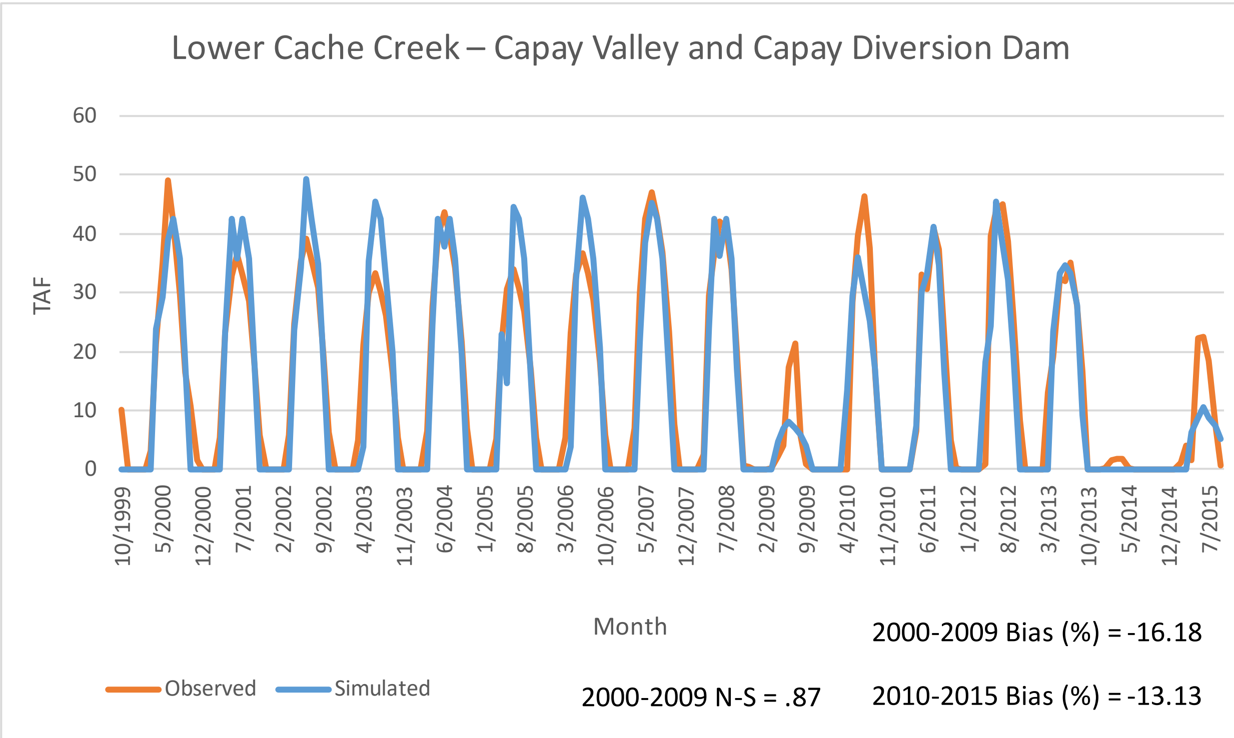


Figure A.3.9a. Lower Cache Creek – Capay Valley and Capay Diversion Dam, Monthly 2000 to 2015

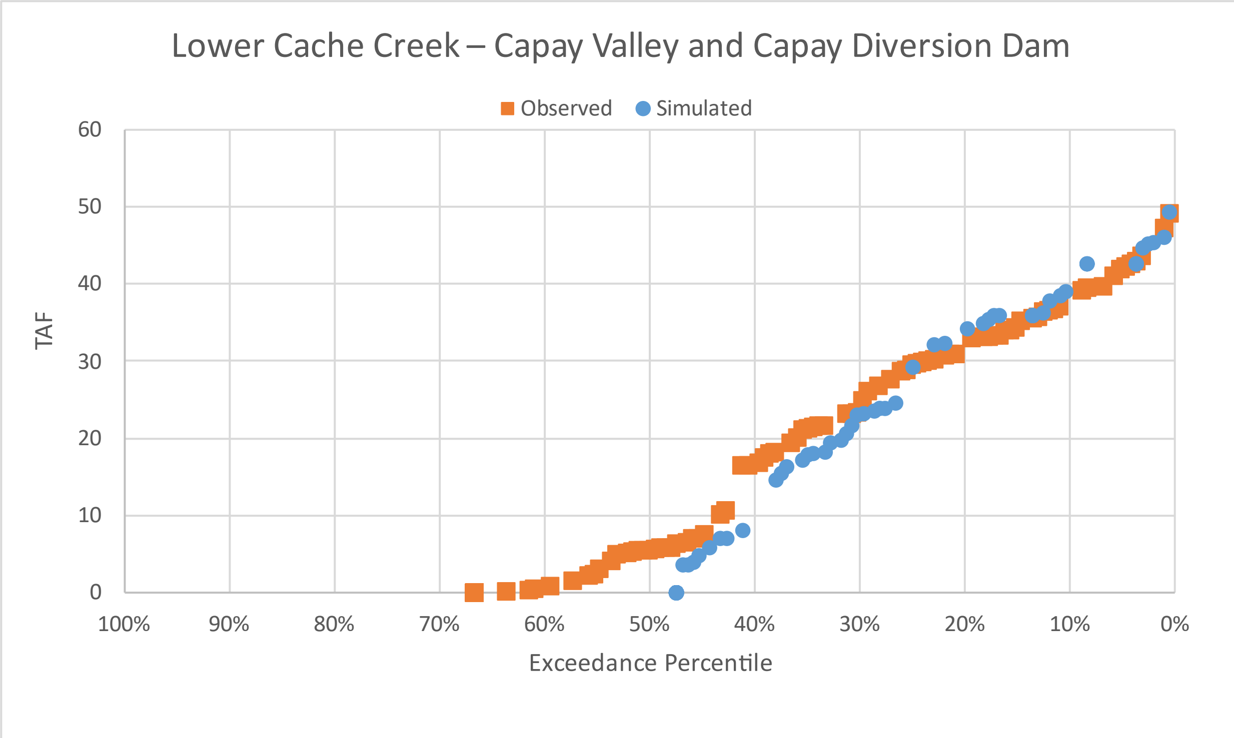


Figure A.3.9b. Lower Cache Creek – Capay Valley and Capay Diversion Dam, Exceedance

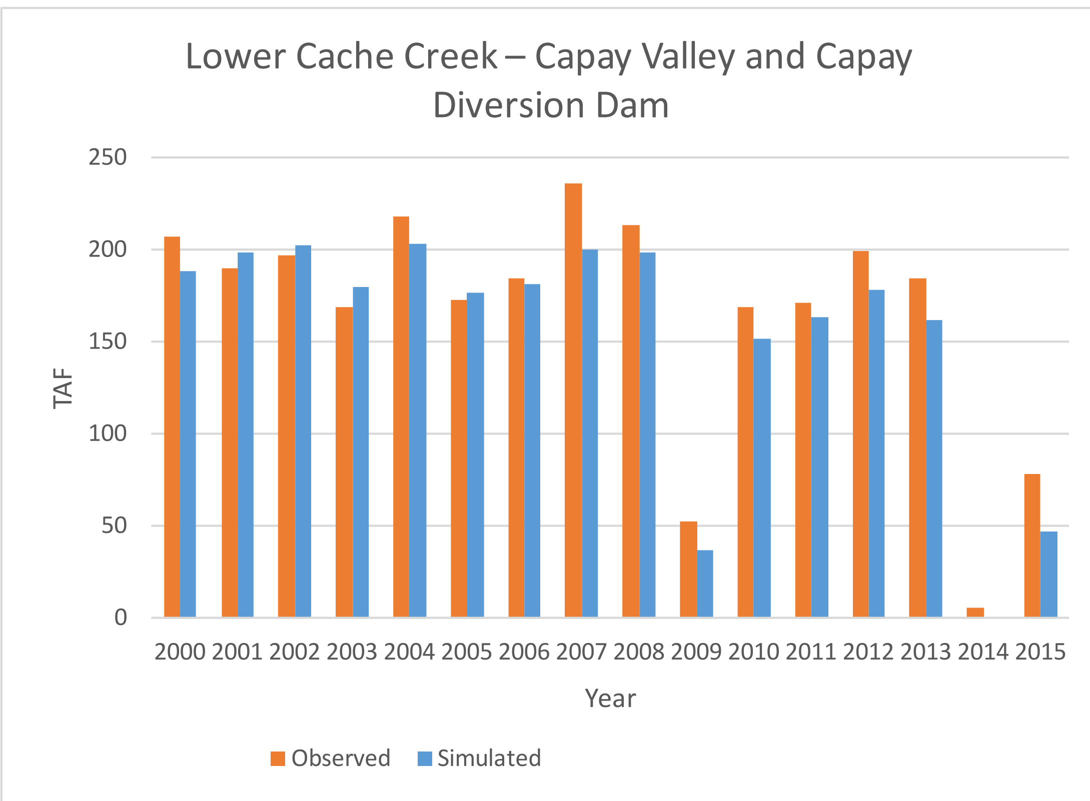


Figure A.3.9c. Lower Cache Creek – Capay Valley and Capay Diversion Dam, Annual 2000 to 2015

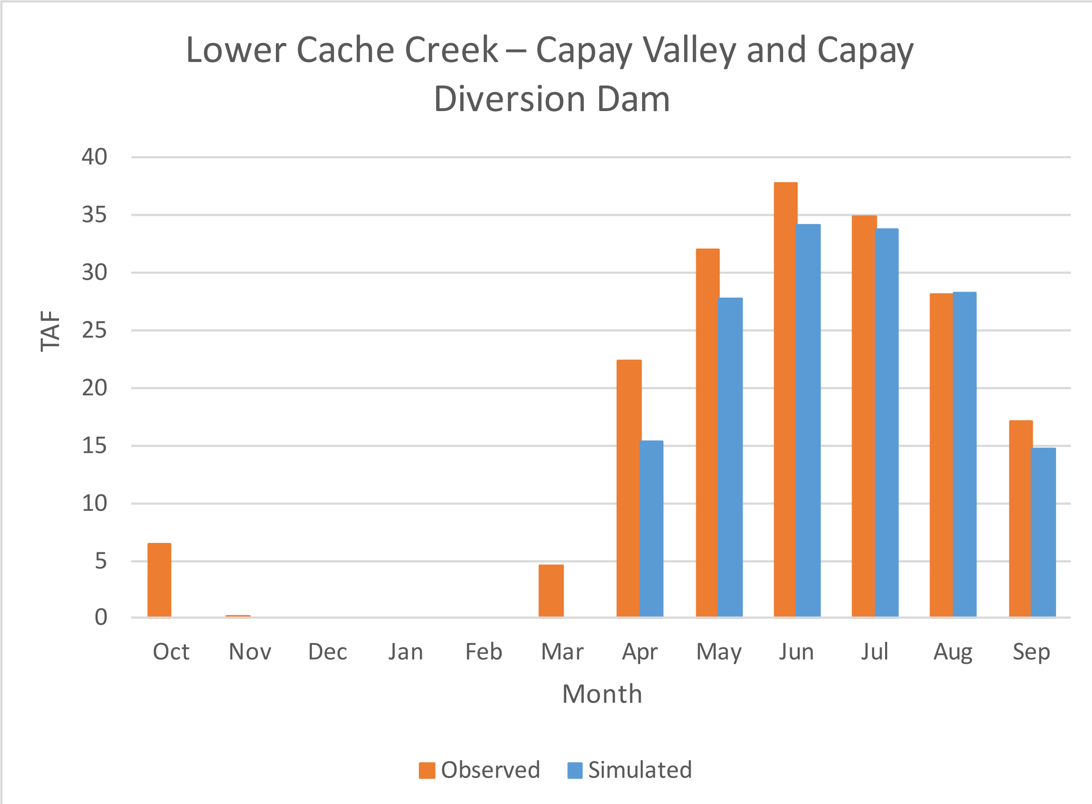


Figure A.3.9d. Lower Cache Creek – Capay Valley and Capay Diversion Dam, Average Monthly

A.3.10 Sacramento River Diversions – Reclamation District 108 and River Garden Farms

RD 108 operates eight pumping plants located on the Sacramento River. The largest of these is the Wilkins Slough Pumping Plant. In 2008, the Emery Poundstone Pumping Plant was constructed to replace 3 older plants (Boyer Bend, Howell Point, and Tyndall Mound). The existing South Steiner Pumping Plant also will be abandoned, replaced by a supply from the new Wilkins Slough Pumping Plant. RD 108 also draws water from the Colusa Basin Drain under an appropriative water right.

DU A_08_SA3 represents total diversions by agricultural settlement contractors on the right bank of the Sacramento River between Wilkins Slough and the town of Knights Landing.

Other diverters include River Garden Farms, which is located immediately to the south of RD 108 and is separated from RD 108 by a drainage channel (RD 108 lateral) that runs along the common boundary between RD 108 and RD 737. The boundary of the land is defined by the Sacramento River, Colusa Basin Drain, and the RD 108 lateral. Sycamore Slough flows through the center of these lands. River Garden Farms diverts Sacramento River water at the El Dorado Bend Pumping Plant and 2 additional points of diversion downstream. In SacWAM, diversions to River Garden Farms are aggregated with diversions to RD108.

The diversions are used to irrigate numerous crops including rice and tomatoes. Observed data are available for April-October. The calibration period average annual bias for Apr-Oct is 2.9%. During calibration the *Release Requirement* was set to 2 mm/d. The simulated delivery pattern largely matches the observed pattern except in June, September, and October. The validation period bias is 4.3%.

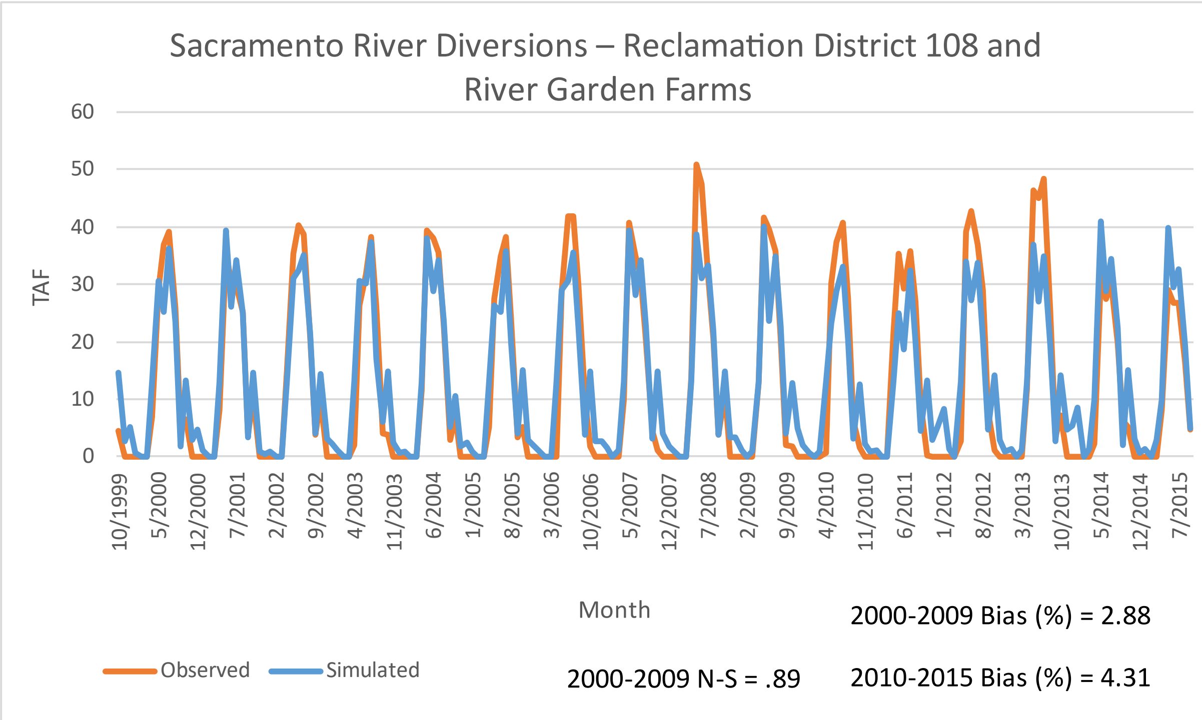


Figure A.3.10a. Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Monthly 2000 to 2015

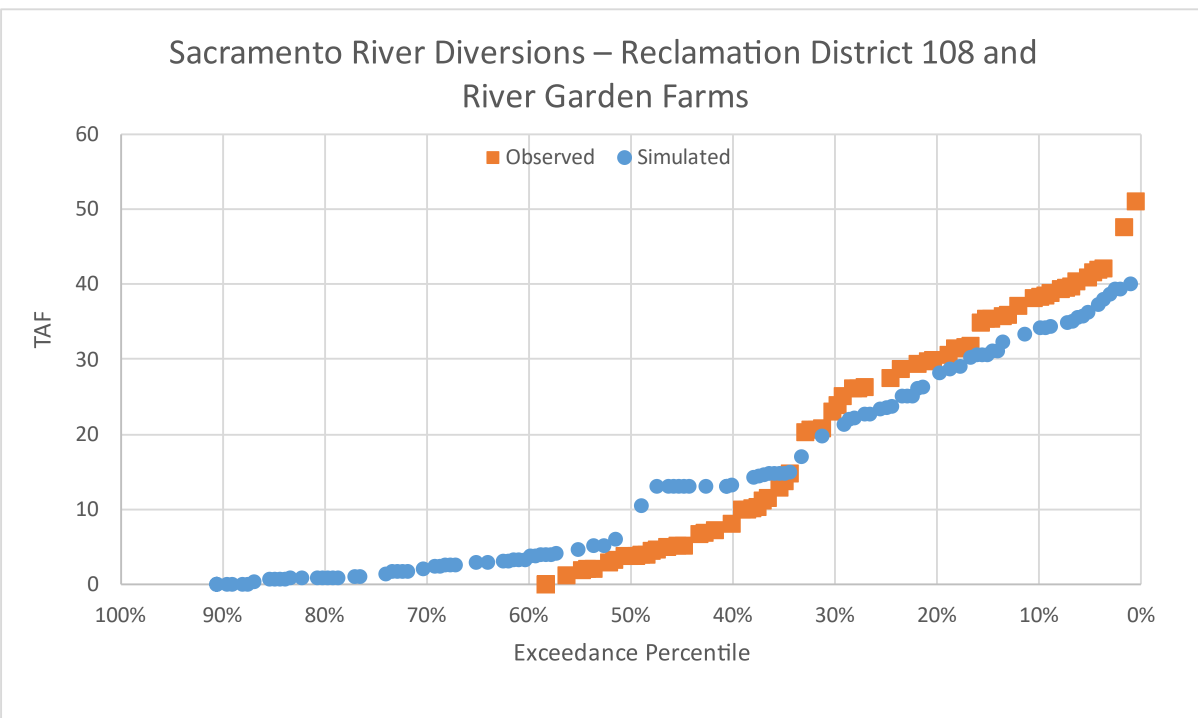


Figure A.3.10b. Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Exceedance

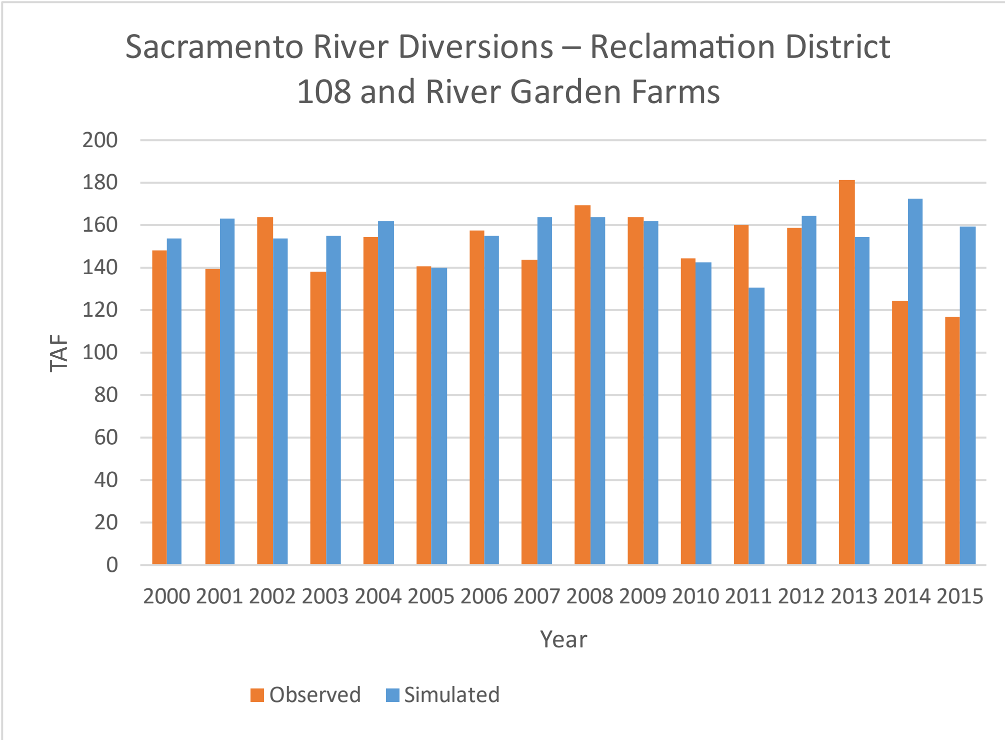


Figure A.3.10c. Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Annual 2000 to 2015

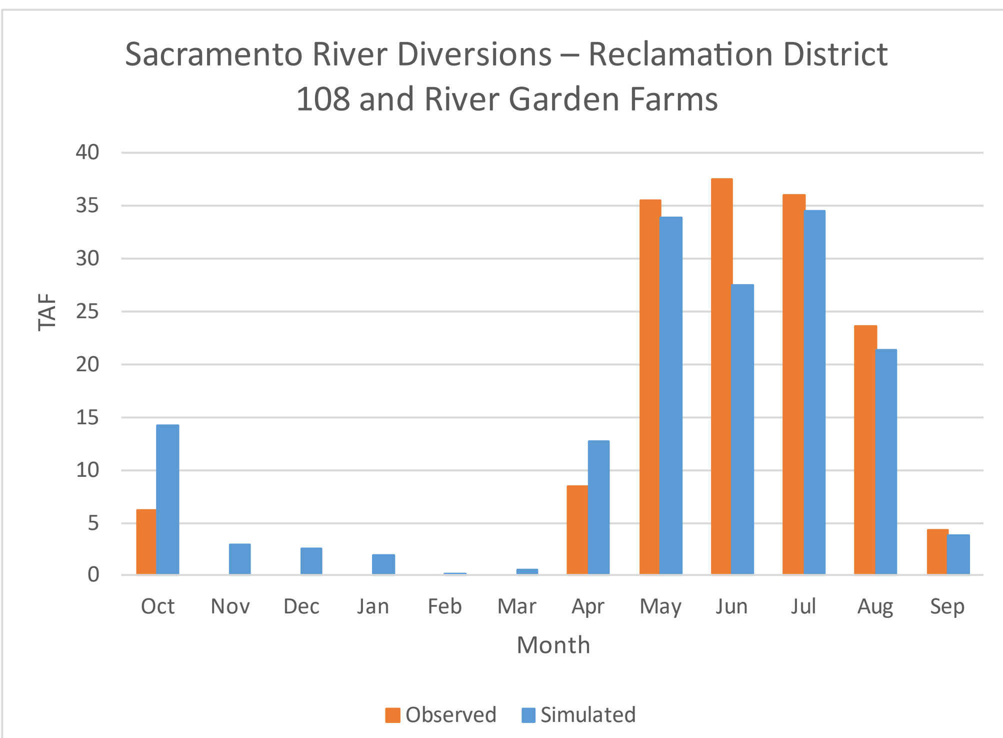


Figure A.3.10d. Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Average Monthly

A.3.11 Sacramento River Diversions – Anderson-Cottonwood Irrigation District

Anderson-Cottonwood ID is the major agricultural water purveyor in the Redding Basin. The district also is a CVP settlement contractor. The district's service area covers approximately 32,000 acres south of the City of Redding on both sides of the river. Anderson-Cottonwood ID is represented in SacWAM by demand units A_02_SA and A_03_SA. The district diverts water from the right bank of the Sacramento River near the City of Redding above a seasonal diversion dam, which creates Lake Redding, and at the Bonnyview diversion and Churn Creek pumping station located on the left bank of the river. Very little groundwater is used within the district, except occasionally during drought conditions.

Anderson-Cottonwood ID diversion data from April through October is from Central Valley Operations (CVO), U.S. Department of Interior, Bureau of Reclamation (Reclamation). Reclamation does not measure data outside of the irrigation season. However, statements of water use submitted by the district to the State Water Resources Control Board (SWRCB) show no diversion outside of the April to October season.

The water diverted for Anderson-Cottonwood ID is predominantly used to irrigate pasture. Observed data are available for April-October. The calibration period average annual Apr-Oct bias is -20.8%. The simulated monthly pattern under predicts April, May, September, and October. This is probably due to the operational constraints of this canal system that require a large minimum diversion to operate. The validation period bias is -11.5%.

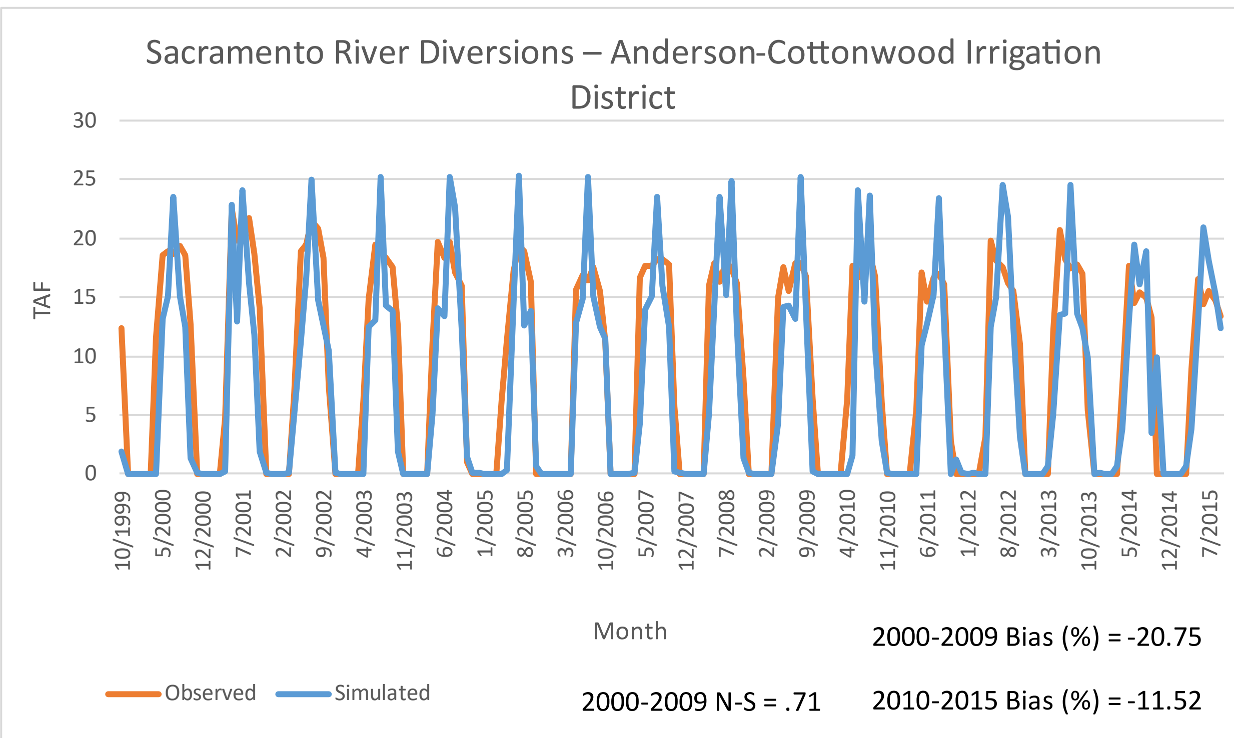


Figure A.3.11a. Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Monthly 2000 to 2015

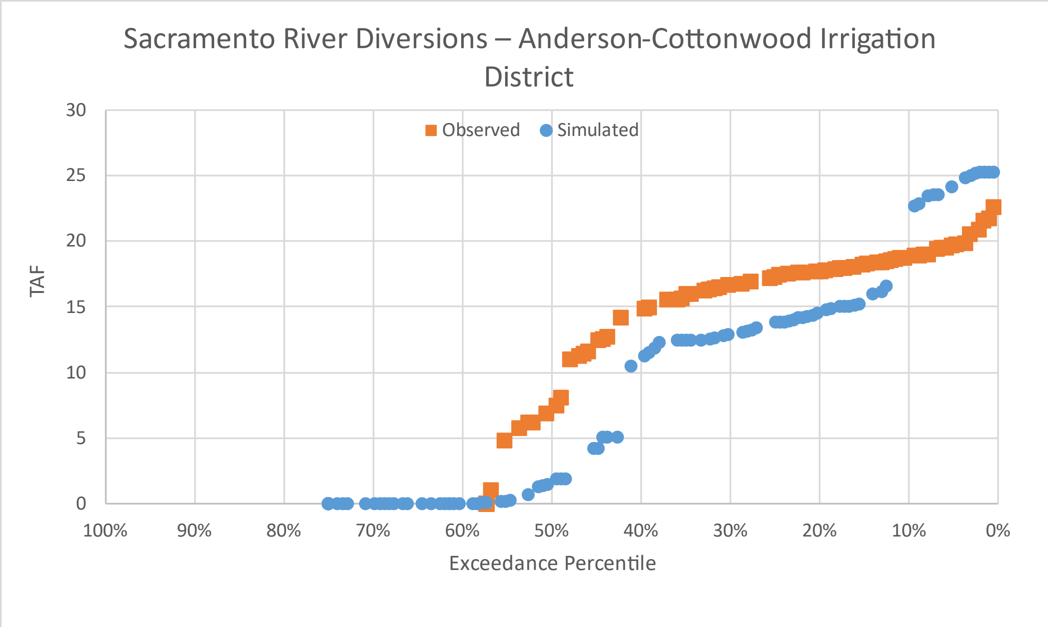


Figure A.3.11b. Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Exceedance

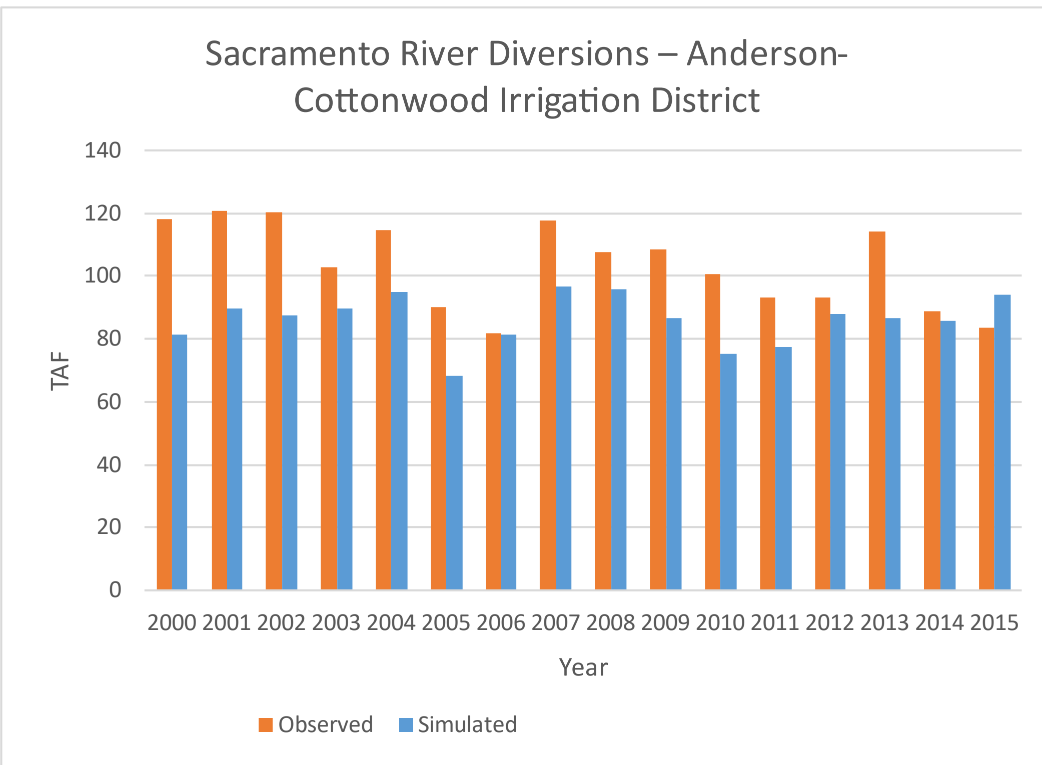


Figure A.3.11c. Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Annual 2000 to 2015

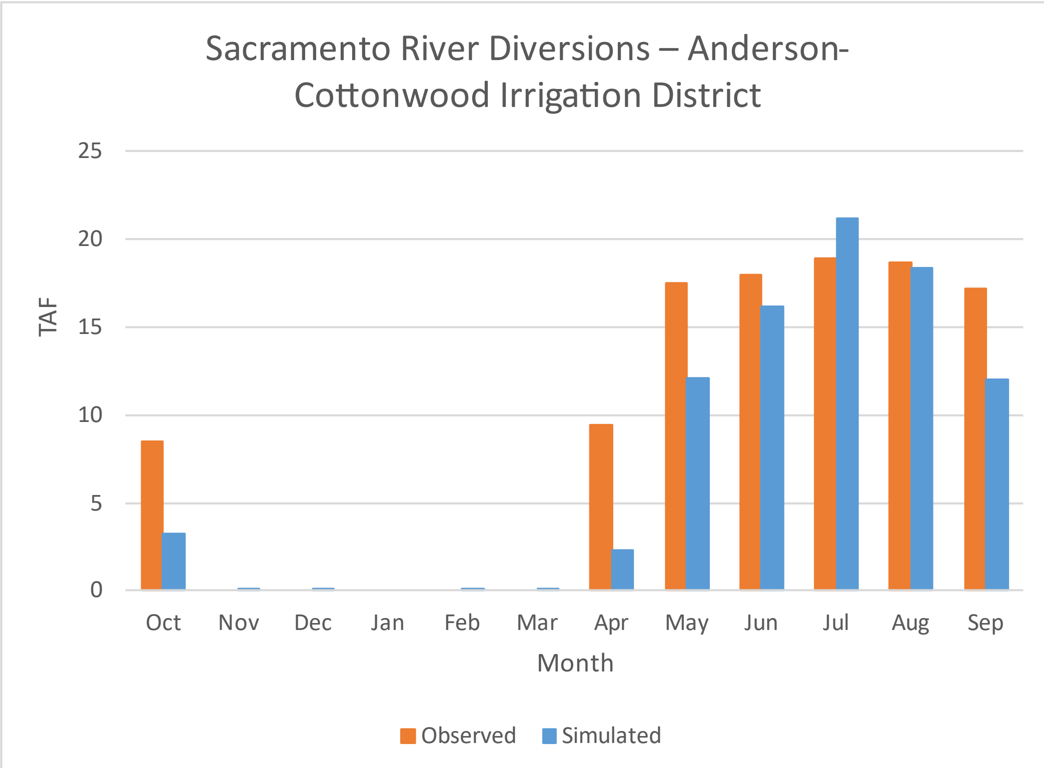


Figure A.3.11d. Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Average Monthly

A.3.12 Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District

The diversions from the Bear River to the South Sutter and Camp Far West IDs provide water to DU A_23_NA. The water is predominantly used to irrigate rice and orchards. Observed data are available for April-October. The average annual Apr-Oct bias is 27.5%. The simulated monthly pattern over predicts April and under predicts June and July. These differences are probably due to rice management practices that were not accounted for in the model. The validation period bias is 32.4%.

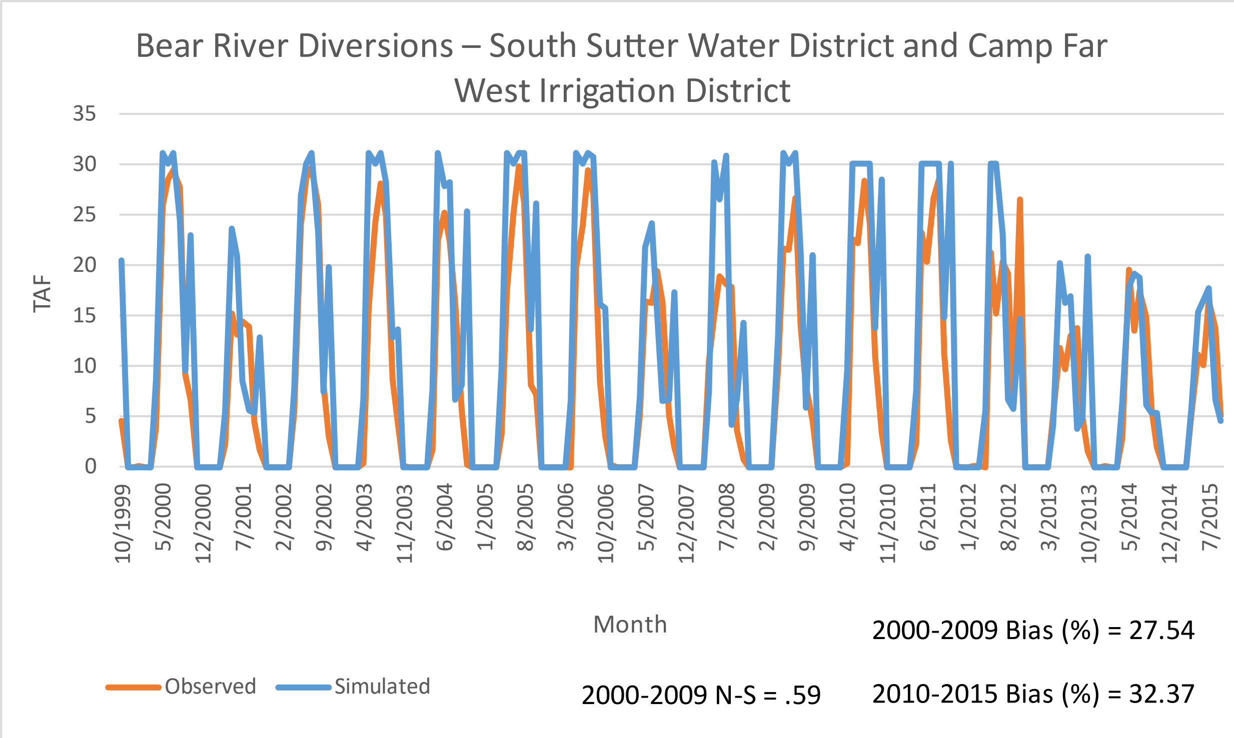


Figure A.3.12a. Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Monthly 2000 to 2015

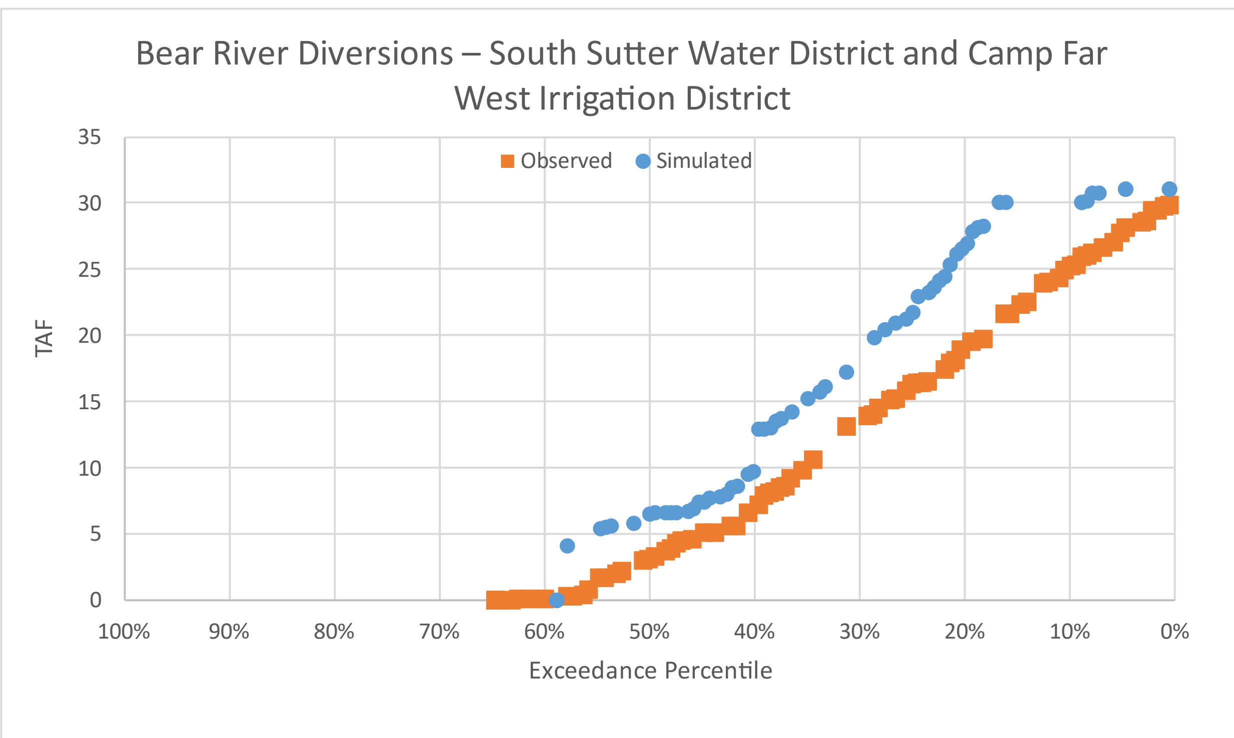


Figure A.3.12b. Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Exceedance

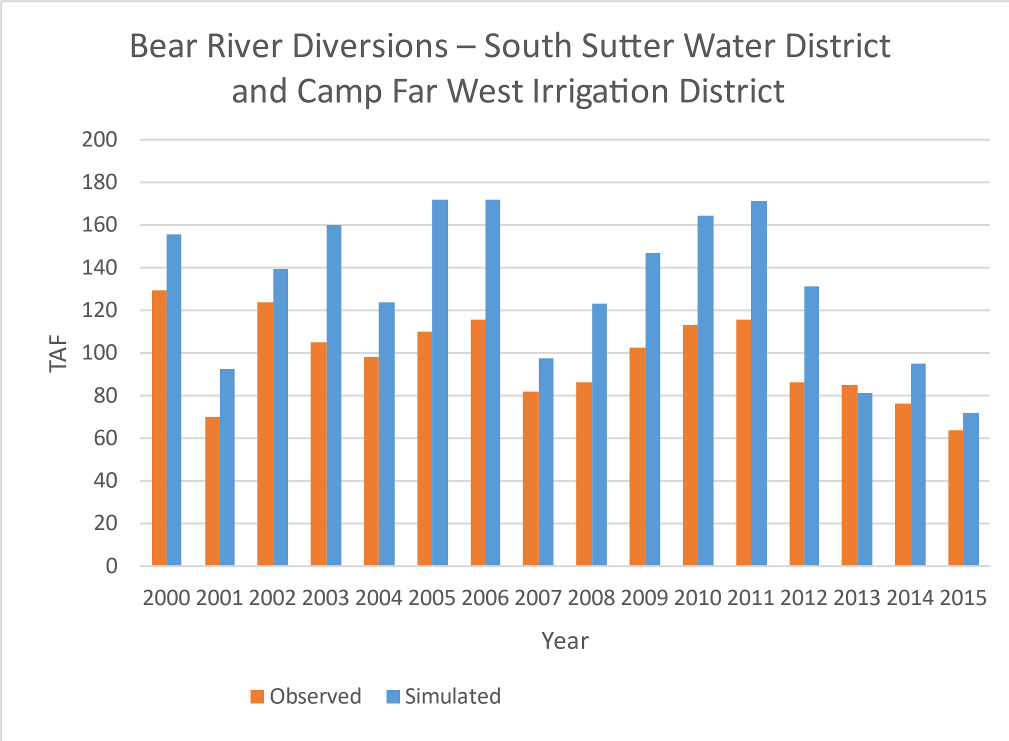


Figure A.3.12c. Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Annual 2000 to 2015

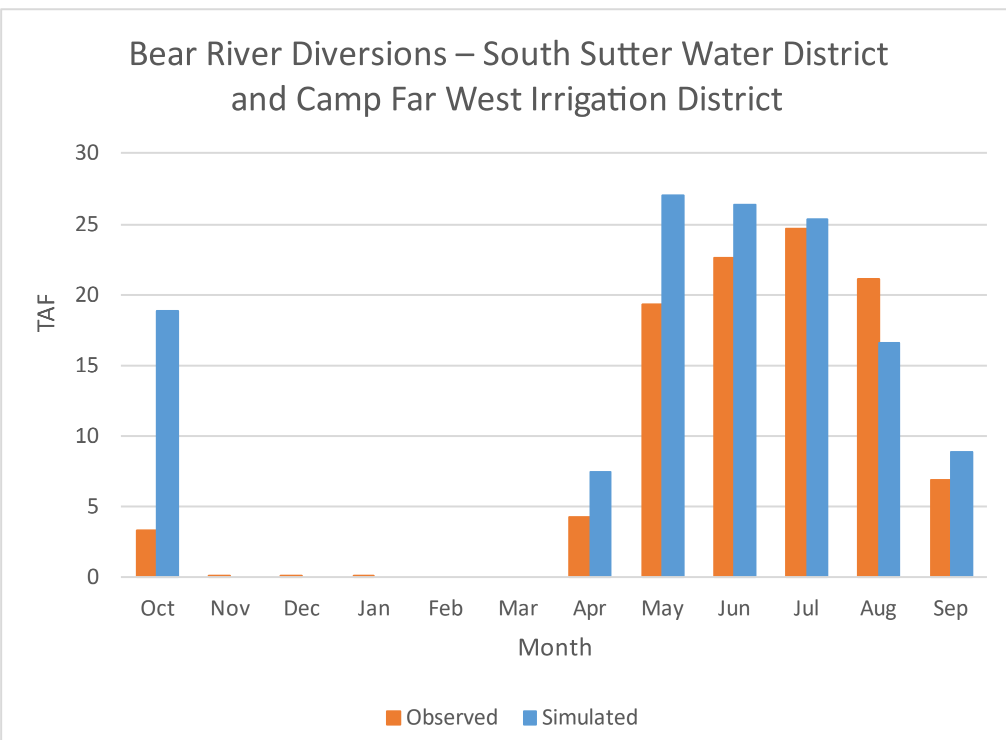


Figure A.3.12d. Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Average Monthly

A.3.13 Lower Yuba River – Yuba County Water Agency Left Bank

The diversions from the left bank of the Yuba River to the Yuba County WA provide water to DUs A_15S_SA and A_15S_NA. The water is predominantly used to irrigate rice, pasture, and orchards. Observed data are available for 12 months. The calibration period average annual bias is -27.8%. The simulated monthly pattern largely agrees with the observed data. The validation period bias is -20.8%.

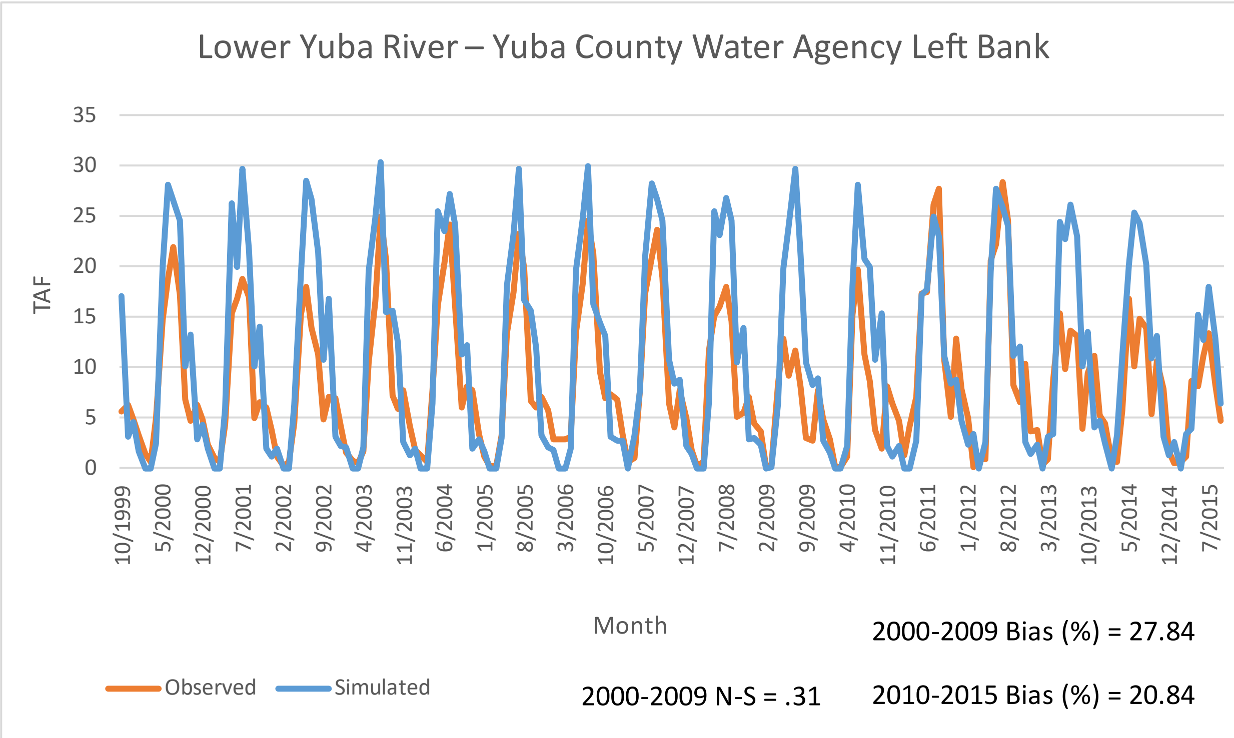


Figure A.3.13a. Lower Yuba River – Yuba County Water Agency Left Bank, Monthly 2000 to 2015

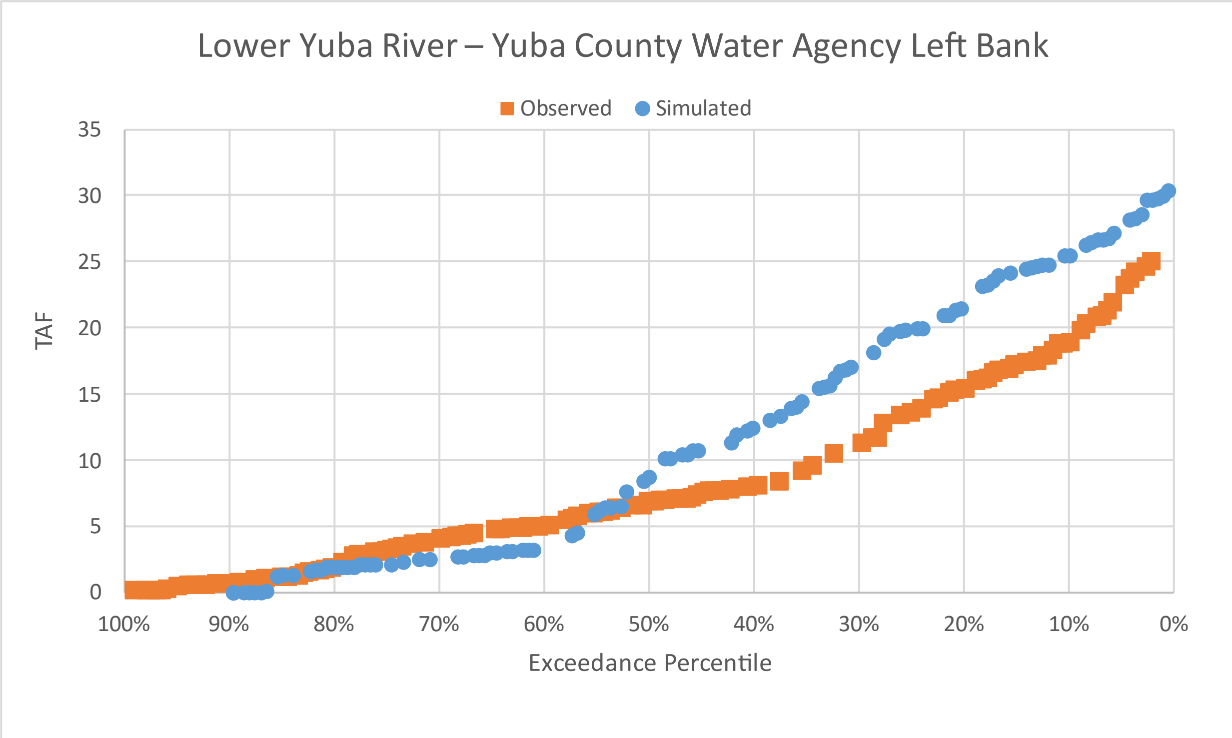


Figure A.3.13b. Lower Yuba River – Yuba County Water Agency Left Bank, Exceedance

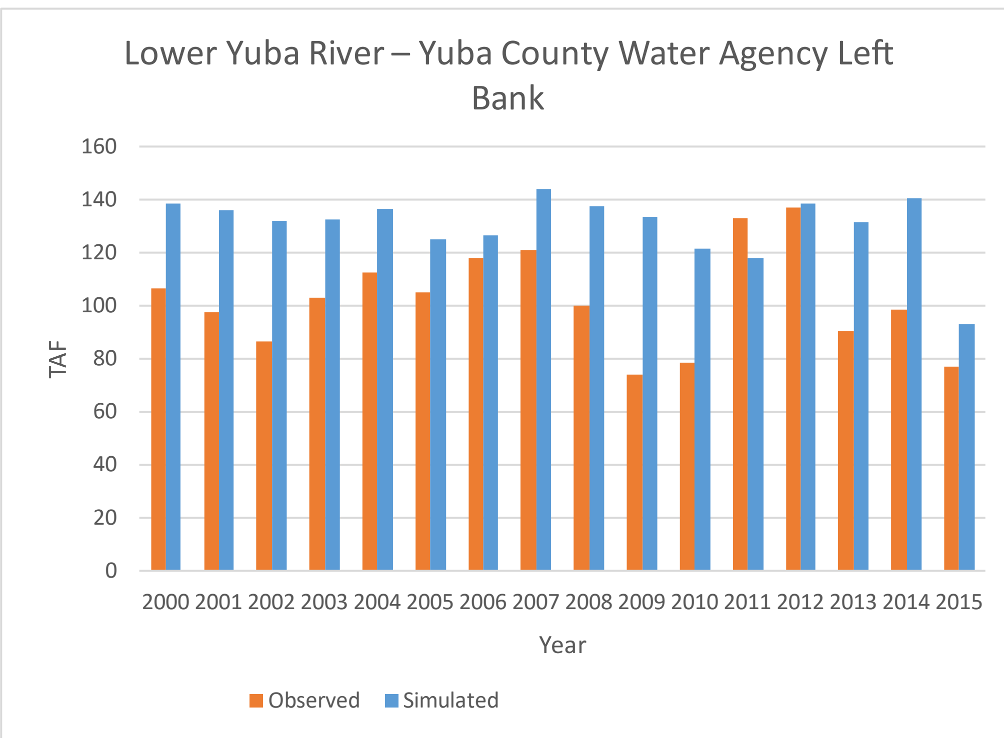


Figure A.3.13c. Lower Yuba River – Yuba County Water Agency Left Bank, Annual 2000 to 2015

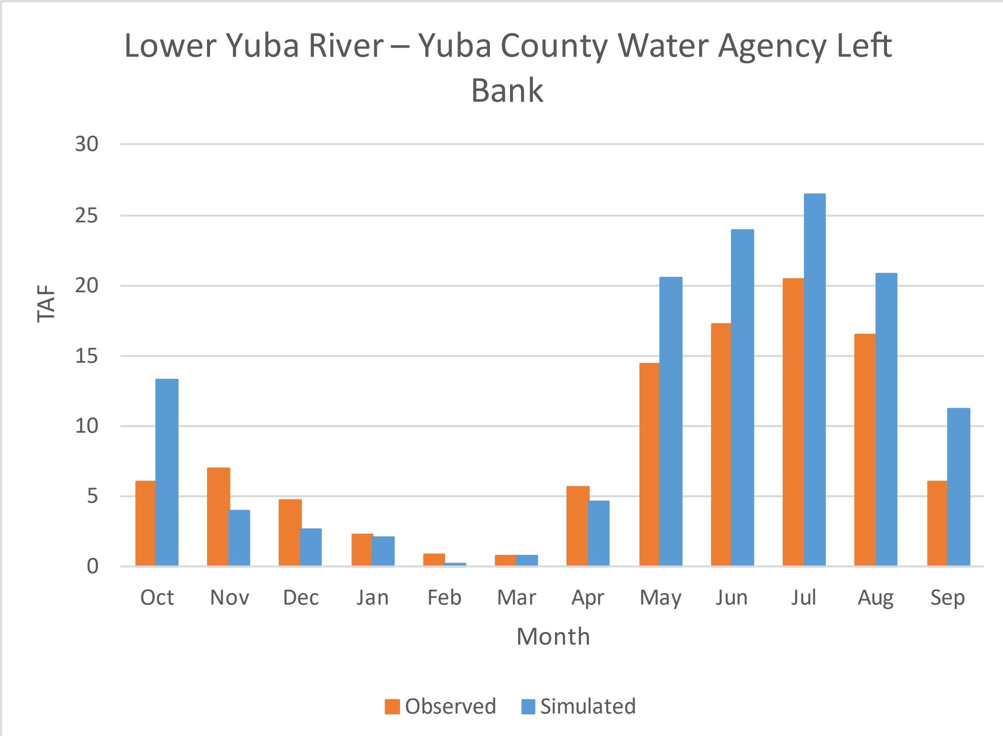


Figure A.3.13d. Lower Yuba River – Yuba County Water Agency Left Bank, Average Monthly

A.3.14 Lower Stony Creek – Orland Project

The Orland Project, centered on Stony Creek, is one of the oldest Federal reclamation projects in the United States. The main elements of the project include East Park Dam, Stony Gorge Dam, Rainbow Diversion Dam and East Park Feeder Canal, South Diversion Intake and South Canal, and Northside Diversion Dam and North Canal. The South Diversion Intake and Canal were built in conjunction with Black Butte Dam in 1963. The North and South Canals serve the Orland Water Users Association. The diversions from the right bank of Stony Creek to the Orland Project provide water to DU A_04_06_NA1. The water is predominantly used to irrigate pasture, alfalfa, and orchards. Observed data are available for 12 months. The calibration period average annual bias is -18.3%. The simulated monthly pattern largely agrees with the observed data except in October. The validation period bias is -6.7%.

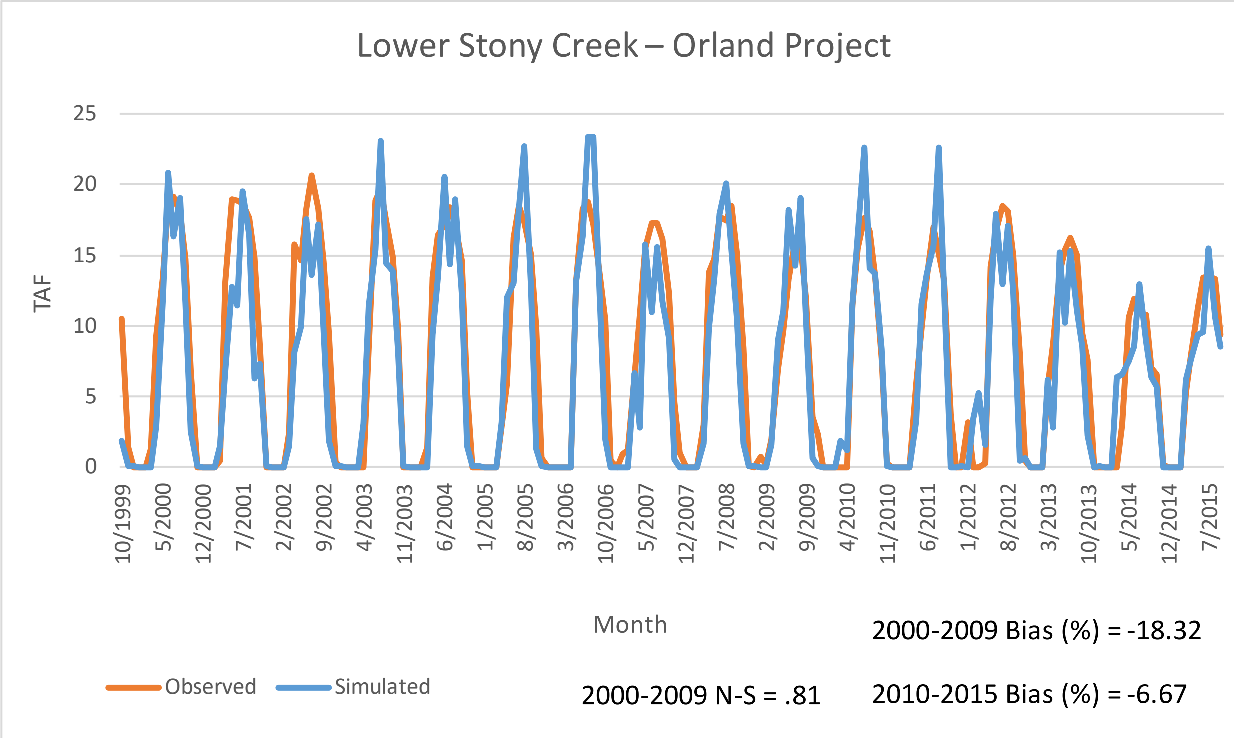


Figure A.3.14a. Lower Stony Creek – Orland Project, Monthly 2000 to 2015

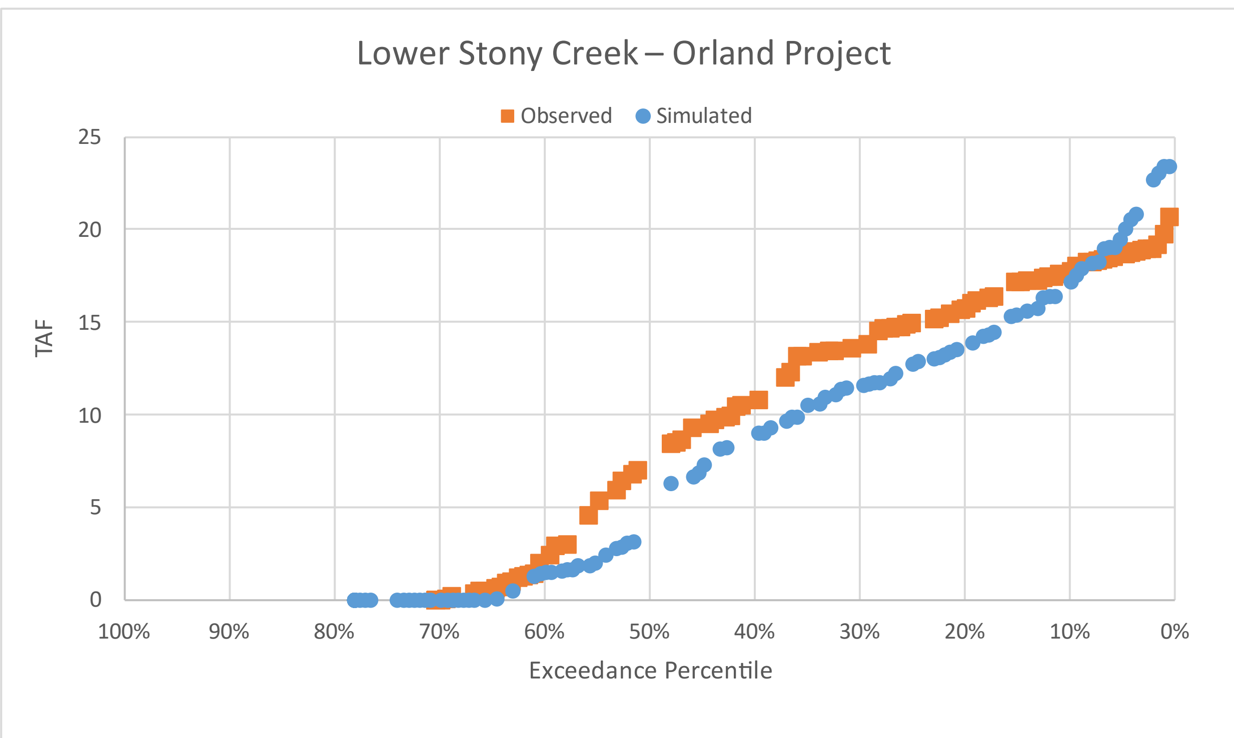


Figure A.3.14b. Lower Stony Creek – Orland Project, Exceedance

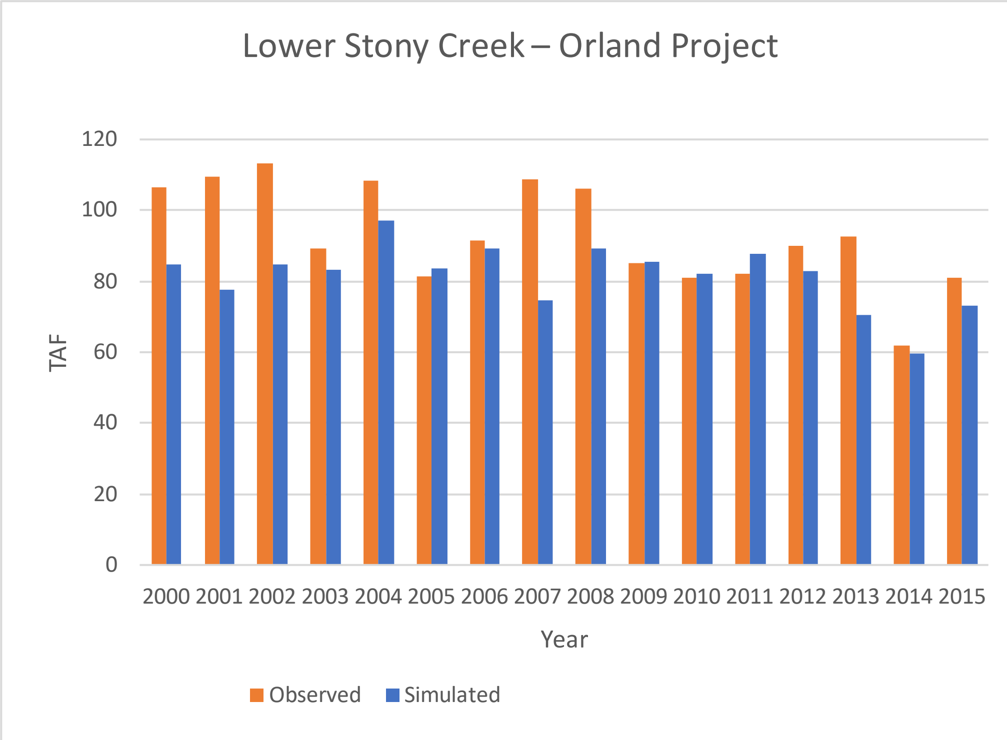


Figure A.3.14c. Lower Stony Creek – Orland Project, Annual 2000 to 2015

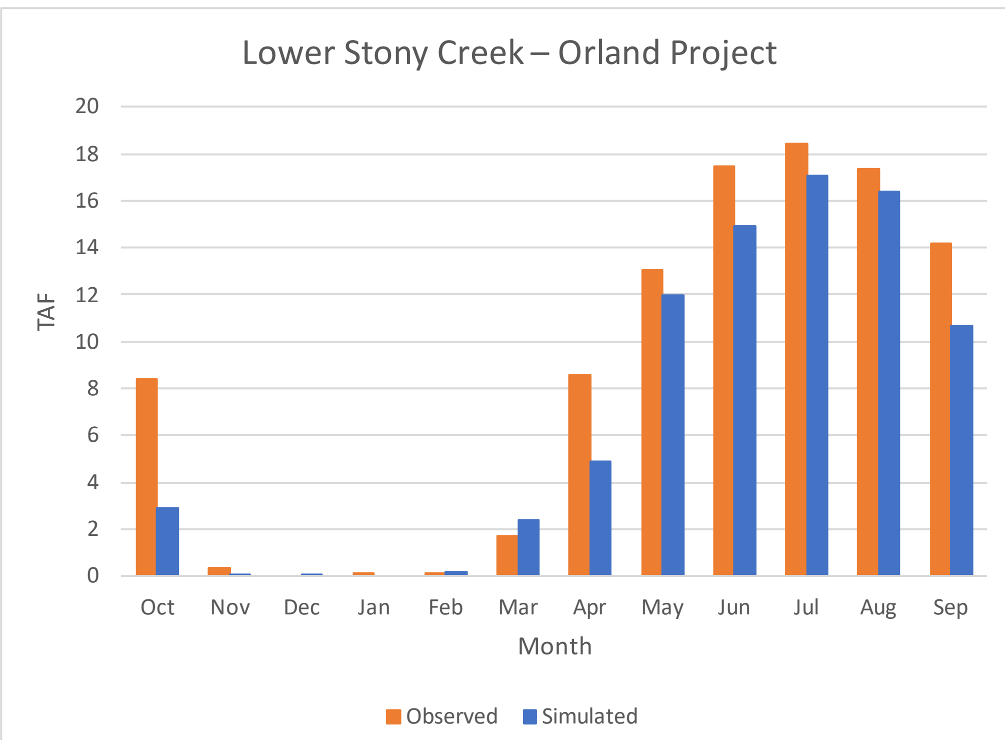


Figure A.3.14d. Lower Stony Creek – Orland Project, Average Monthly

A.3.15 Lower American and Sacramento River Diversions – City of Sacramento

The City of Sacramento water supplies include surface water diversions from the lower American River to its Fairbairn water treatment plant, diversions from the Sacramento River to its Sacramento water treatment plant, and supplementary groundwater pumping. Additionally, the place of use for water diverted under the American River permits includes the city limits and adjacent portions of service areas of several other water purveyors. The city's surface water entitlements include five appropriative water right permits, pre-1914 rights, and a water rights settlement contract with Reclamation. The City of Sacramento provides treated surface water to Sacramento Suburban WD, Fruitridge Vista WC, and the California American WC under various wholesale agreements. The city also wheels water to Sacramento County WA Zone 40, and wholesales/wheels water to the Sacramento International Airport and Metro Air Park.

The water is provided to DUs U_26_NU3, U_26_PU4, U_26_NU1, and U_26_NU4. Observed data are available for 12 months. The calibration period average annual bias is 11.7%. The simulated monthly pattern reasonably represents the observed data during the calibration period, however in the validation period actual demand is 56.7% of the simulated demand. This is probably due to a mix of widespread water conservation measures that were implemented during the drought and possibly incorrect diversion data.

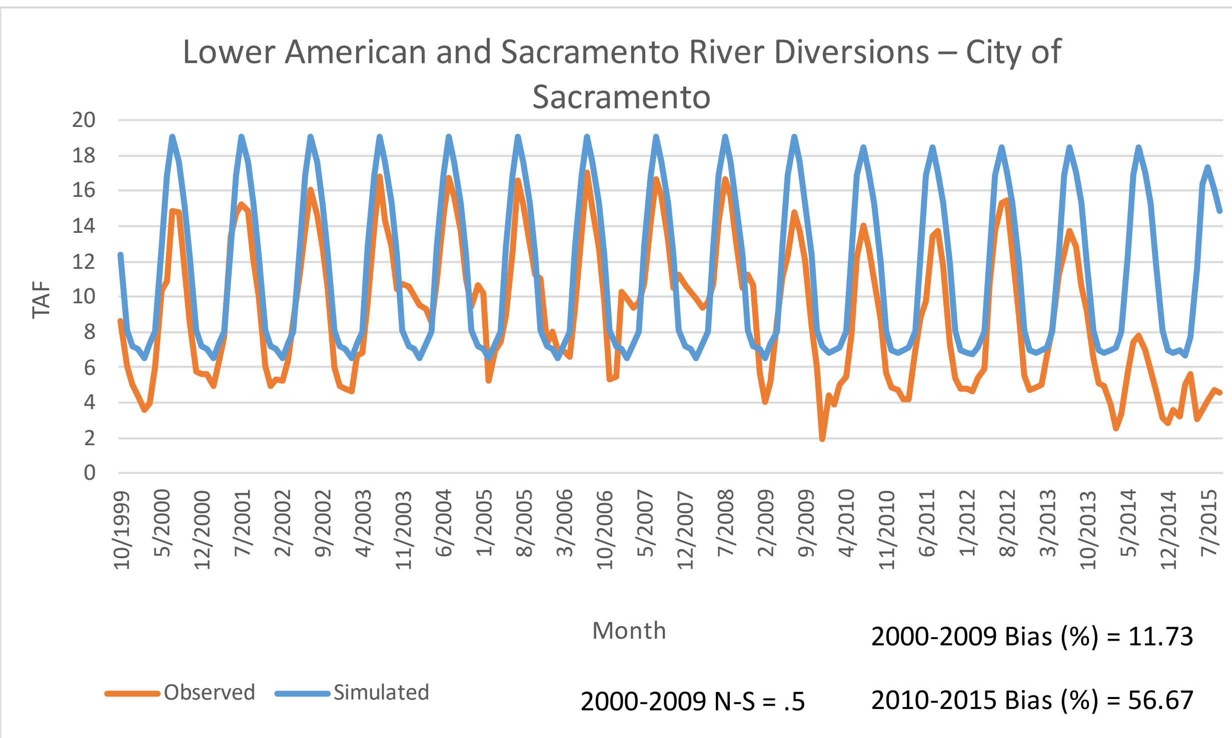


Figure A.3.15a. Lower American and Sacramento River Diversions – City of Sacramento, Monthly 2000 to 2015

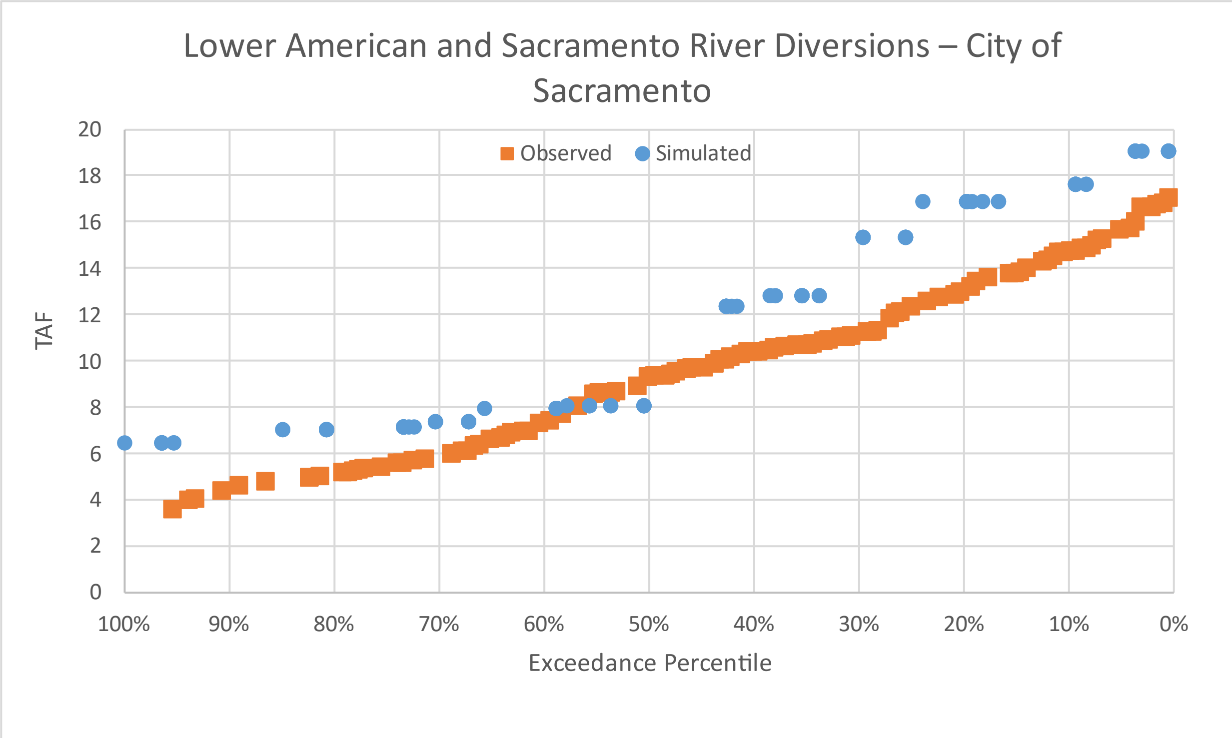


Figure A.3.15b. Lower American and Sacramento River Diversions – City of Sacramento, Exceedance

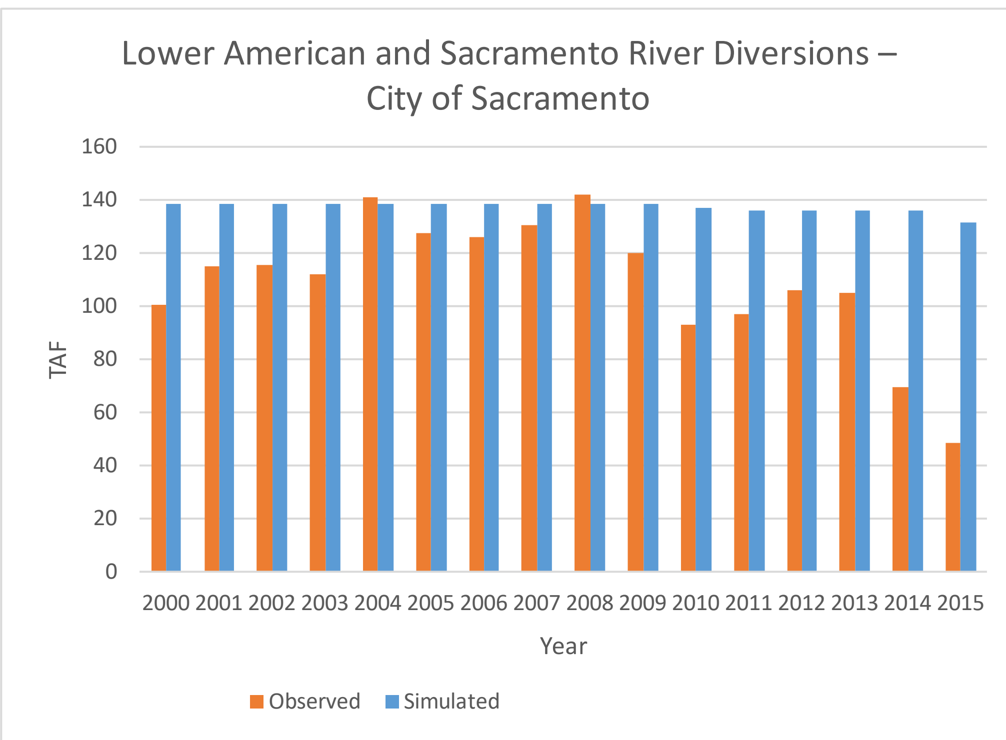


Figure A.3.15c. Lower American and Sacramento River Diversions – City of Sacramento, Annual 2000 to 2015

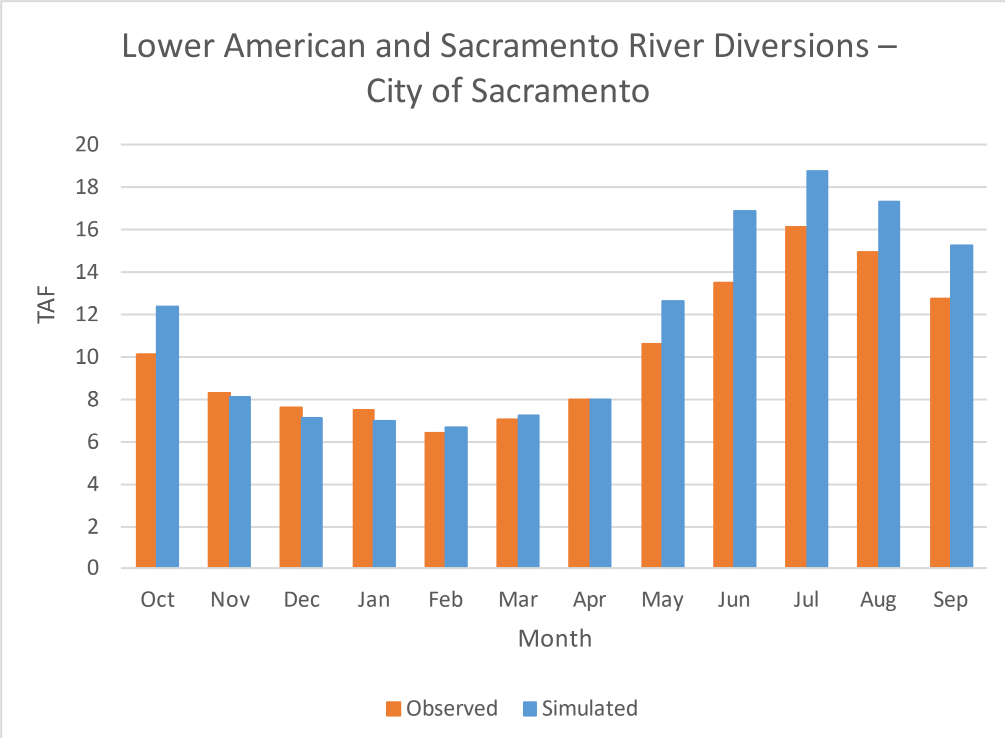


Figure A.3.15d. Lower American and Sacramento River Diversions – City of Sacramento, Average Monthly

A.4 Rainfall Runoff Calibration

With the calibration of crop ET rates and irrigation diversions complete, the final effort in calibration was focused on rainfall-runoff and stream-aquifer interactions. During this phase of calibration, emphasis was placed on model performance during recent years (1986-2015) because this period is most consistent with the land use specified in the model and the recent prolonged stretch of dry conditions from 2007 to 2015 is indicative of model performance when the water resources of the Central Valley are under stress. This section describes calibration of rainfall-runoff parameters.

During the calibration of rainfall-runoff parameters the stream-aquifer interactions were set as described in Section 6.3.1.3. Additional adjustments were made to these parameters following the calibration of the rainfall-runoff parameters as described in Section B.5.

The rainfall-runoff calibration consisted of adjusting parameters so that simulated surface water accretions during winter months were similar to observed surface water accretions. This portion of the calibration effectively determined the division of precipitation on the valley floor into infiltration and surface runoff. As discussed in the definition of *Effective Precipitation* (Section 4.4.3.4), a modified Curve Number algorithm was used to partition rainfall into infiltration and surface runoff in the daily MABIA model. This algorithm increases the proportion of rainfall that becomes surface runoff as the soil becomes wetter. During calibration, literature-based curve numbers were adjusted on a monthly basis until simulated and historical accretions for water years 1985-2015 matched. The comparison was made for the months of November to March as these months experience the most rainfall and have the least amount of irrigation operations.

In order to calibrate the curve numbers, a comparison was made between historical and simulated accretions on the Sacramento Valley floor upstream of the gauge at Freeport. Historical accretions were calculated by subtracting all observed rim inflows from the sum of the observed flow at Freeport and through the Knights Landing Ridge Cut. This calculation was not performed for months when Fremont Weir was spilling in order to avoid errors caused by the lack of consistent data related to the Yolo Bypass flows during high flow events. For the simulated data, reservoir releases and tributary inflows were subtracted from the sum of the simulated flow at Freeport and through the Knights Landing Ridge Cut. The resulting time series is the sum of the stream-aquifer interactions and the rainfall-runoff. Little water is diverted to meet irrigation demands during this period.

The calibrated curve numbers are presented in Table A-3. The curve numbers increase in magnitude from November to February and decrease slightly in March, which is largely consistent with the soil being wetter as the rainy season progresses, resulting in a larger runoff fraction. Only agricultural and native vegetation lands were adjusted as they represent a large majority of the valley floor area.

During calibration it was found that the accretions during Critical years (as defined by the Sacramento 40-30-30 index) were too large. Therefore, the intercept value described in Section 6.3.1.3 was reduced by a factor of 0.6 for Critical years only.

Using the curve numbers shown in Table A-3 and the intercept value scaling factor for Critical years, the average simulated monthly accretions for 1986 to 2015 match to within 4% of the observed values on average (top left graph in Figure A.4.1). Analysis of the comparison on a water year type basis (based on the Sacramento 40-30-30 index) shows that the agreement between simulated and observed values is not as close for several of the year types (Table A-4). It should be noted that due to removal of months in which the Fremont Weir was spilling the amount of data available for each water year type graph is limited. For instance, Fremont Weir spilled in February of all wet years, therefore there is no comparison for that month.

Table A-3. Calibrated Curve Number Values Based on Matching Average Monthly Accretions, Sacramento Valley

Land Cover Type	Initial Curve Number	Calibrated Curve Numbers				
		November	December	January	February	March
Agriculture	86	68.8	92.9	94.6	95.5	94.6
Native Vegetation	79	63.2	85.3	86.9	87.7	86.9
Urban Outdoor	69	69	69	69	69	69
Refuge	46	46	46	46	46	46

Note: Performance of the rainfall runoff processes were assessed for November – March. Performance of the stream-aquifer interactions were assessed April-October.

Figure A-4.1 Simulated and Historical Sacramento Valley Accretions and Depletions (1986-2015) Following the Calibration of Rainfall Runoff Parameters and Stream Aquifer Interactions

Table A-4. November – March Simulated Accretions Bias by Water Year Type (1986-2015)

Water Year Type	Number of Years	Bias (%)
Wet	8	-17
Above Normal	4	9
Below Normal	3	38
Dry	7	-9
Critical	8	6

A.5 Stream Aquifer Interactions Calibration

Calibration of parameters governing stream-aquifer interactions followed calibration of the rainfall-runoff. The initial parameterization of the stream-aquifer interactions is described in Section 6.3.1.3. During calibration the parameters that characterize stream aquifer interactions were adjusted for two aspects of the model.

A.5.1 Colusa Basin

Analysis of model results following calibration of rainfall-runoff and stream-groundwater parameters revealed that outflow from the basin through the Colusa Basin Drain and Knights Landing Ridge Cut were much larger than historical values. Average annual simulated flows, 1990-2009 were approximately 185 TAF or 32 percent greater than historical. In order to reduce simulated outflow from the Colusa Basin the baseflow was reduced by scaling the intercept value described in Section 6.3.1.3 for the reaches in the Colusa Basin Drain by a value of 0.6. After changes to the base flow parameters, the Colusa Basin outflow was reduced by an average of 95 TAF per year, however, a 16% bias persisted.

A.5.2 Growing Season Depletions

An analysis of net depletions and accretions (using the method of calculation described in Section B.4) during the April-October period indicated that the model was generally over-predicting flows in the drier years and under predicting flows in the wetter years. In order to remedy this, a water year type specific scaling factor was used to adjust the intercept value described in Section 6.3.1.3 (Table A-5) during the months of April-October. For Critical years, even with a factor of 0.0, the net depletions in April-October were too low. In order to reduce Critical year flows further, the slope value described in Section 6.3.1.3 was increased by the factor in Table A-5.

Table A-5. Stream-Aquifer Interactions Scaling Factors

Water Year Type	Apr-Oct Baseflow Scaling Factor	Apr-Oct Slope Scaling Factor	Nov-Mar Baseflow Scaling Factor	Nov-Mar Slope Scaling Factor
Wet	2.20	1.00	1.00	1.00
Above Normal	1.80	1.00	1.00	1.00
Below Normal	0.35	1.00	1.00	1.00
Dry	0.20	1.00	1.00	1.00
Critical	0.00	1.90	0.60	1.00

A.6 Project Operations Validation (CalSim)

An extensive set of logic was developed to represent CVP-SWP operations in SacWAM. A description of this logic is found in chapters 7 and 8 of the main report. This section compares CVP-SWP simulated operations in SacWAM to those from CalSim II. CalSim II results are from the 2015 SWP Delivery Capability Report – Existing Conditions. The common period of simulation is water years 1922-2003. Simulated operations over this period cannot be compared to historical data because both models represent existing land use conditions, water control facilities, contracts, and regulatory requirements.

The analysis presented here focuses on the principal components of CVP-SWP operations, as follows:

1. CVP storage north-of-Delta
2. SWP storage north-of-Delta (Oroville)
3. CVP storage south-of-Delta (San Luis)
4. SWP storage south-of-Delta (San Luis)

5. Trinity River Imports
6. American River at Confluence
7. Feather River at Confluence
8. Sacramento River at Freeport
9. Delta Inflow
10. CVP Exports
11. SWP Exports
12. CVP-SWP Exports Combined
13. Required Delta Outflow
14. Surplus Delta Outflow

For each of these components, graphs of model results are presented in the form of monthly values, average monthly values, annual values, and monthly exceedance for water years 1922-2003. Values for bias and Nash-Sutcliffe efficiency are also provided. Positive values of 'bias' correspond with larger values simulated by SacWAM in comparison to CalSim II.

A.6.1 CVP NOD Storage

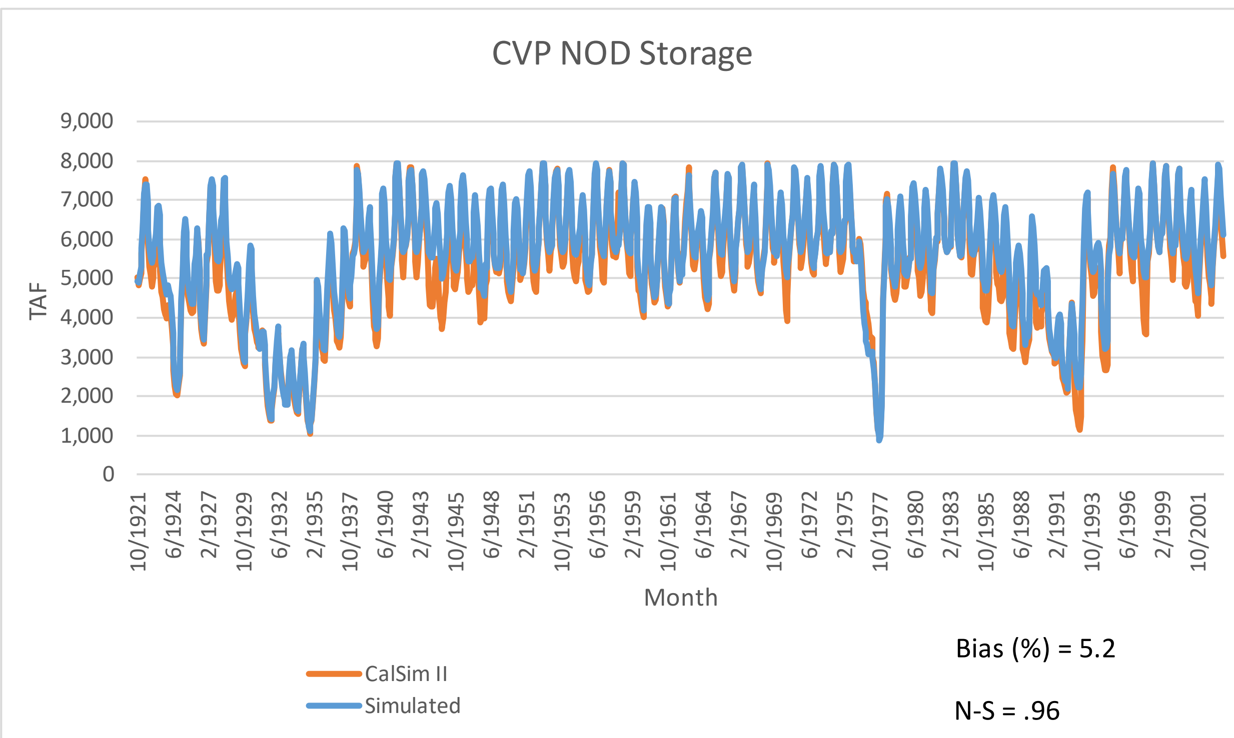


Figure A.6.1a. CVP NOD Storage, Monthly 1922 to 2003

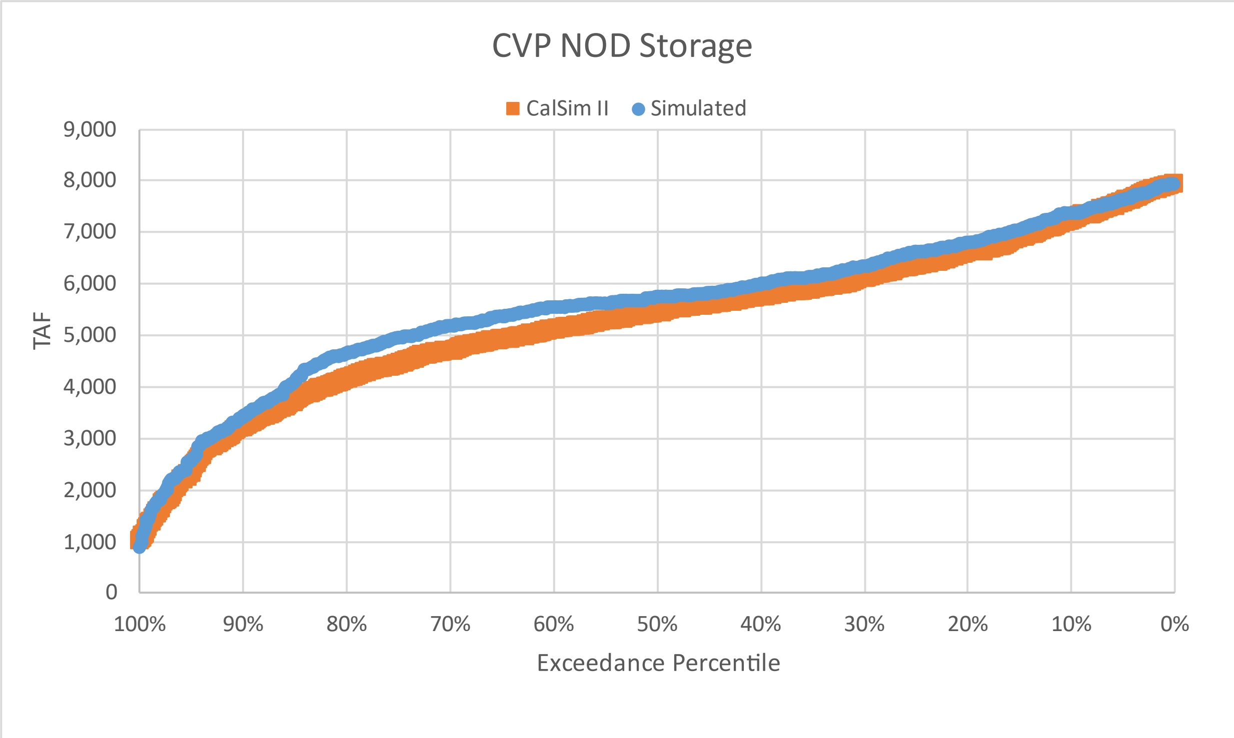


Figure A.6.1b. CVP NOD Storage, Exceedance

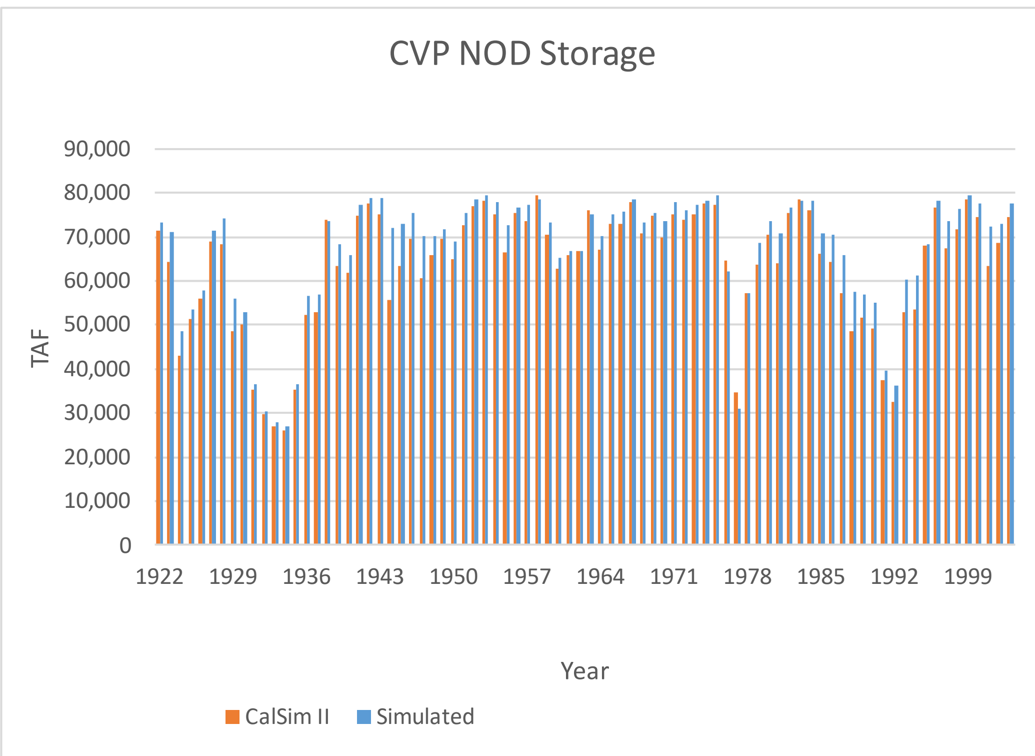


Figure A.6.1c. CVP NOD Storage, Annual 1922 to 2003

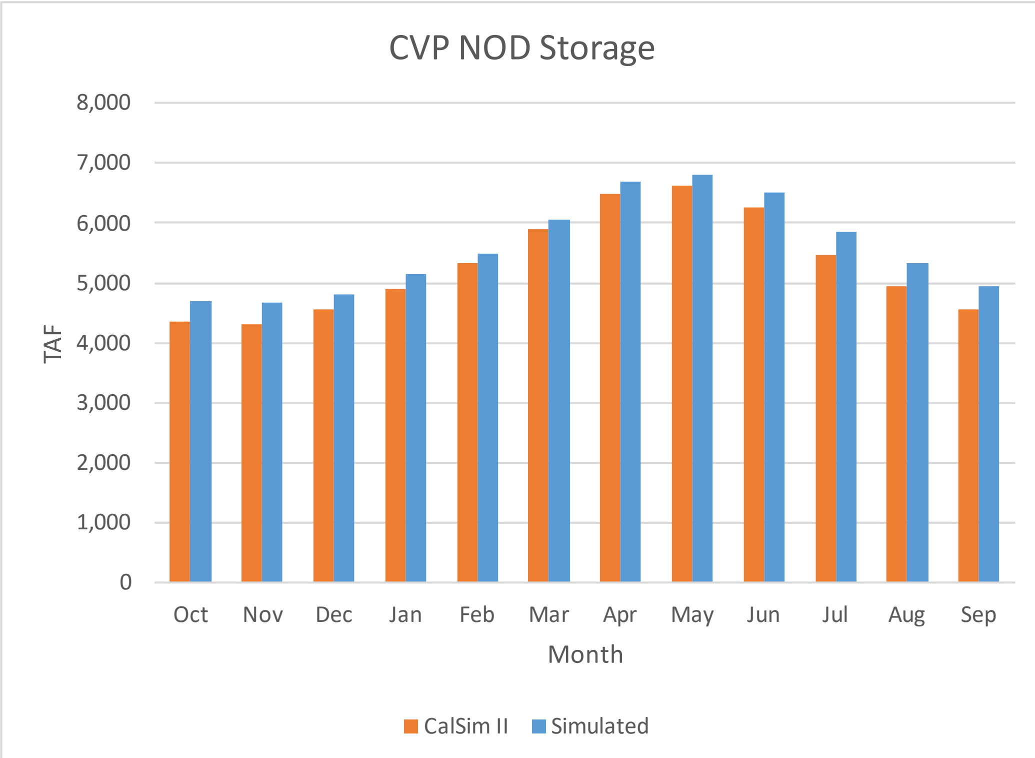


Figure A.6.1d. CVP NOD Storage, Average Monthly

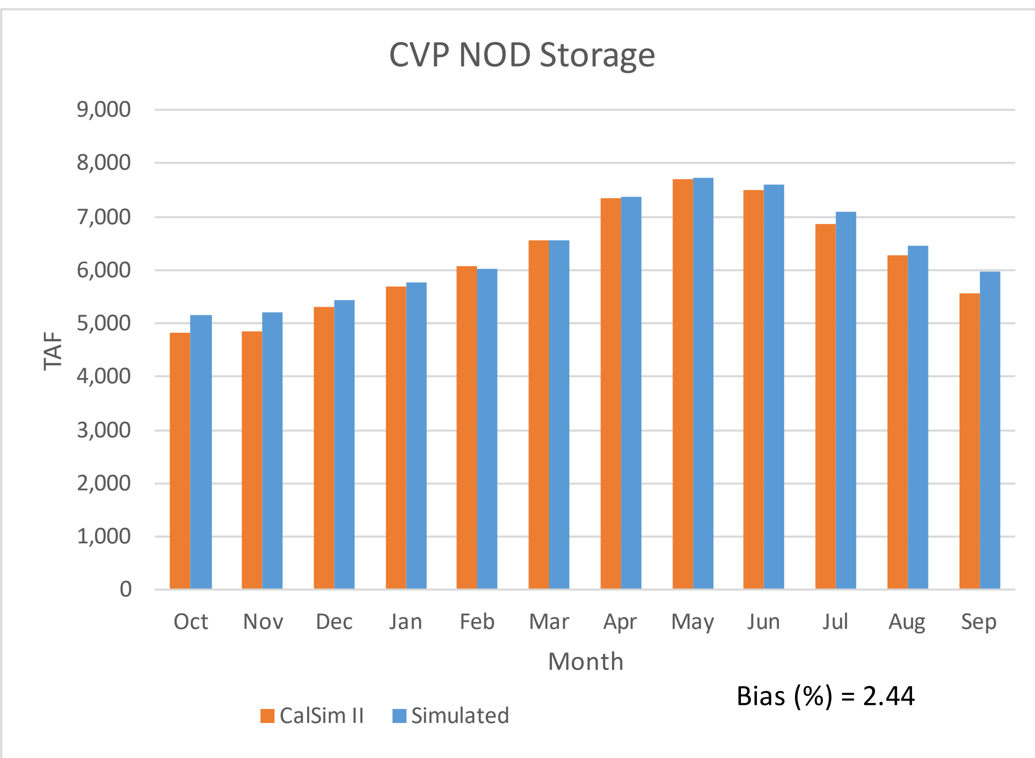


Figure A.6.1e. CVP NOD Storage, Average Monthly (Wet)

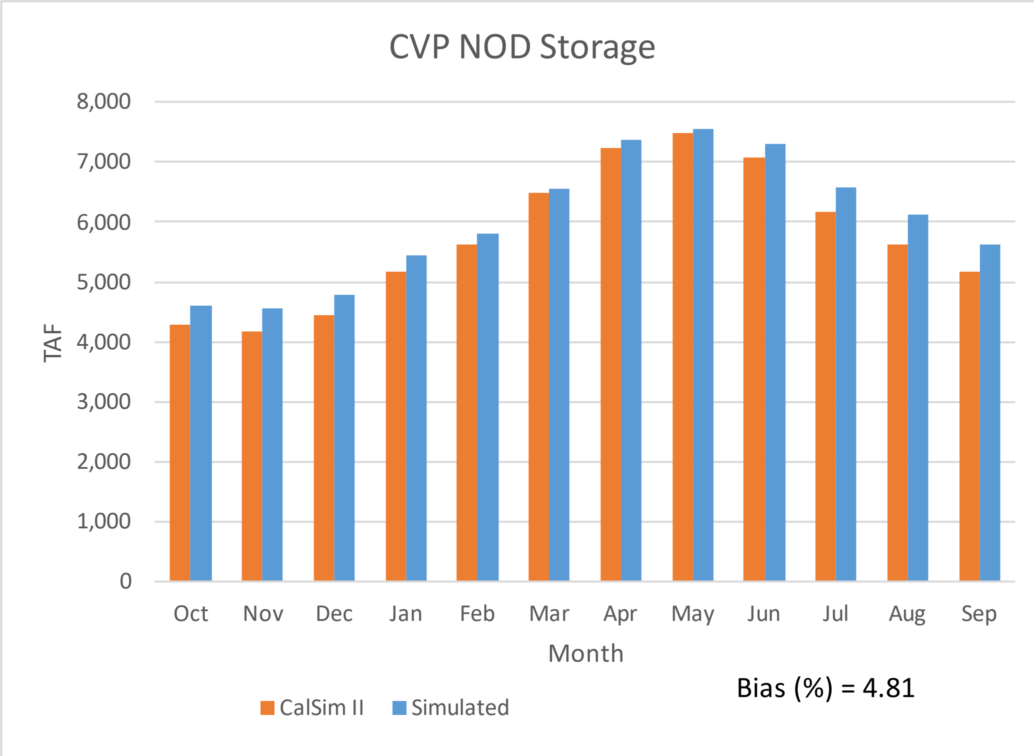


Figure A.6.1f. CVP NOD Storage, Average Monthly (Above Normal)

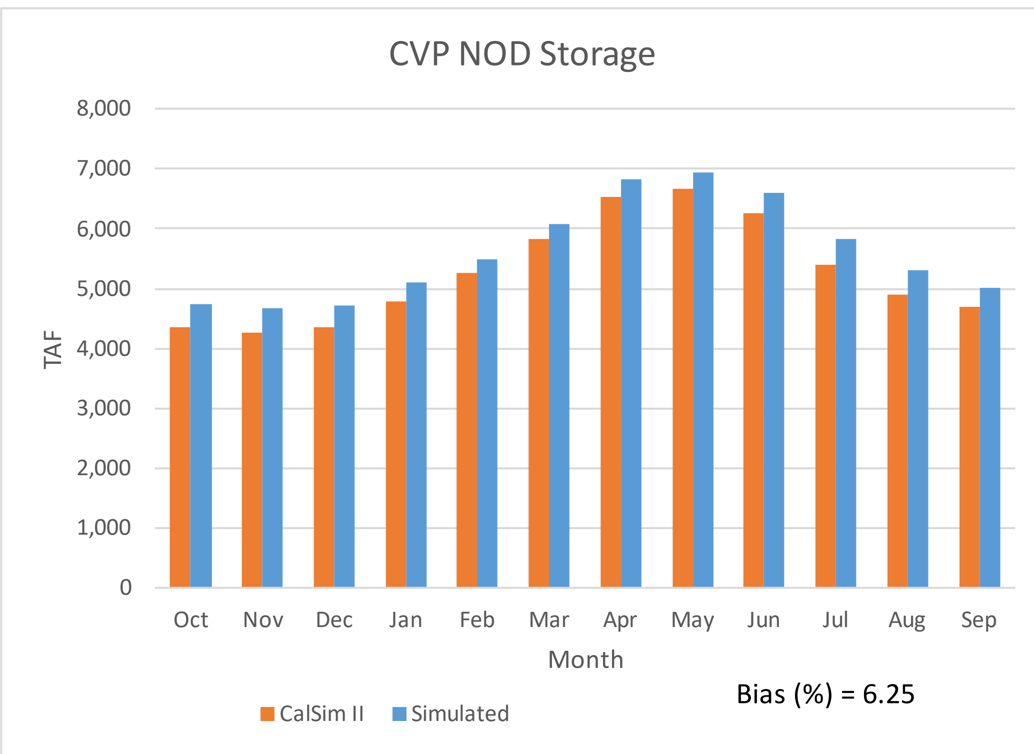


Figure A.6.1g. CVP NOD Storage, Average Monthly (Below Normal)

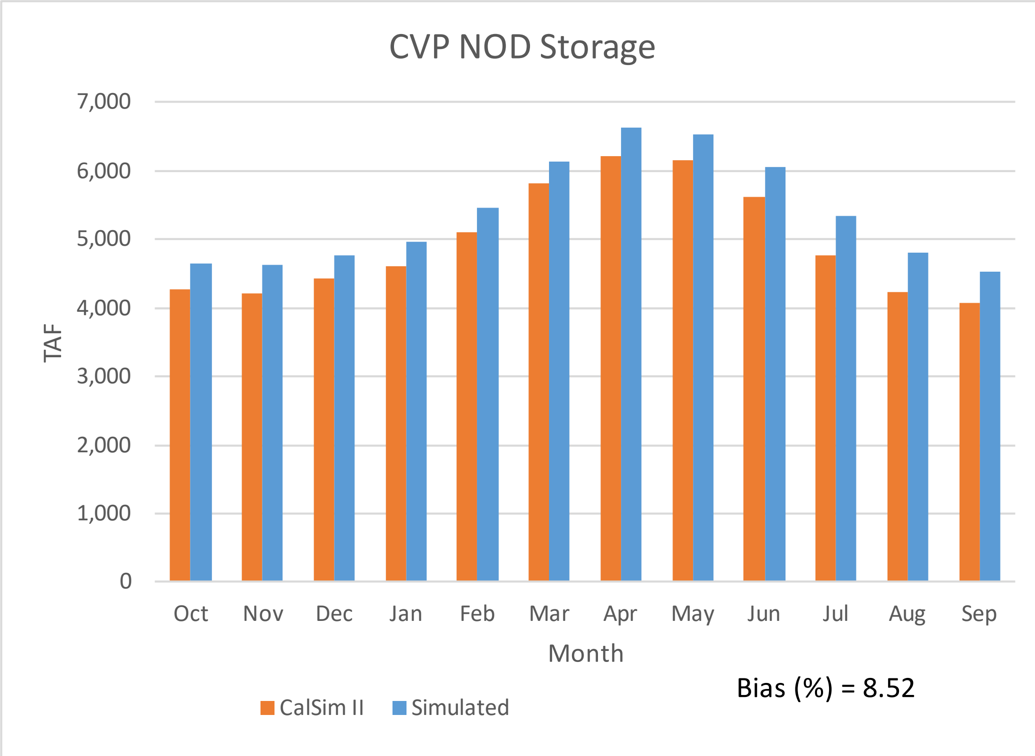


Figure A.6.1h. CVP NOD Storage, Average Monthly (Dry)

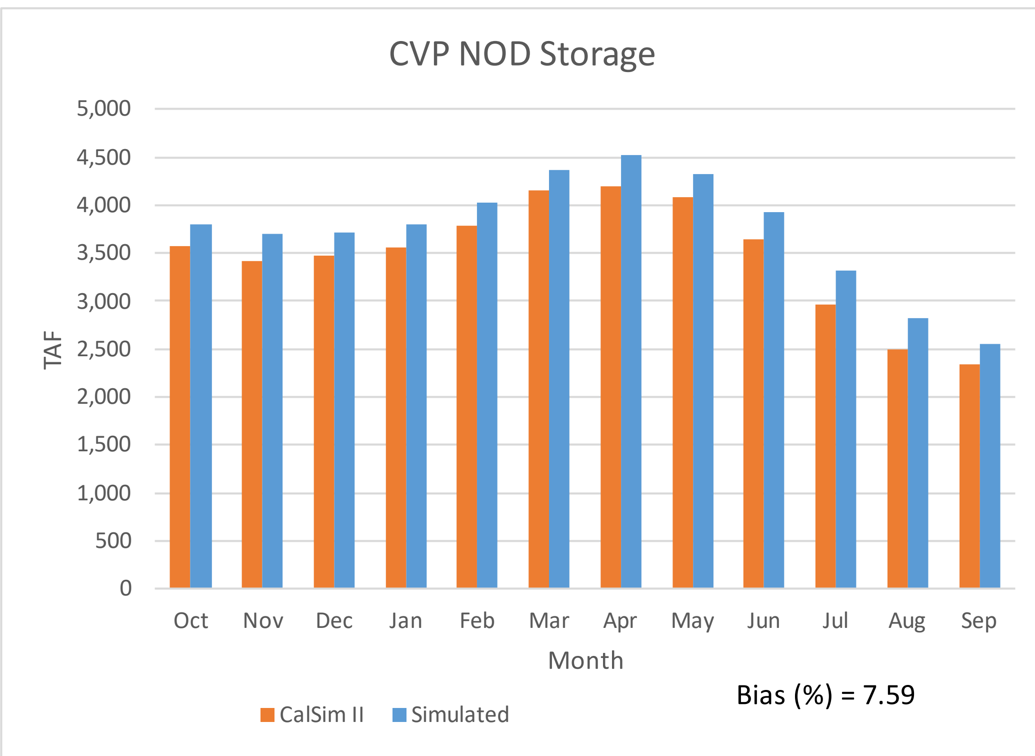


Figure A.6.1i. CVP NOD Storage, Average Monthly (Critical)

A.6.2 SWP NOD Storage

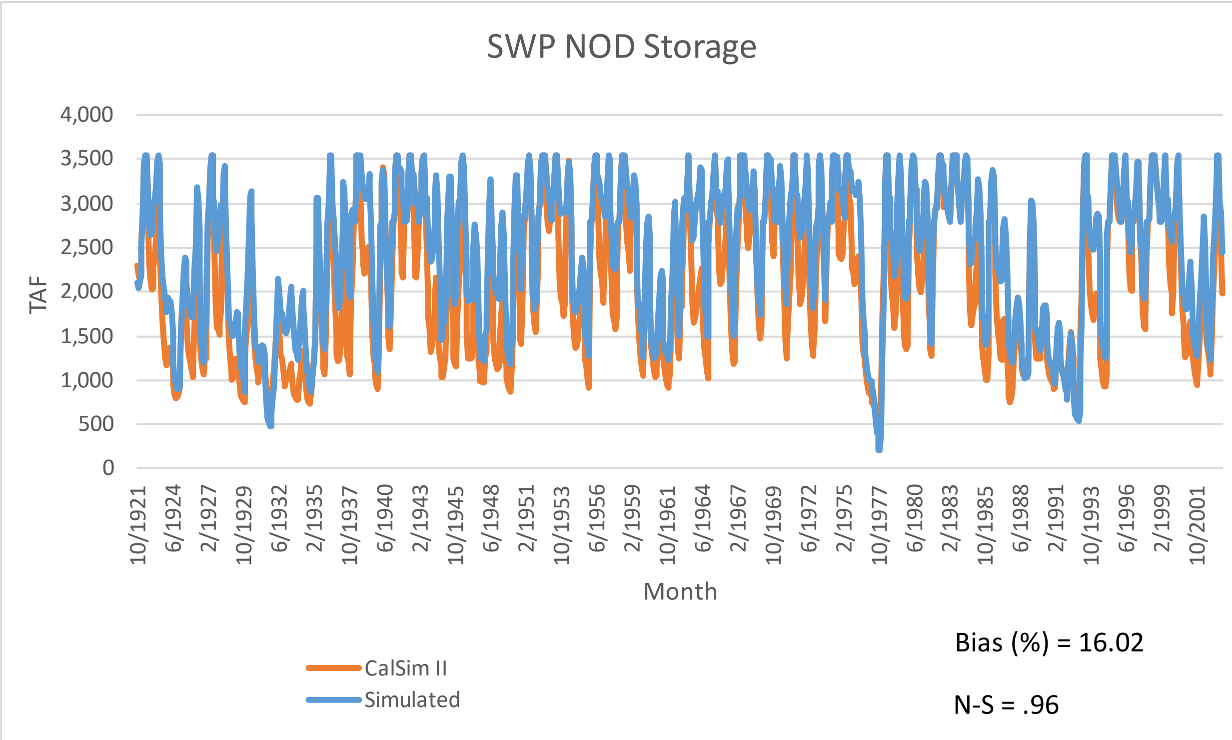


Figure A.6.2a. SWP NOD Storage, Monthly 1922 to 2003

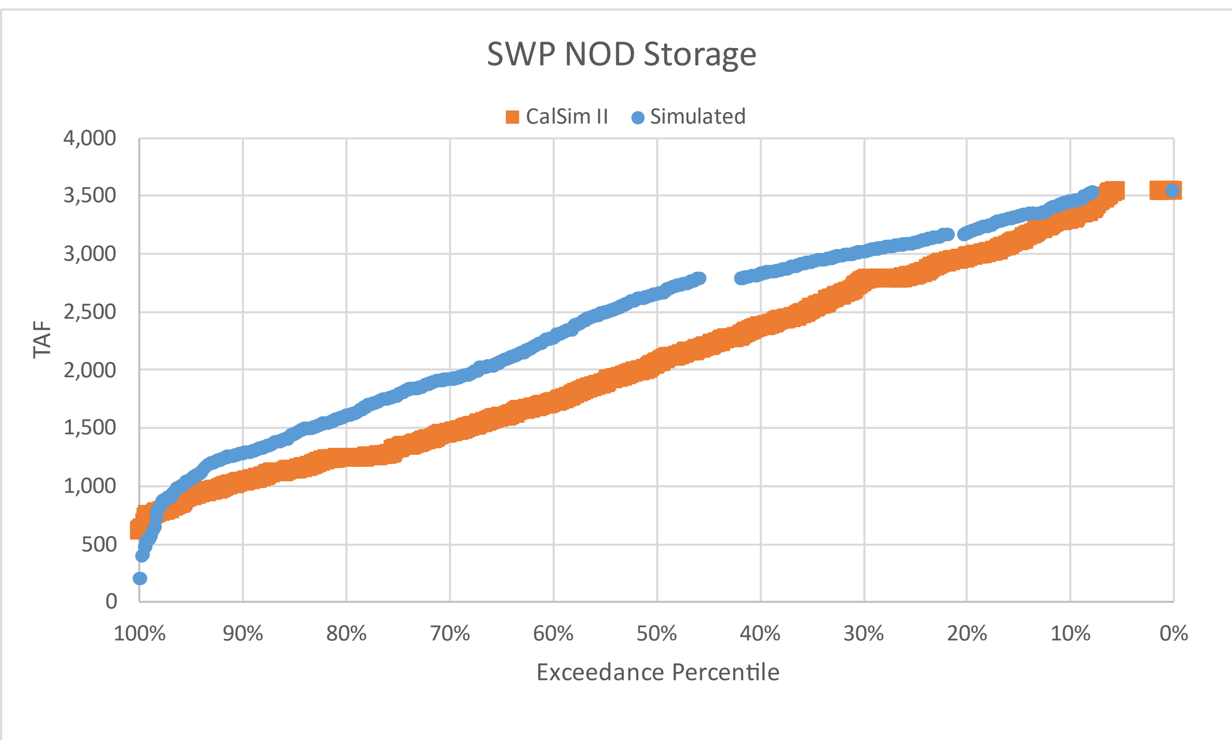


Figure A.6.2b. SWP NOD Storage, Exceedance

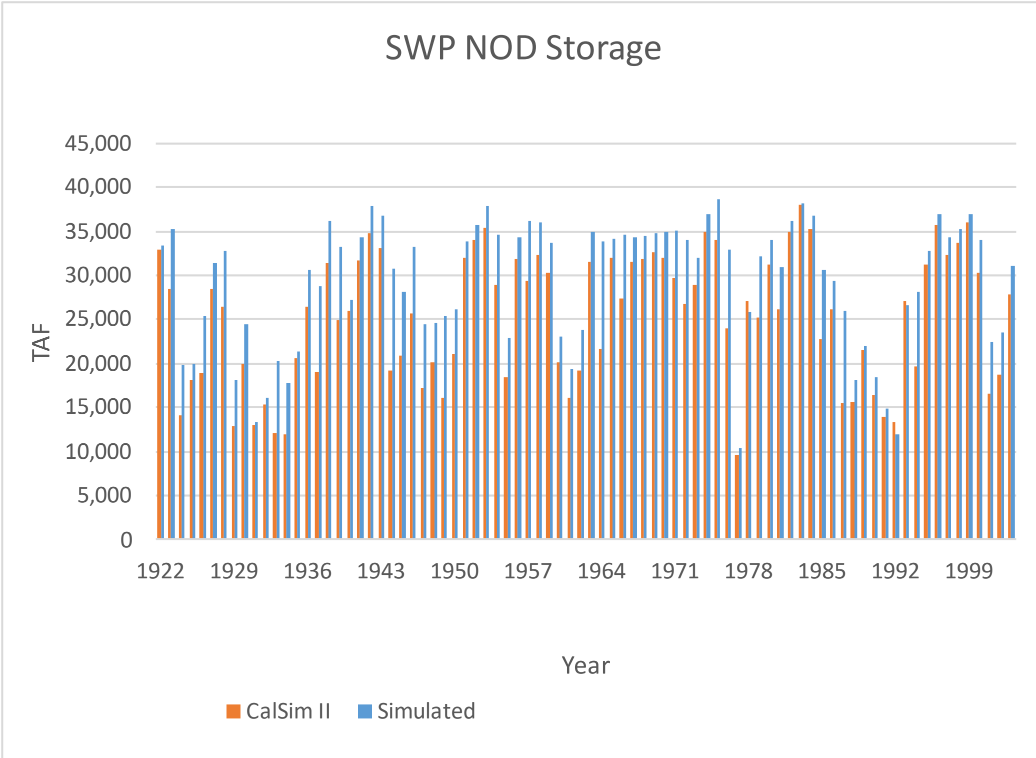


Figure A.6.2c. SWP NOD Storage, Annual 1922 to 2003

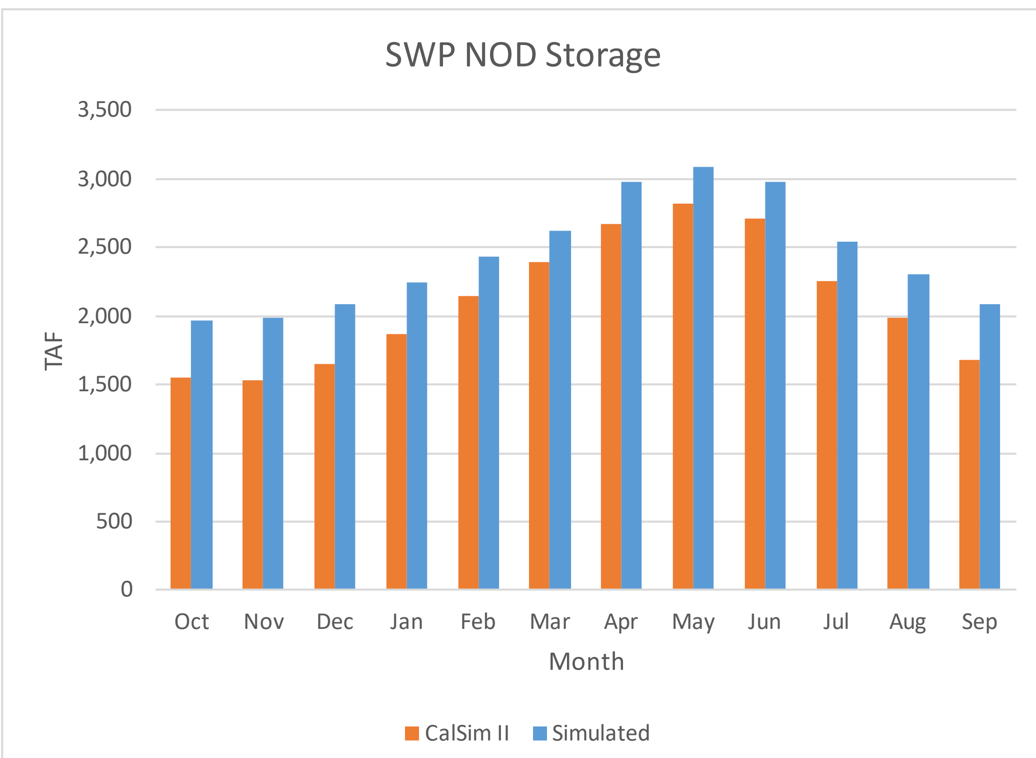


Figure A.6.2d. SWP NOD Storage, Average Monthly

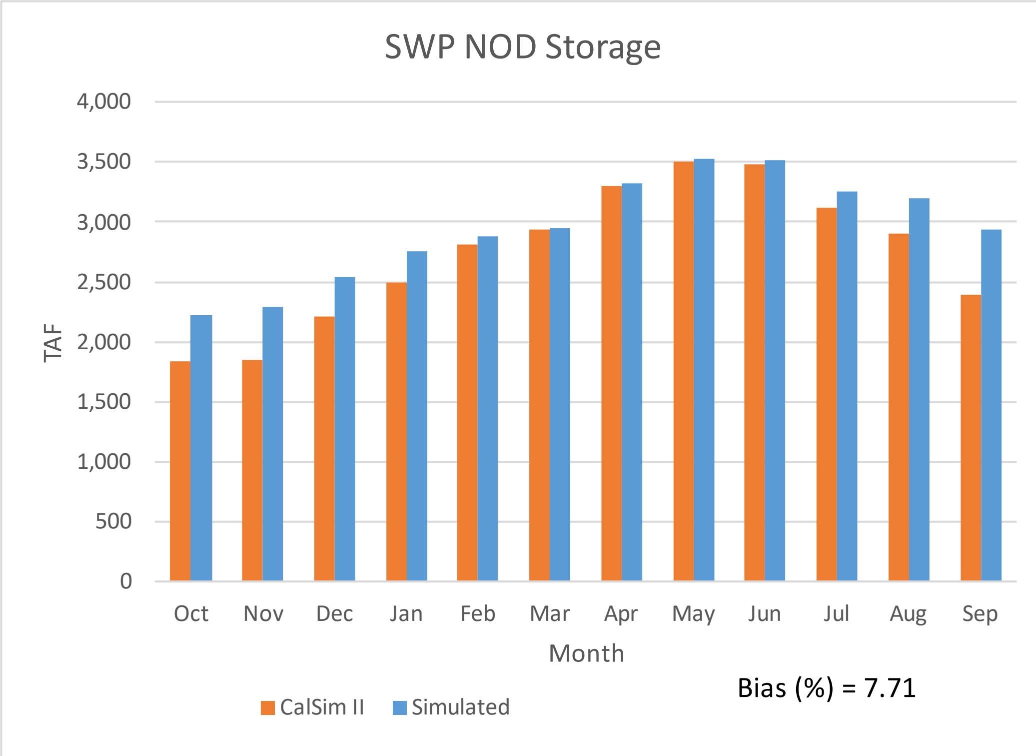


Figure A.6.2e. SWP NOD Storage, Average Monthly (Wet)

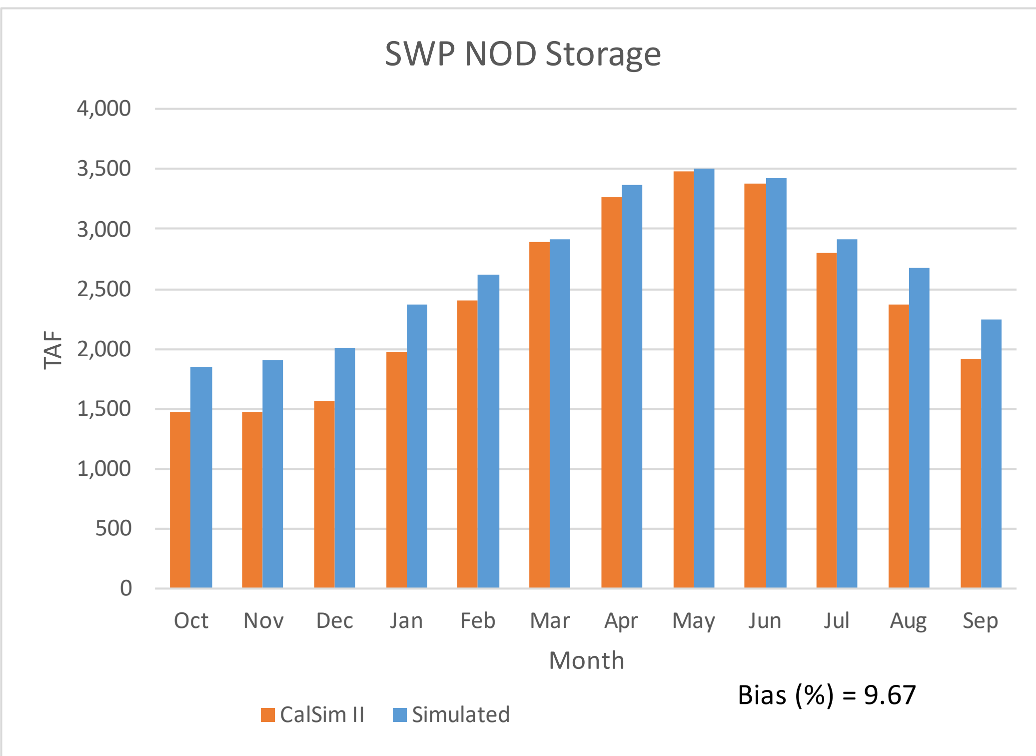


Figure A.6.2f. SWP NOD Storage, Average Monthly (Above Normal)

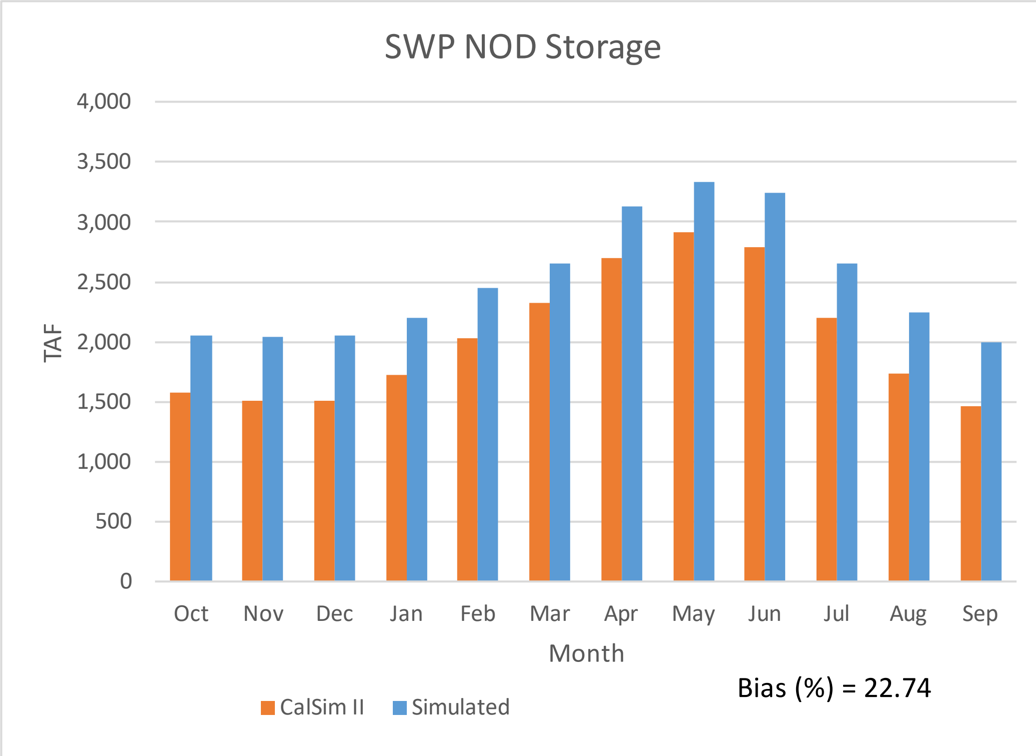


Figure A.6.2g. SWP NOD Storage, Average Monthly (Below Normal)

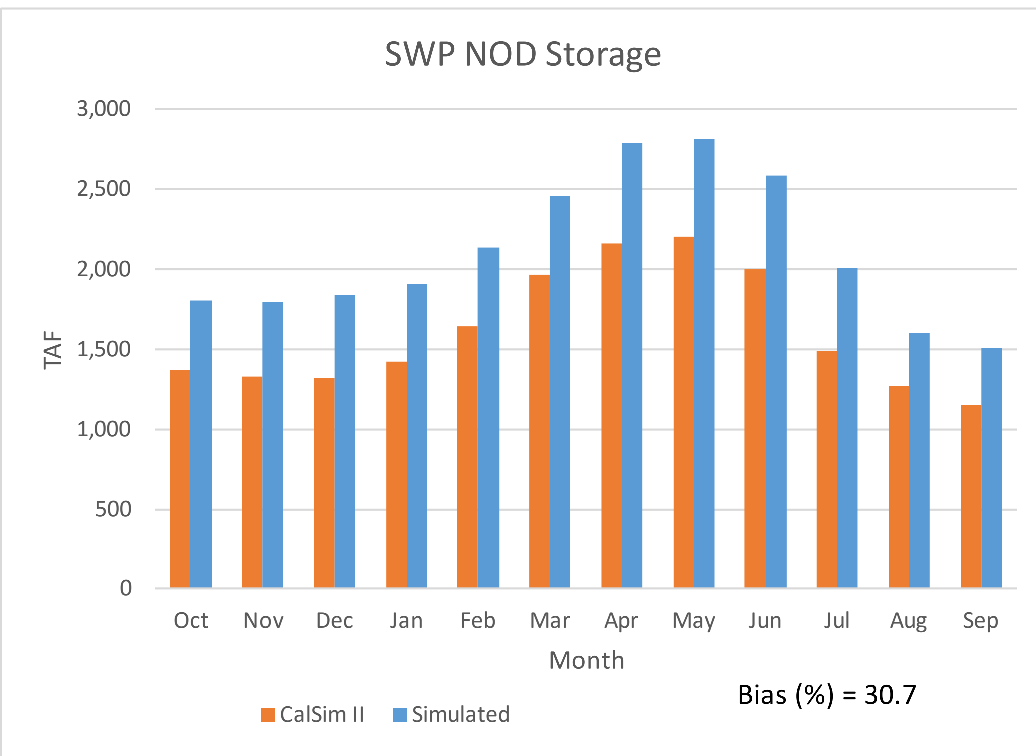


Figure A.6.2h. SWP NOD Storage, Average Monthly (Dry)

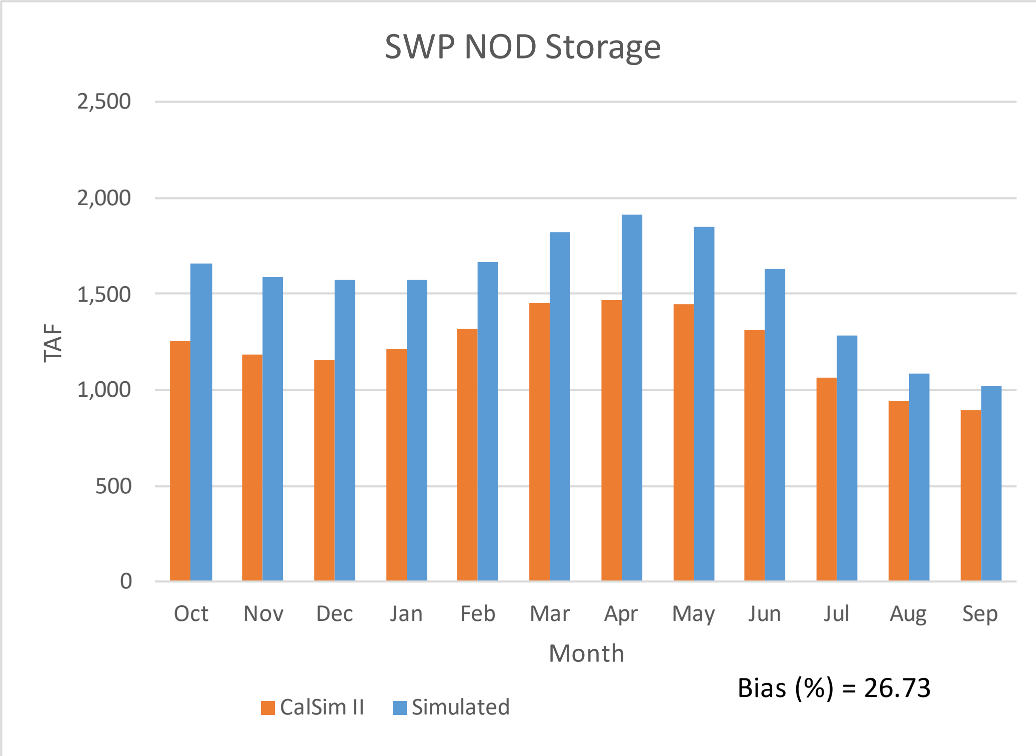


Figure A.6.2i. SWP NOD Storage, Average Monthly (Critical)

A.6.3 CVP San Luis Storage

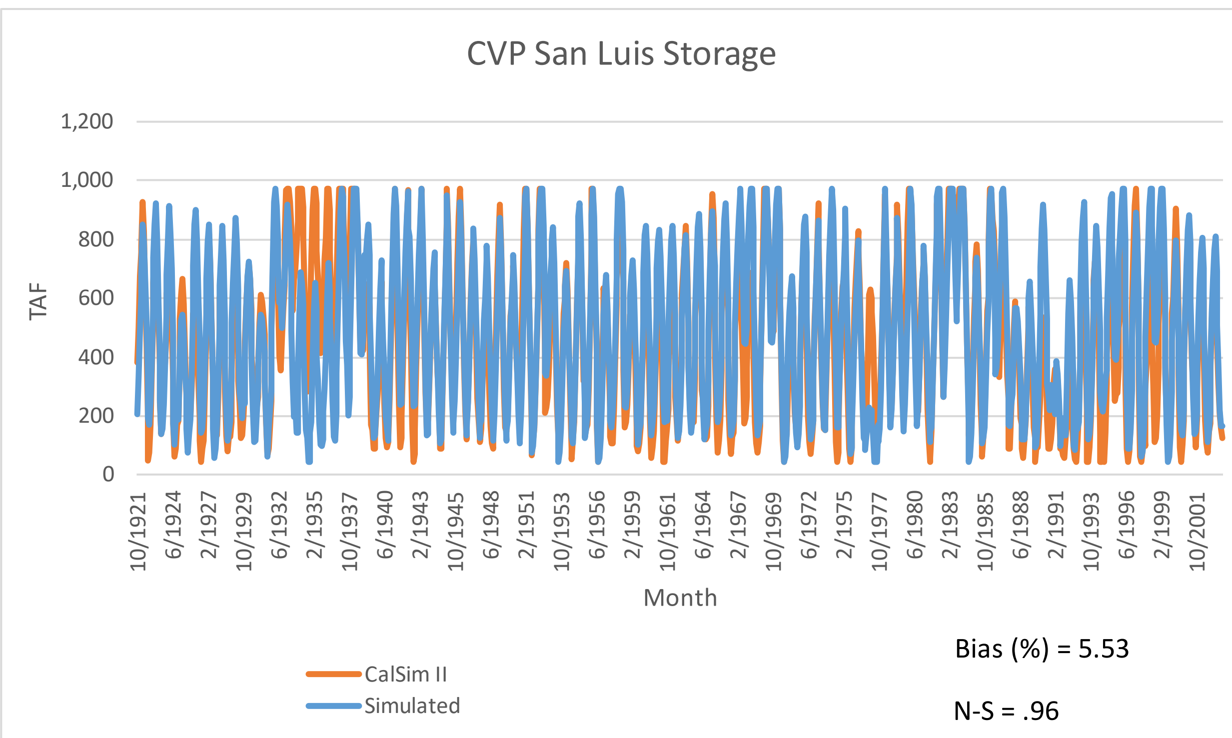


Figure A.6.3a. CVP San Luis Storage, Monthly 1922 to 2003

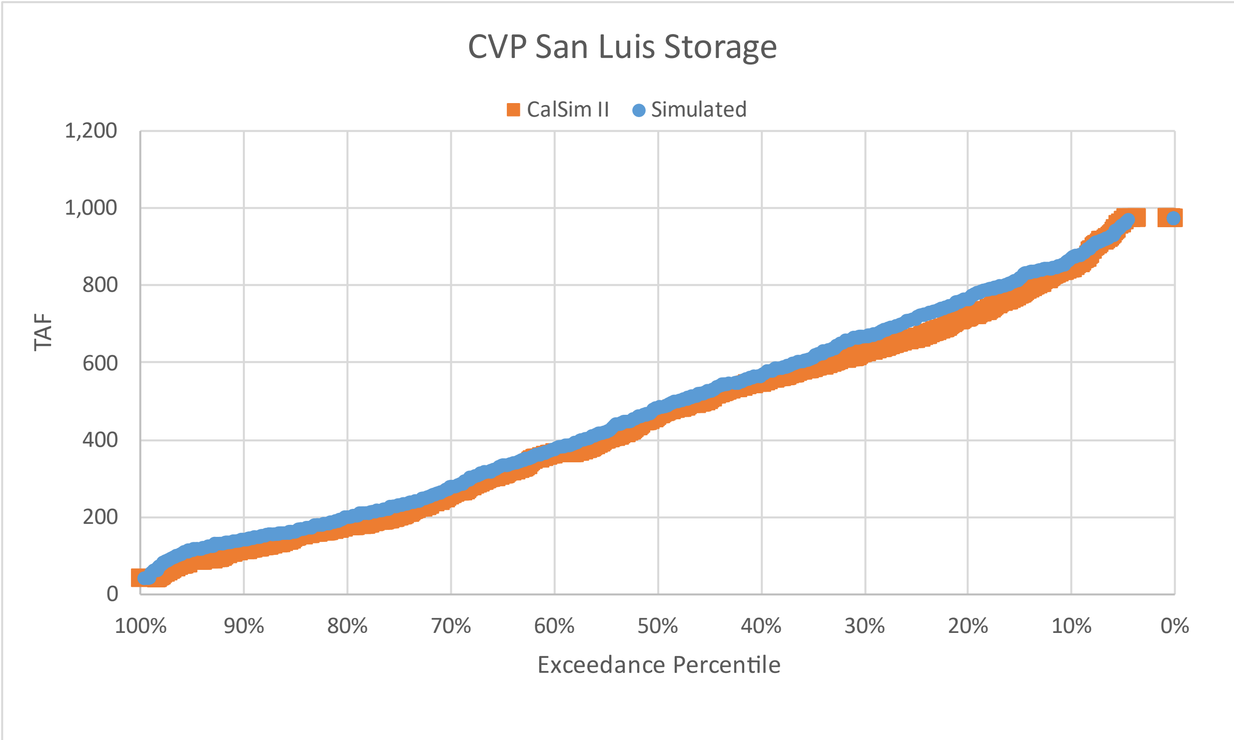


Figure A.6.3b. CVP San Luis Storage, Exceedance

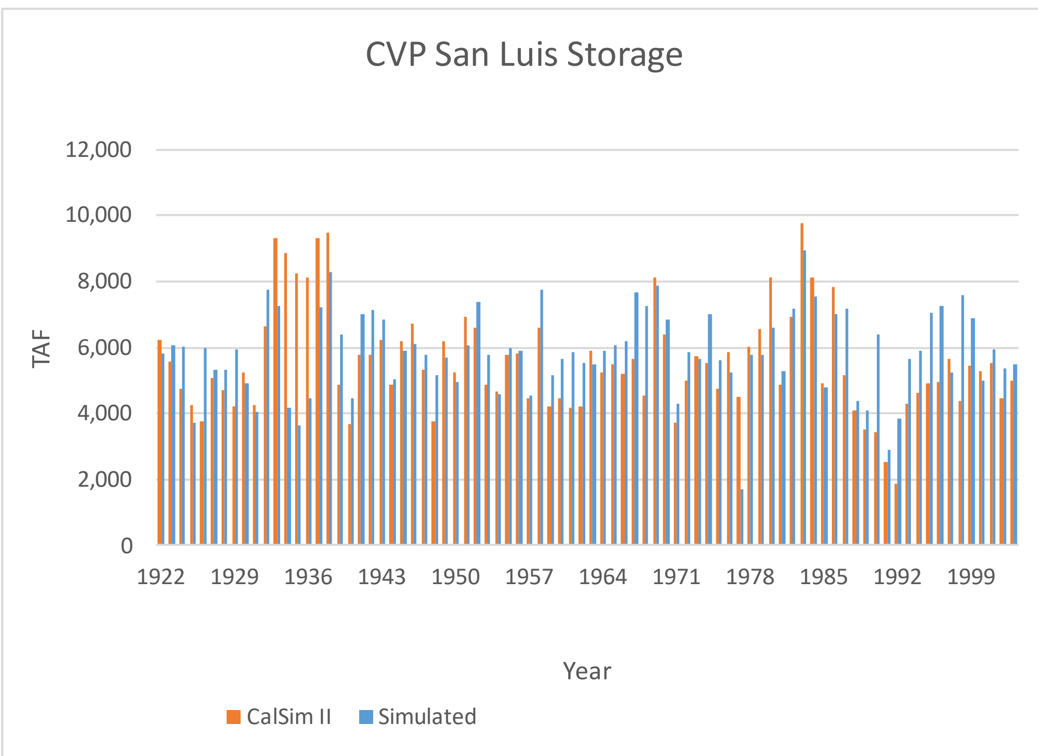


Figure A.6.3c. CVP San Luis Storage, Annual 1922 to 2003

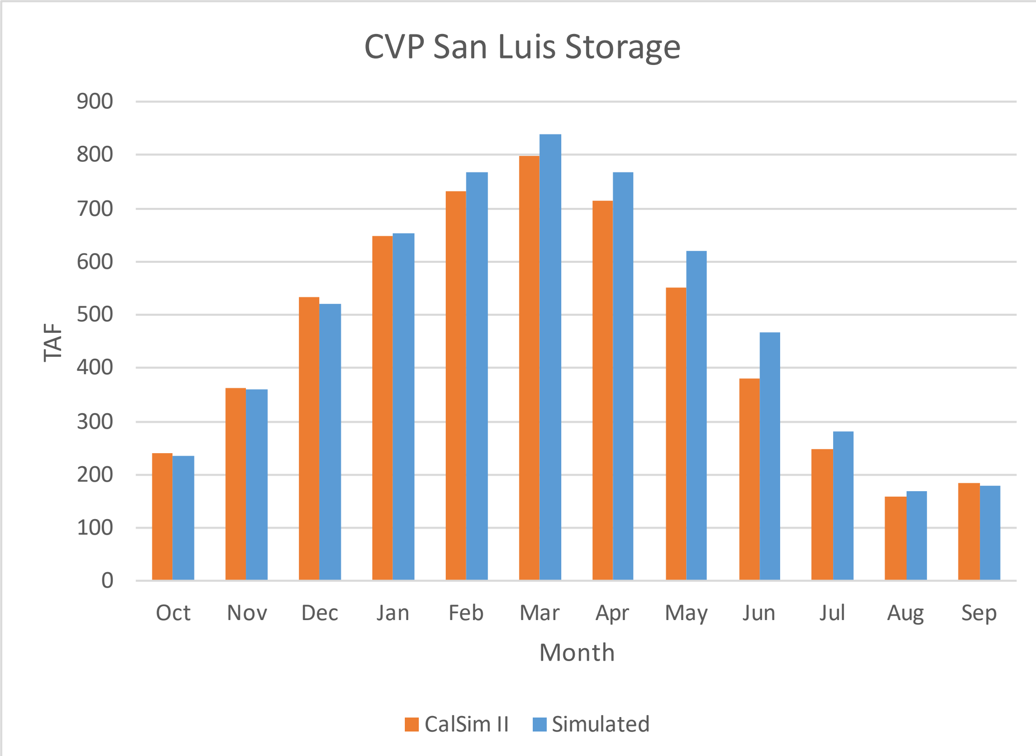


Figure A.6.3d. CVP San Luis Storage, Average Monthly

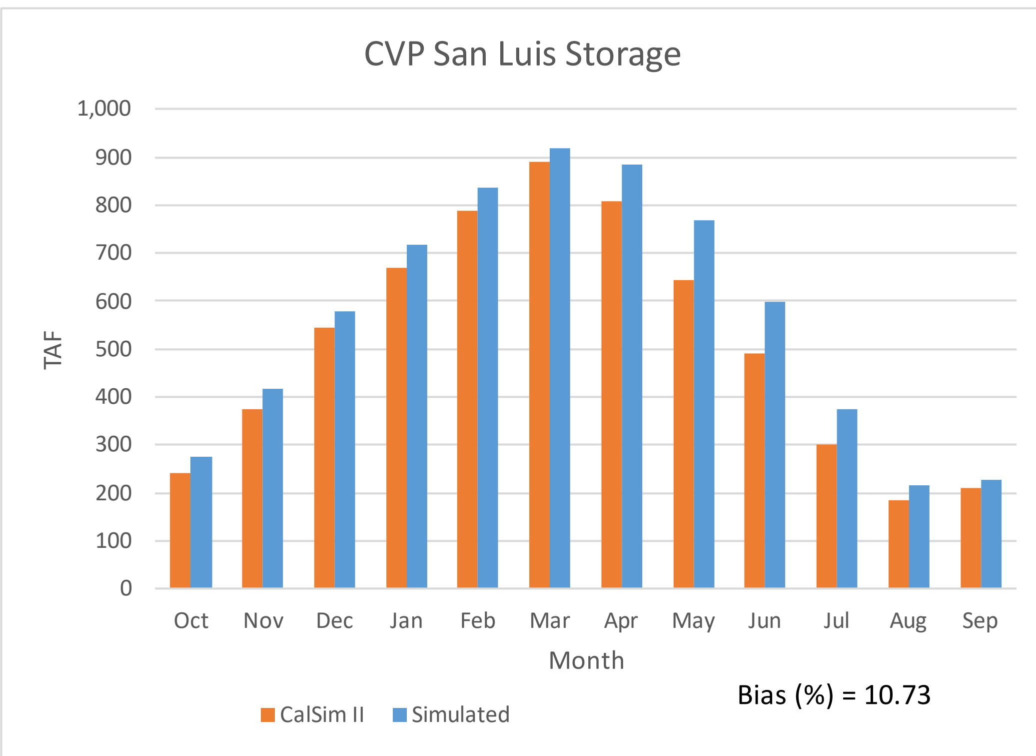


Figure A.6.3e. CVP San Luis Storage, Average Monthly (Wet)

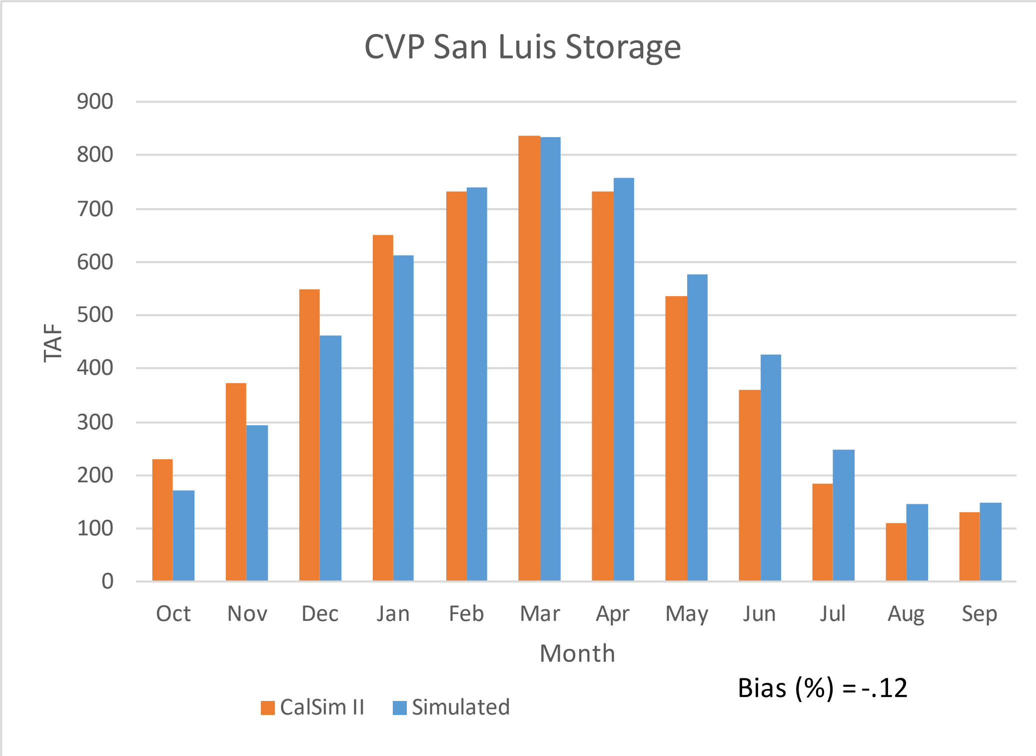


Figure A.6.3f. CVP San Luis Storage, Average Monthly (Above Normal)

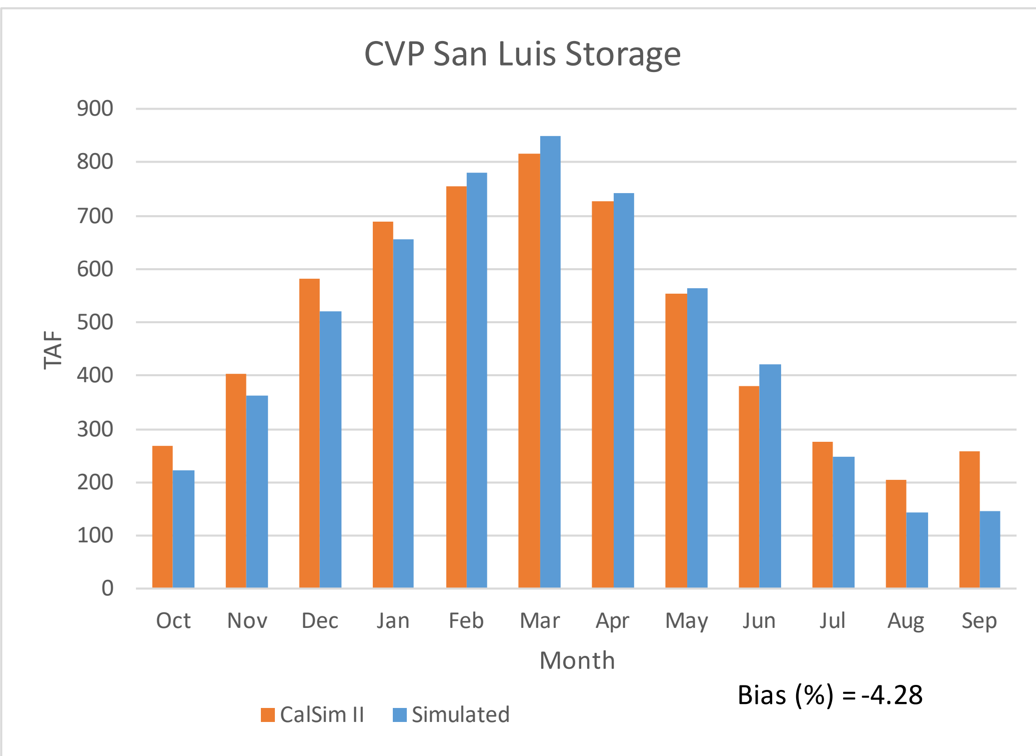


Figure A.6.3g. CVP San Luis Storage, Average Monthly (Below Normal)

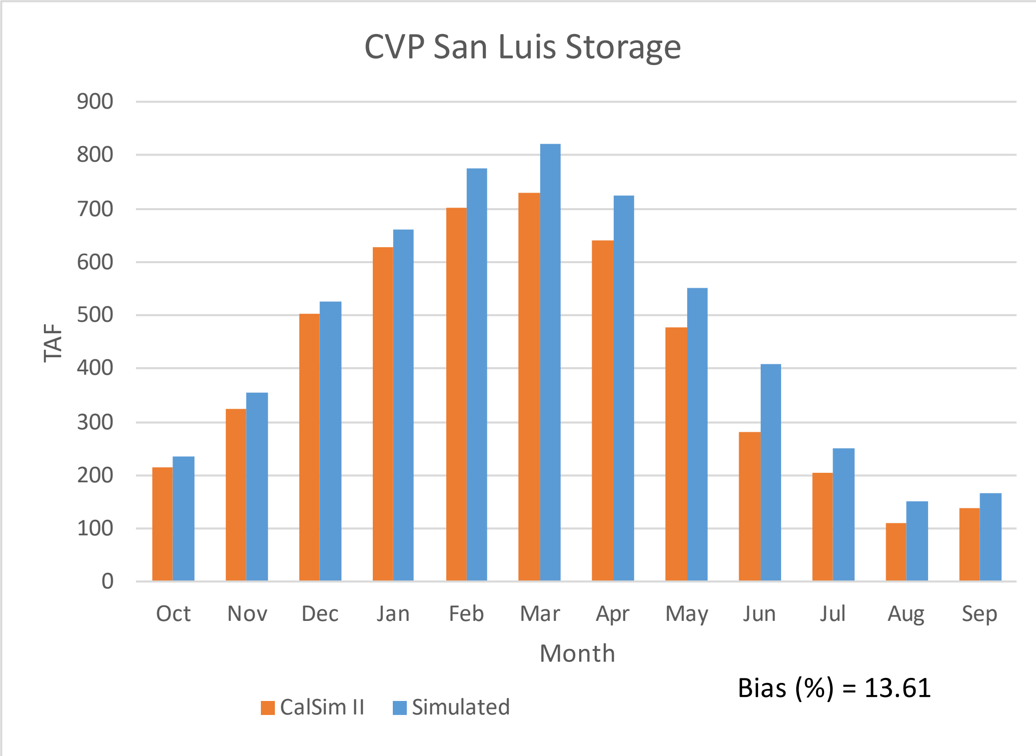


Figure A.6.3h. CVP San Luis Storage, Average Monthly (Dry)

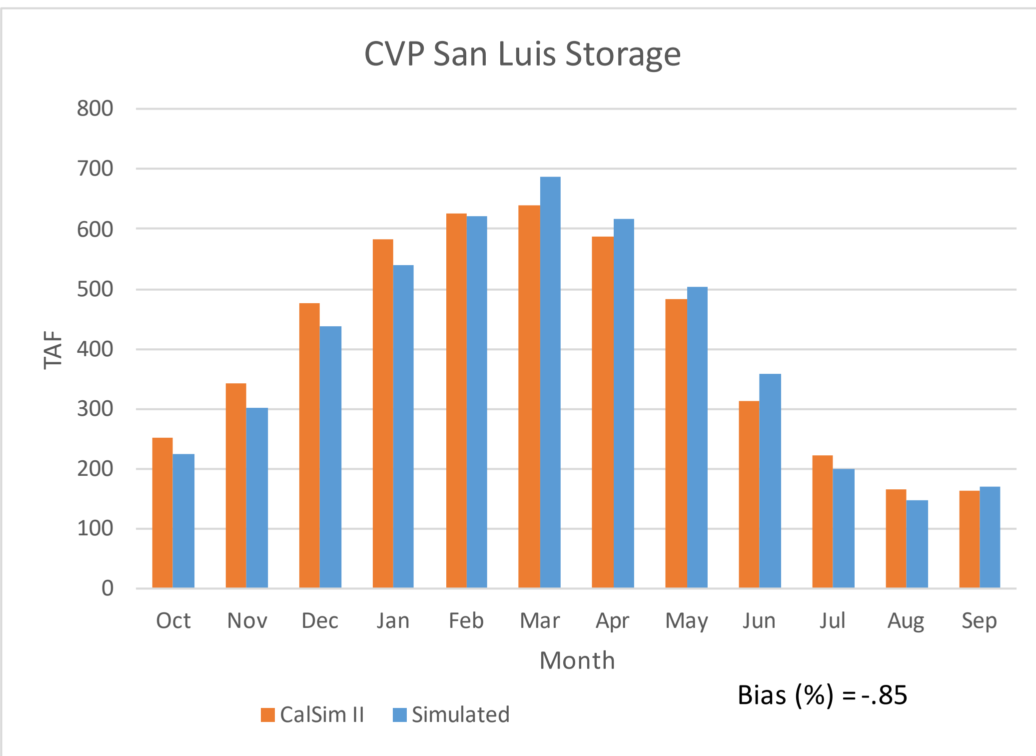


Figure A.6.3i. CVP San Luis Storage, Average Monthly (Critical)

A.6.4 SWP San Luis Storage

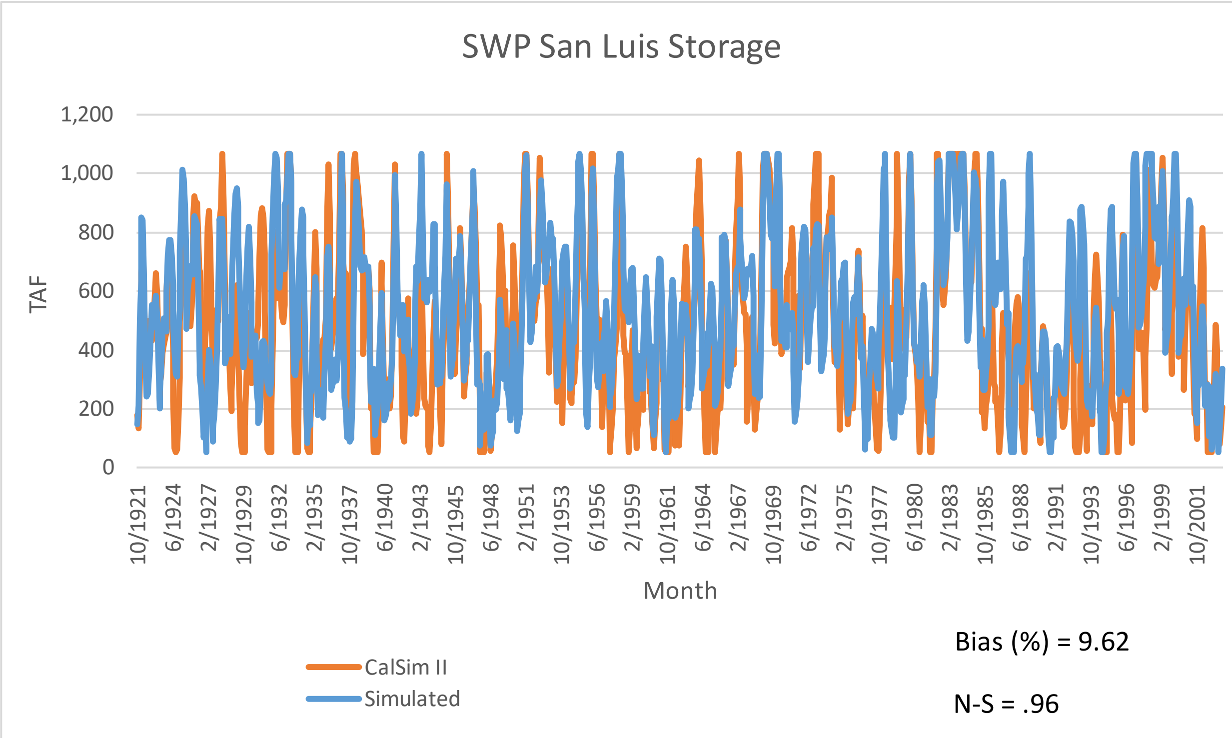


Figure A.6.4a. SWP San Luis Storage, Monthly 1922 to 2003

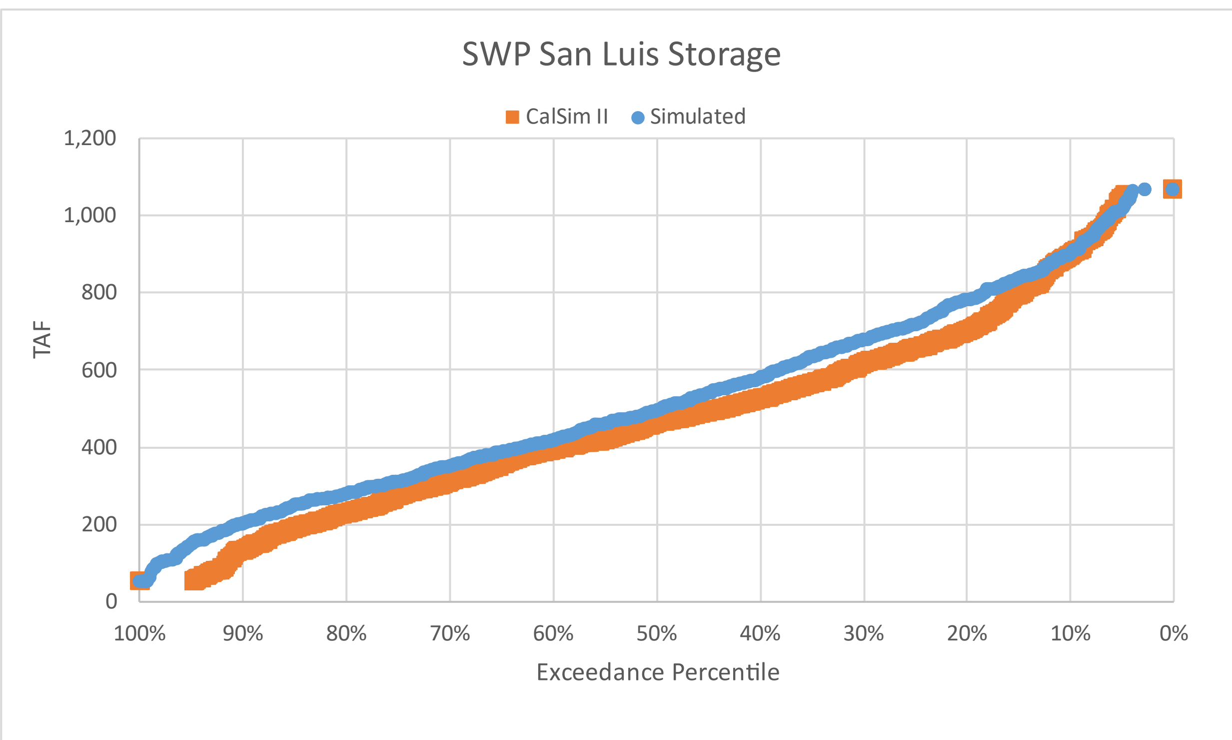


Figure A.6.4b. SWP San Luis Storage, Exceedance

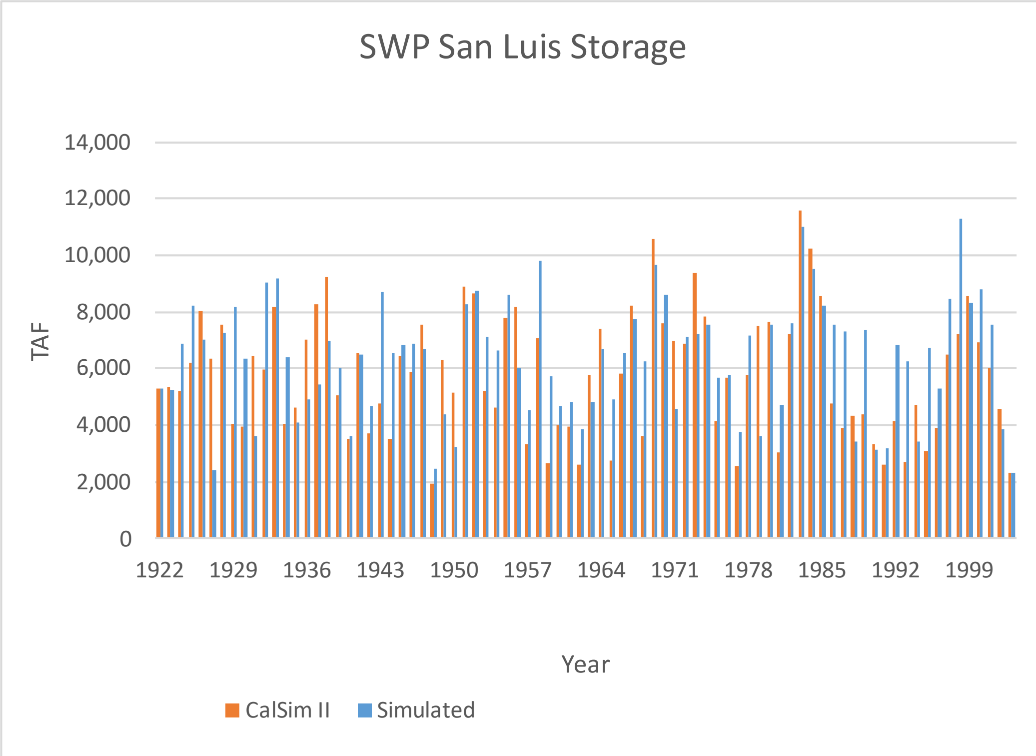


Figure A.6.4c. SWP San Luis Storage, Annual 1922 to 2003

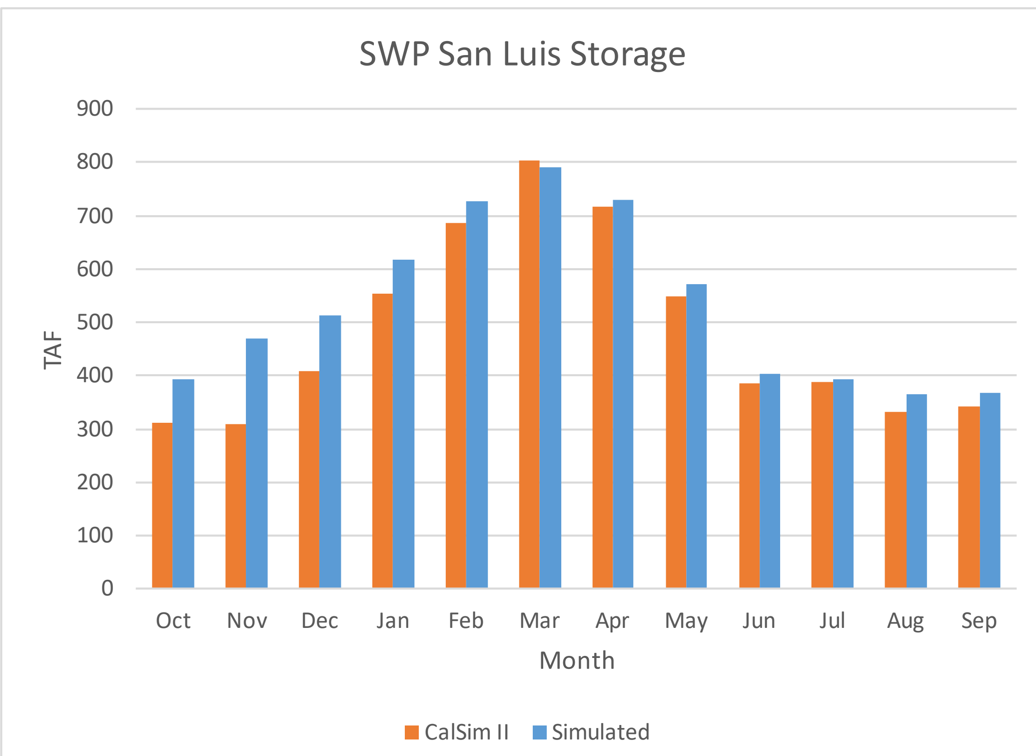


Figure A.6.4d. SWP San Luis Storage, Average Monthly

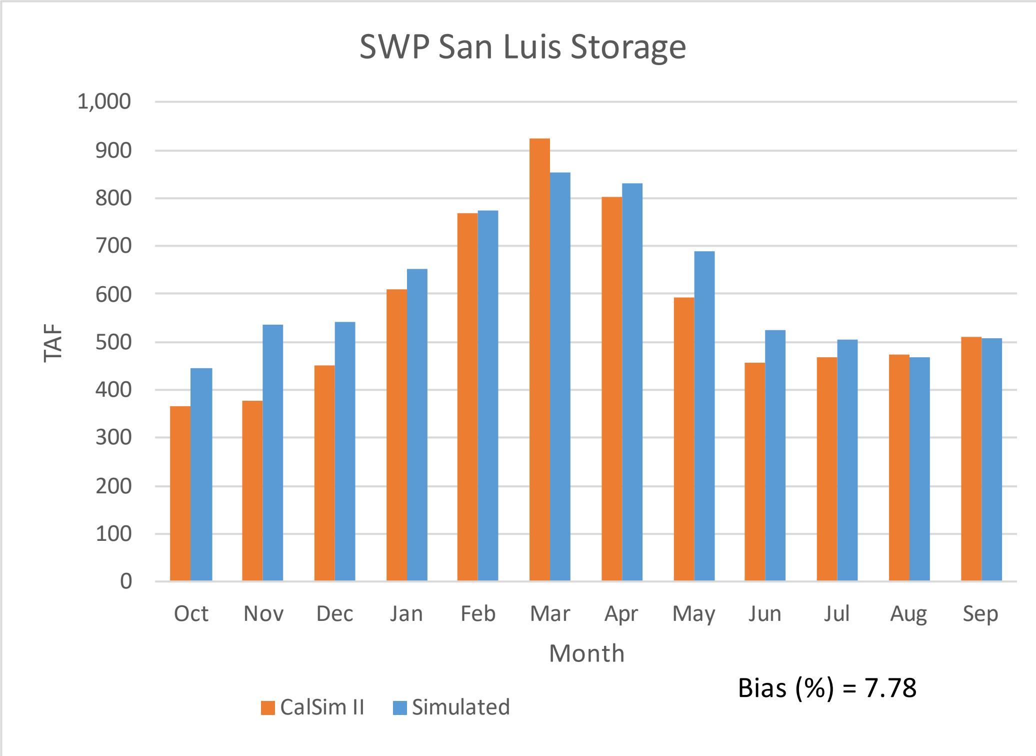


Figure A.6.4e. SWP San Luis Storage, Average Monthly (Wet)

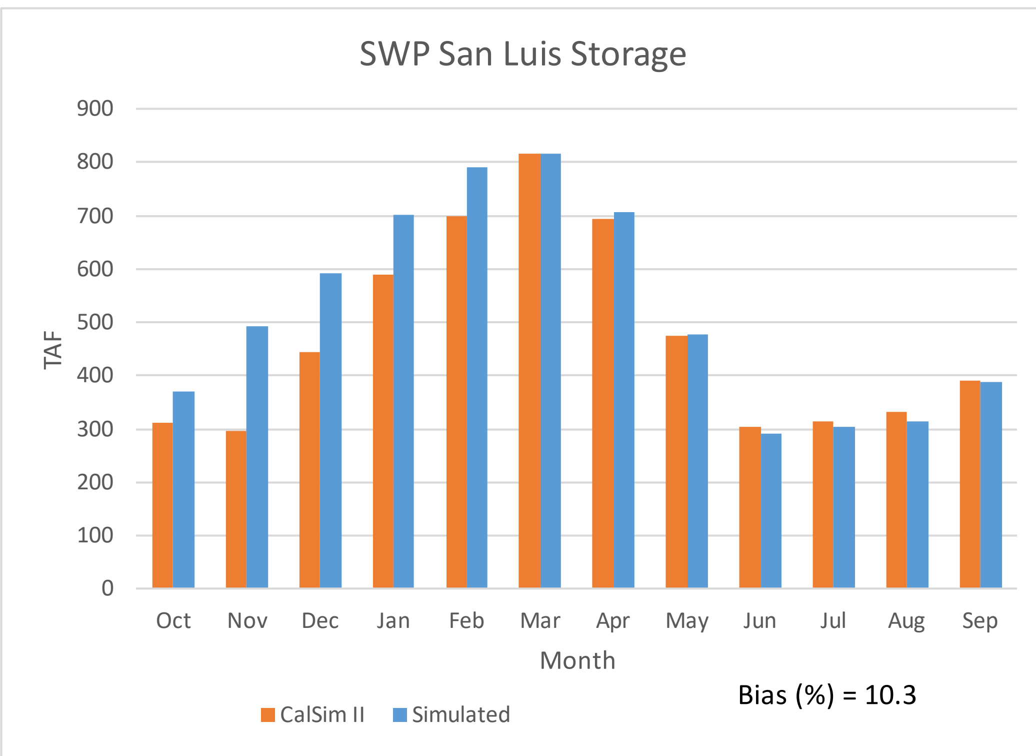


Figure A.6.4f. SWP San Luis Storage, Average Monthly (Above Normal)

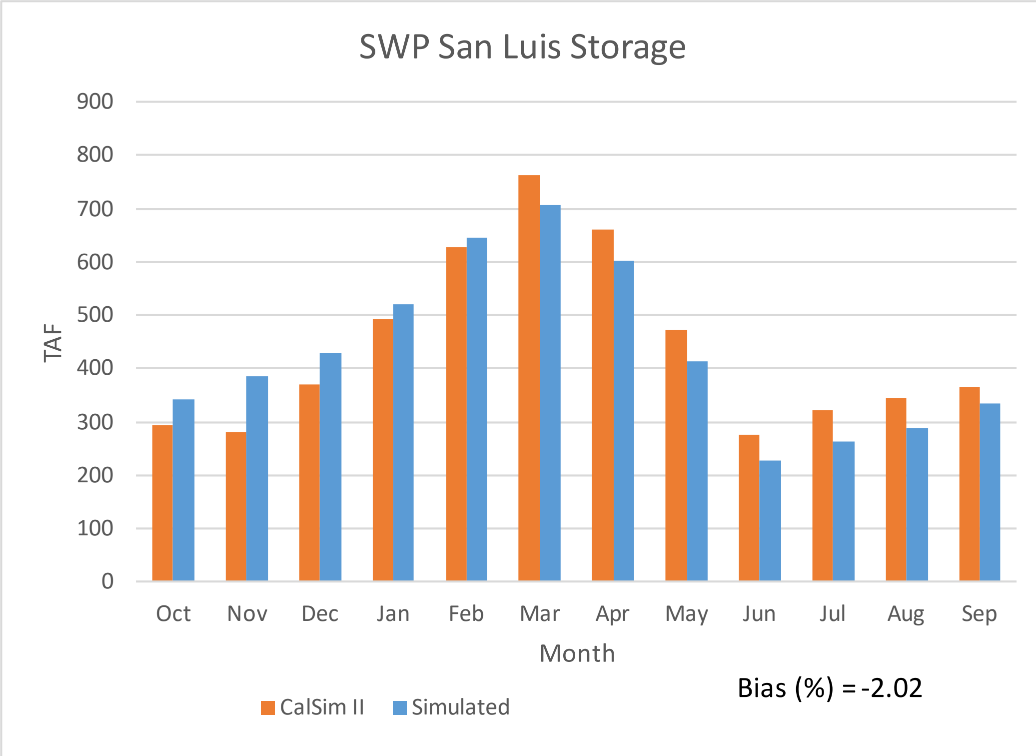


Figure A.6.4g. SWP San Luis Storage, Average Monthly (Below Normal)

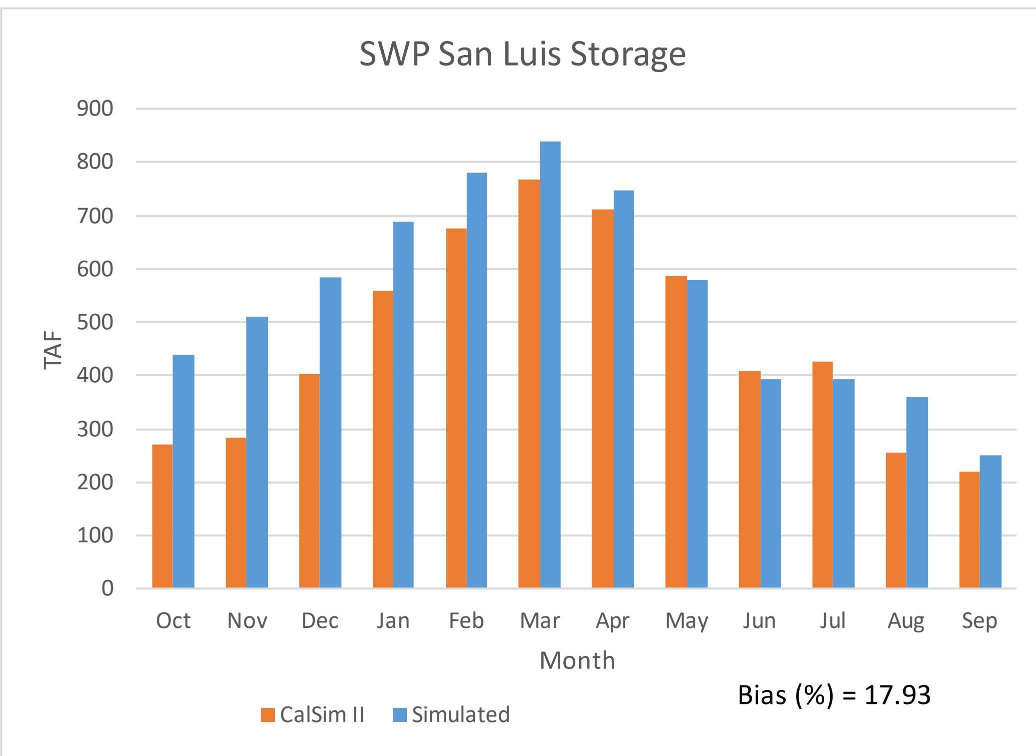


Figure A.6.4h. SWP San Luis Storage, Average Monthly (Dry)

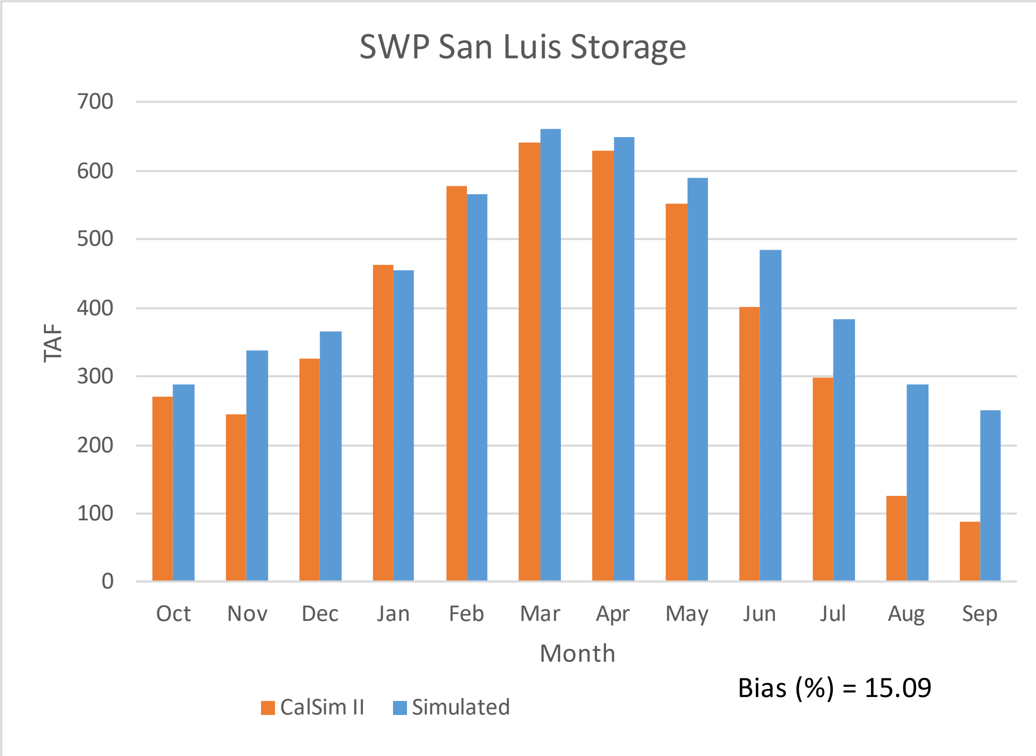


Figure A.6.4i. SWP San Luis Storage, Average Monthly (Critical)

A.6.5 Trinity River Imports

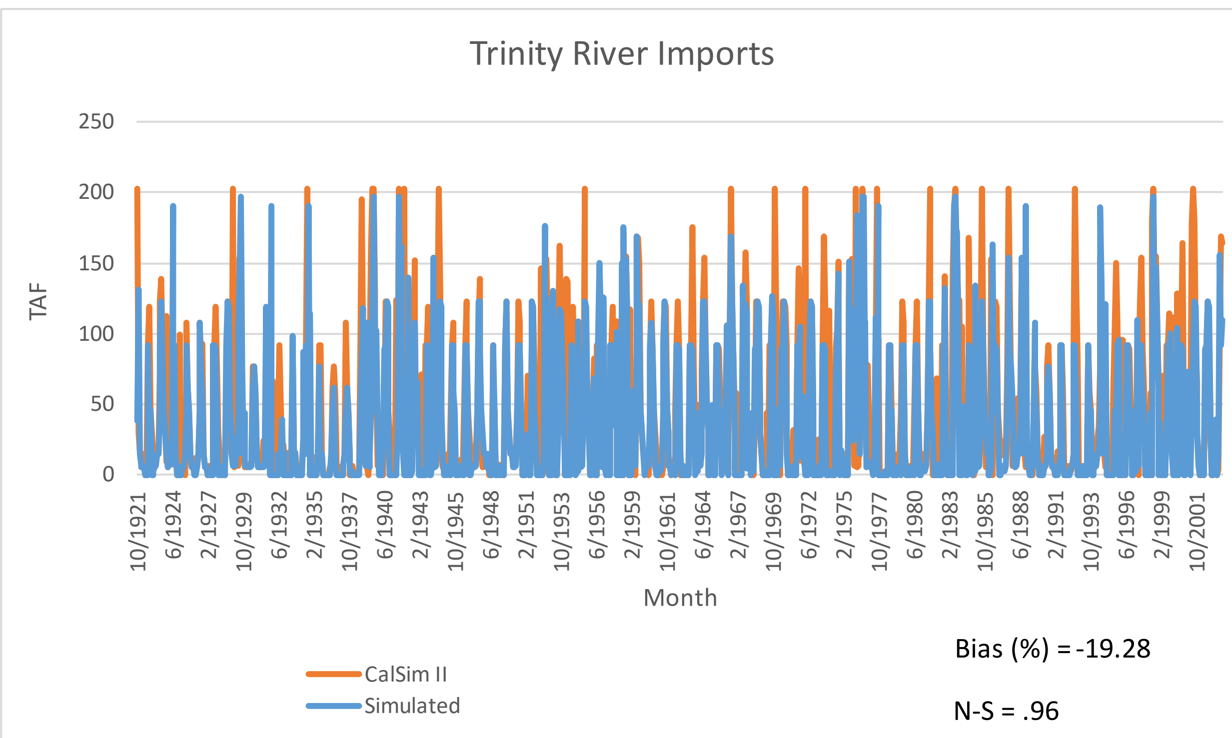


Figure A.6.5a. Trinity River Imports, Monthly 1922 to 2003

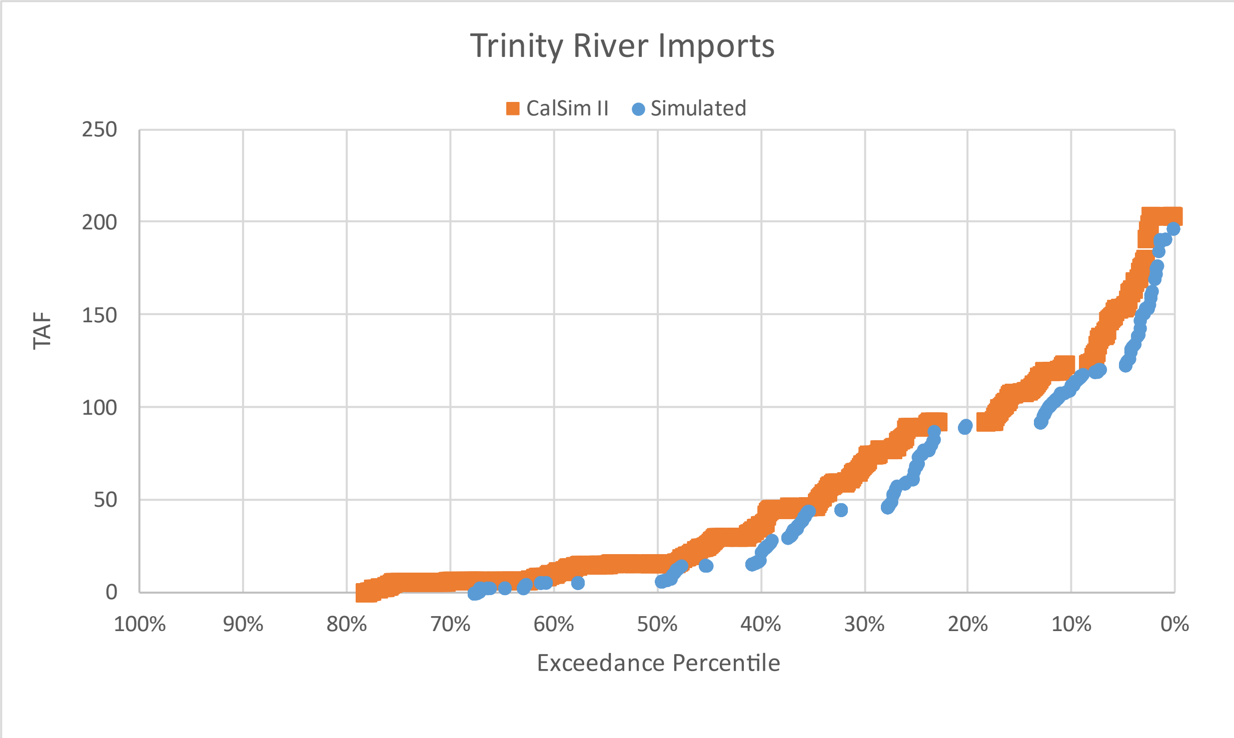


Figure A.6.5b. Trinity River Imports, Exceedance

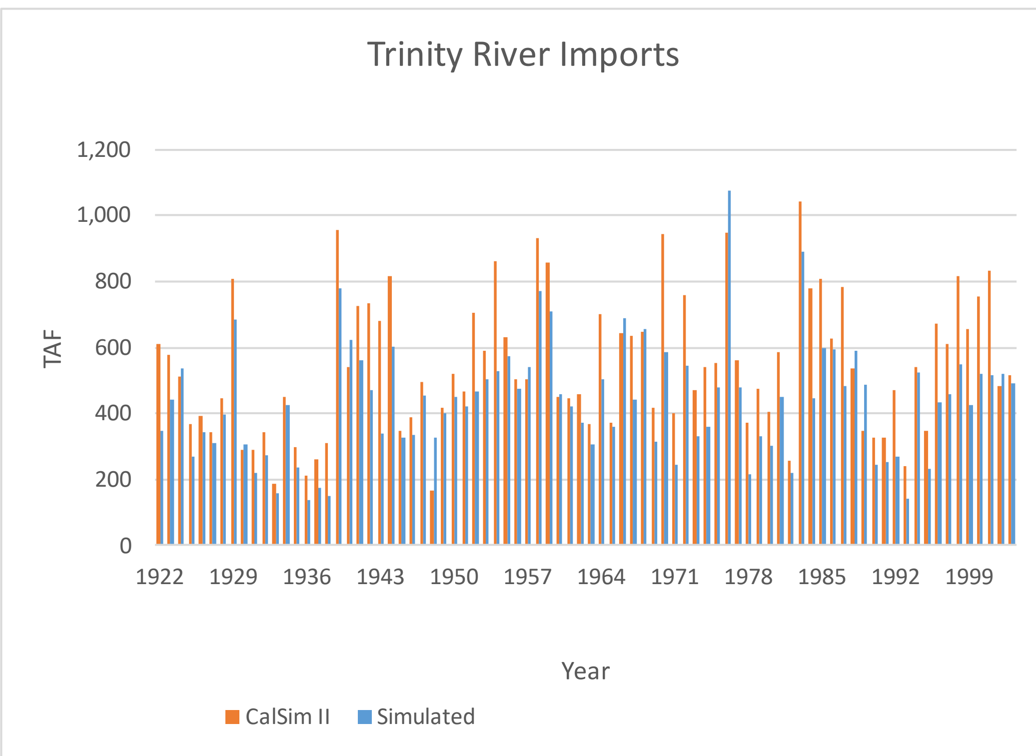


Figure A.6.5c. Trinity River Imports, Annual 1922 to 2003

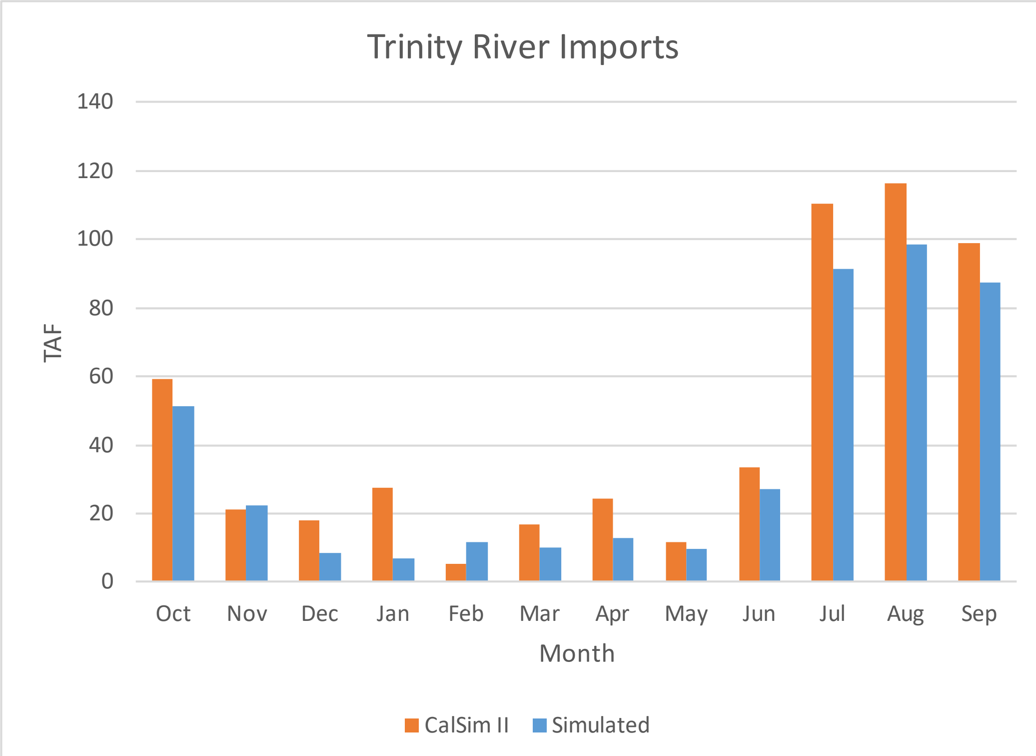


Figure A.6.5d. Trinity River Imports, Average Monthly

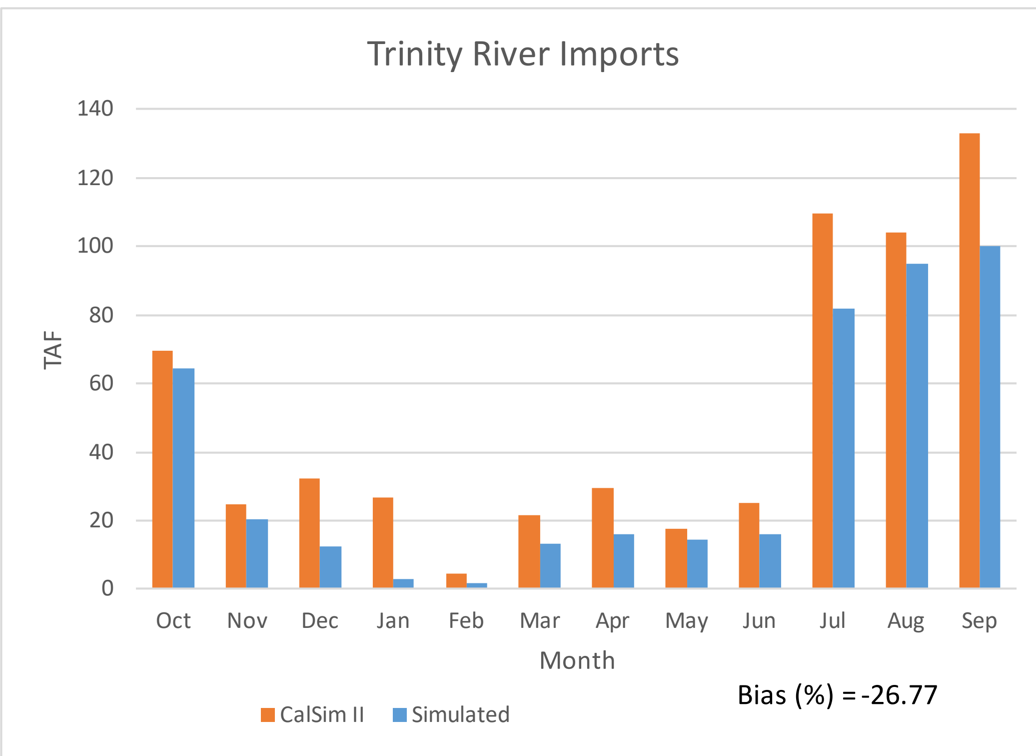


Figure A.6.5e. Trinity River Imports, Average Monthly (Wet)

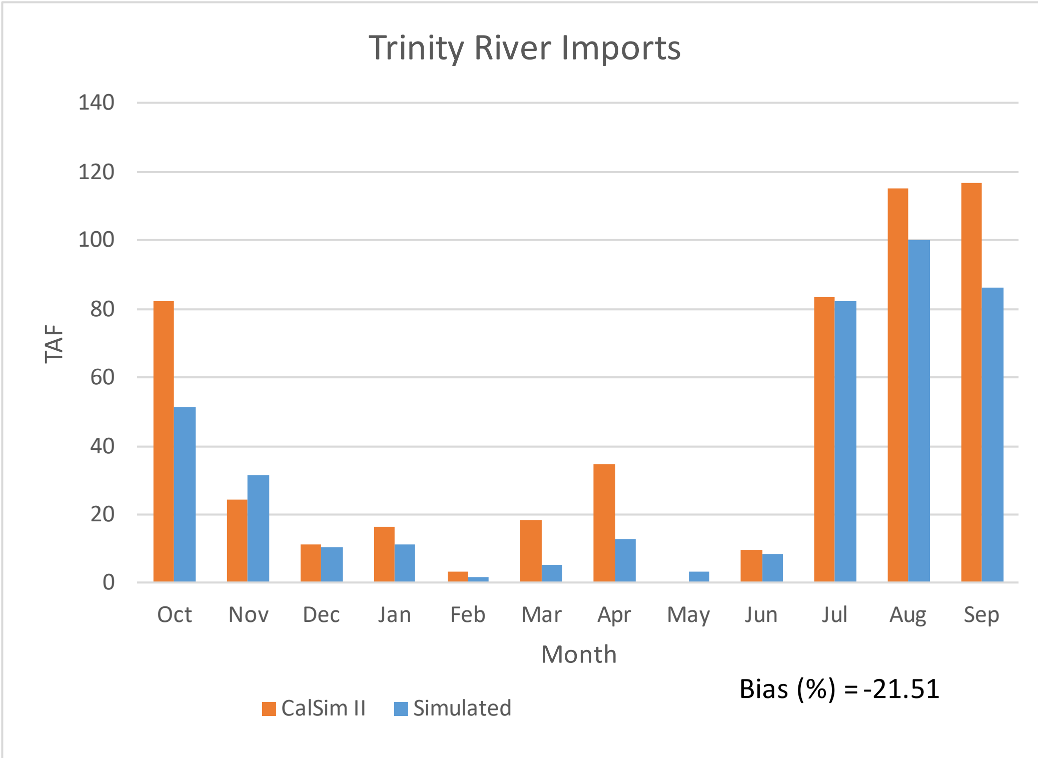


Figure A.6.5f. Trinity River Imports, Average Monthly (Above Normal)

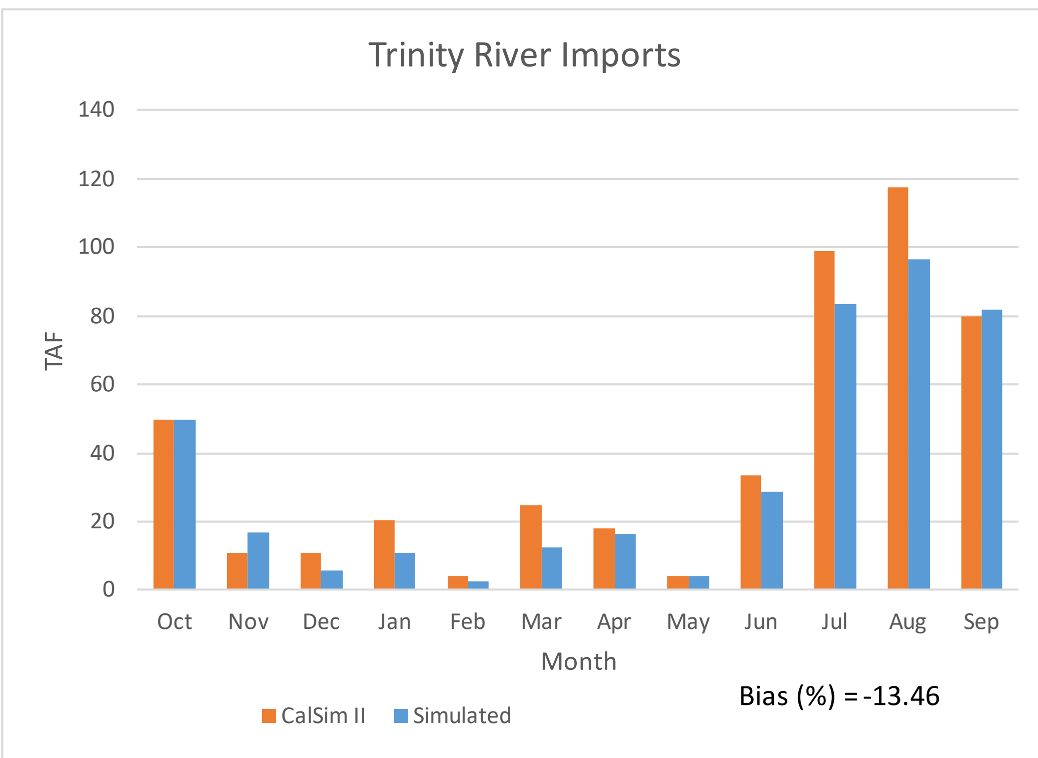


Figure A.6.5g. Trinity River Imports, Average Monthly (Below Normal)

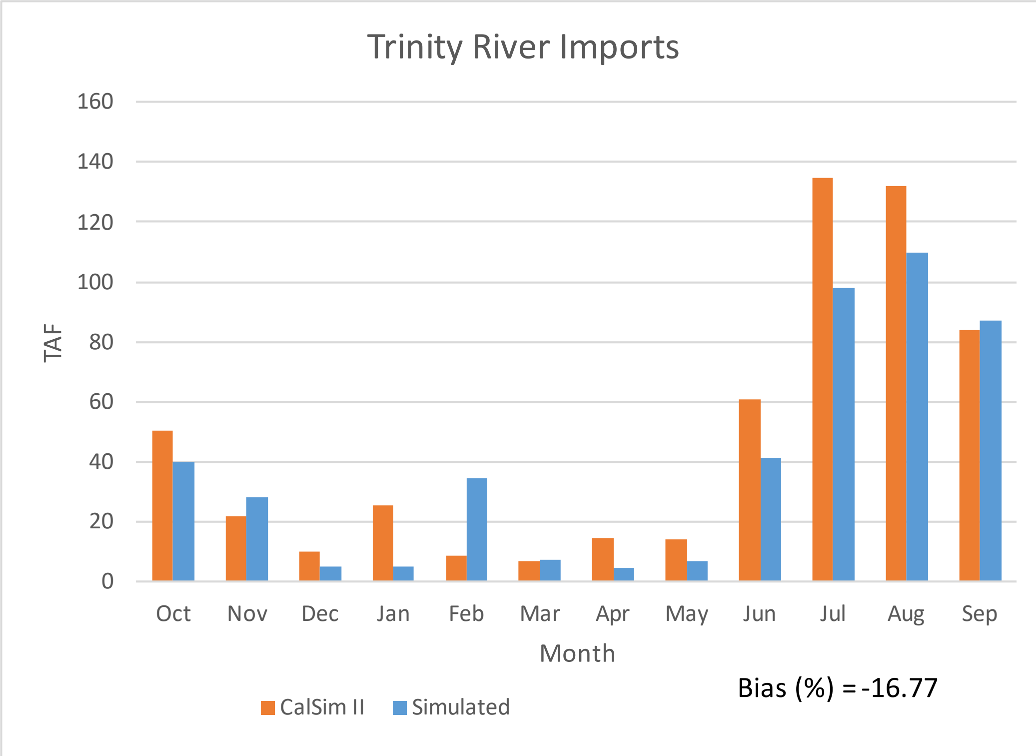


Figure A.6.5h. Trinity River Imports, Average Monthly (Dry)

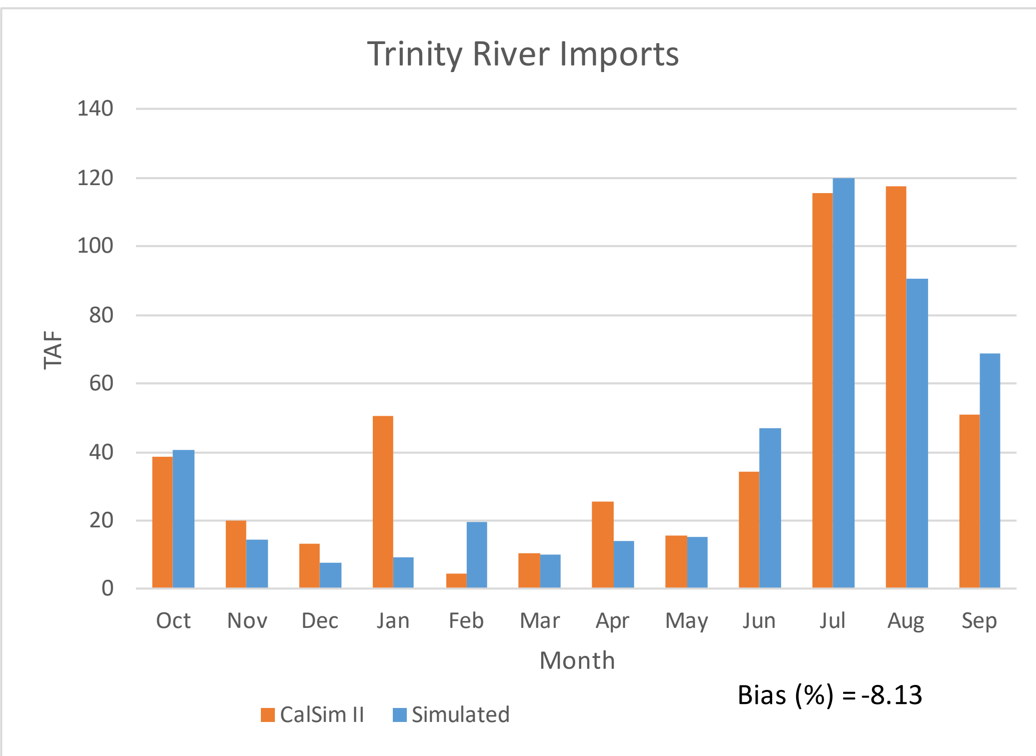


Figure A.6.5i. Trinity River Imports, Average Monthly (Critical)

A.6.6 American River at Confluence

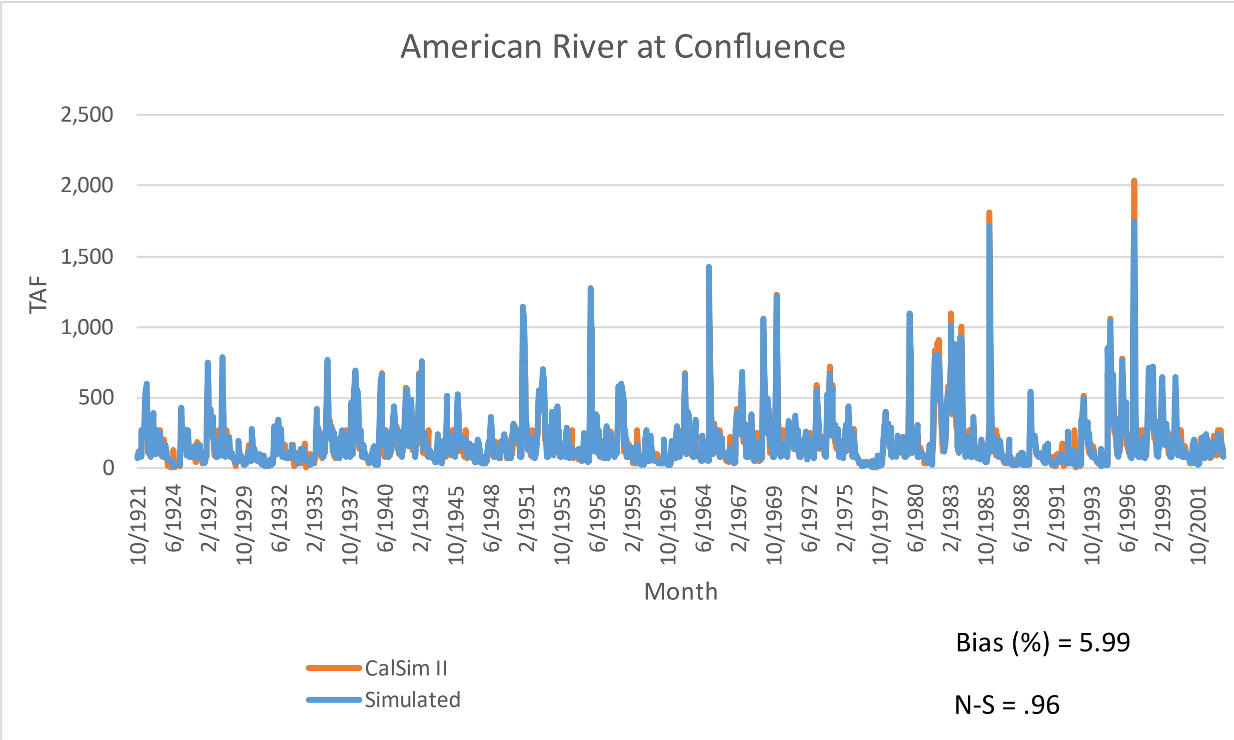


Figure A.6.6a. American River at Confluence, Monthly 1922 to 2003

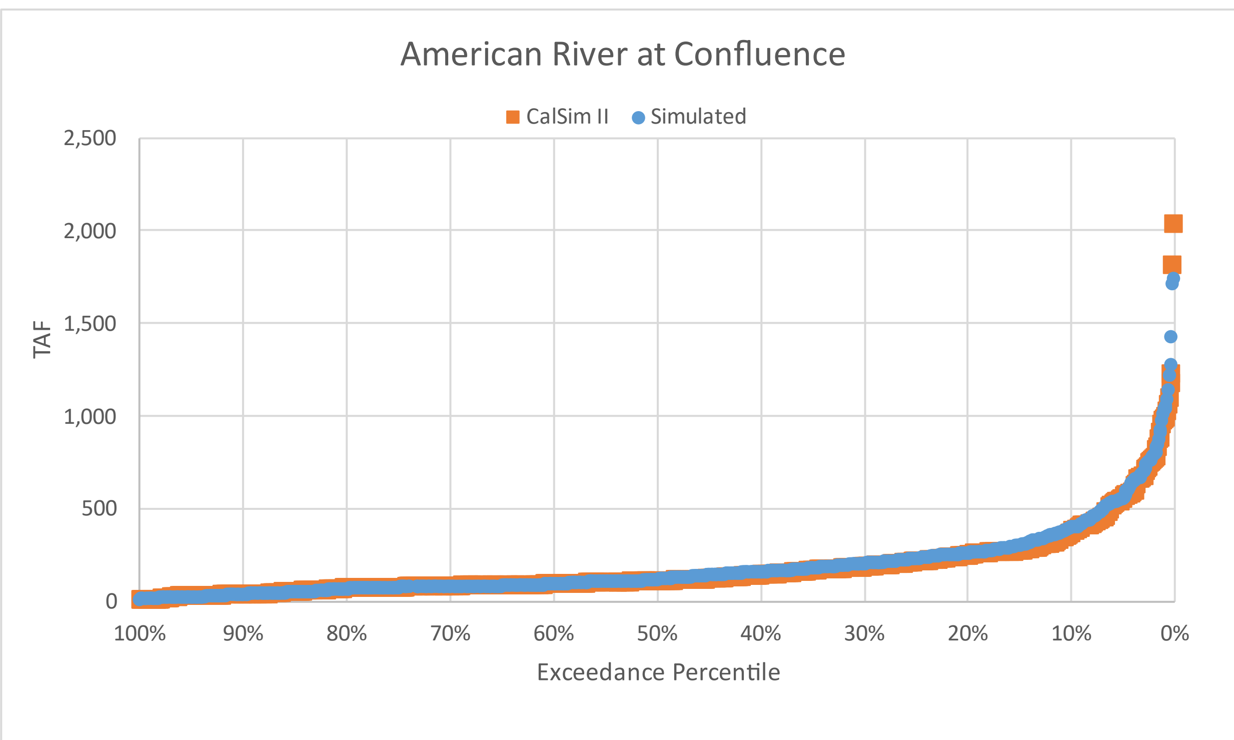


Figure A.6.6b. American River at Confluence, Exceedance

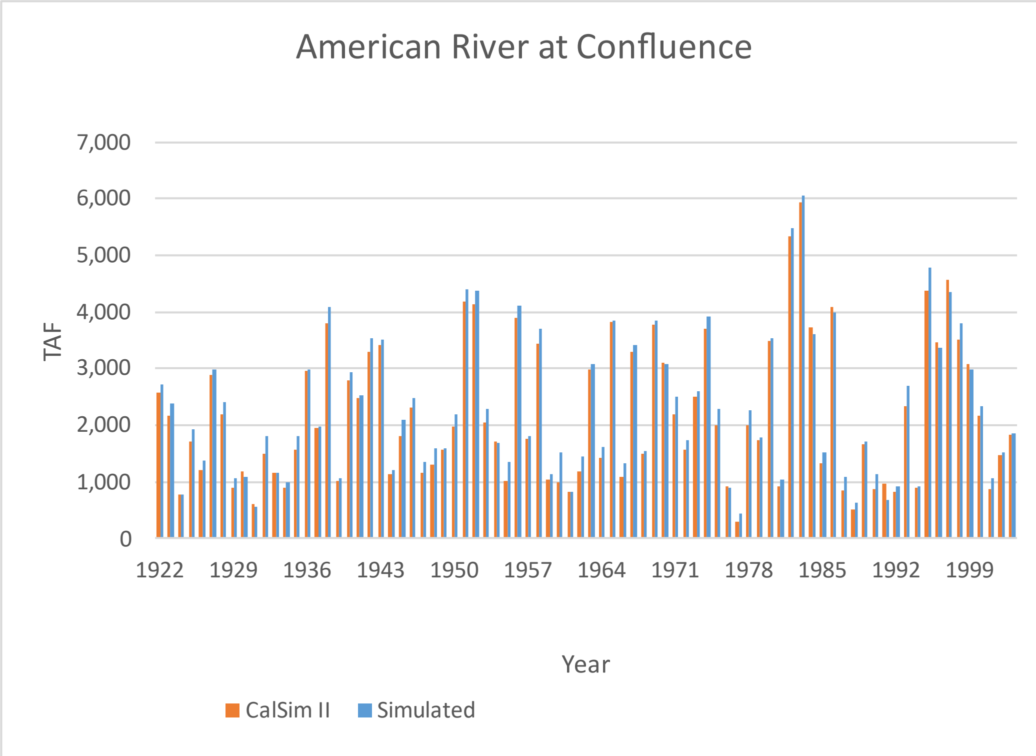


Figure A.6.6c. American River at Confluence, Annual 1922 to 2003

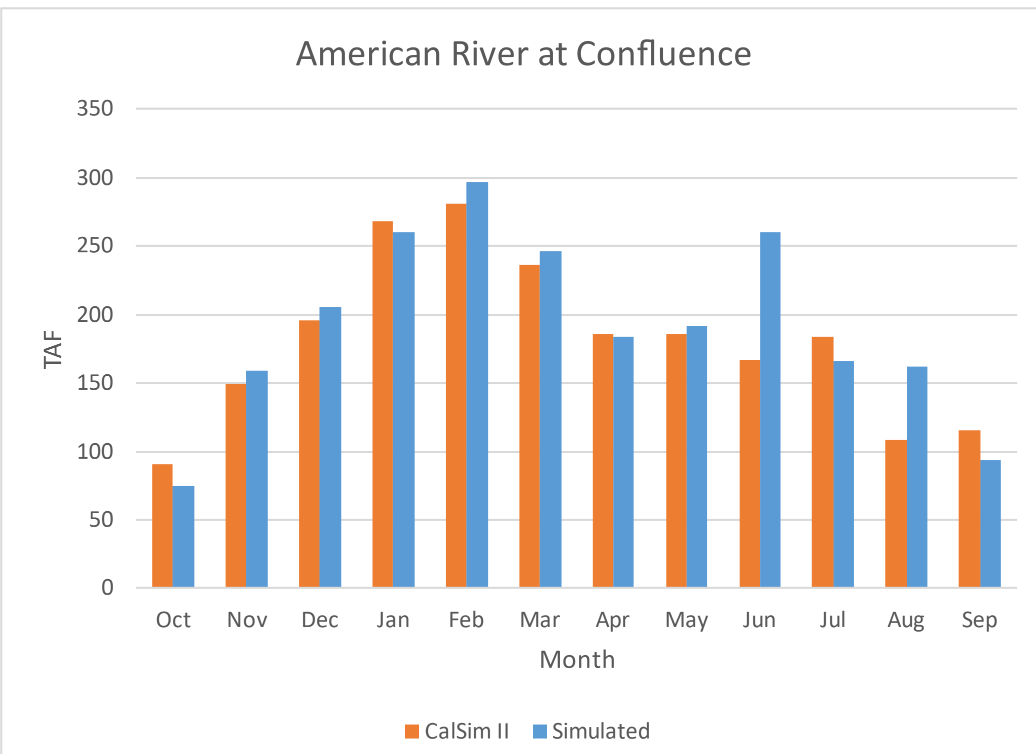


Figure A.6.6d. American River at Confluence, Average Monthly

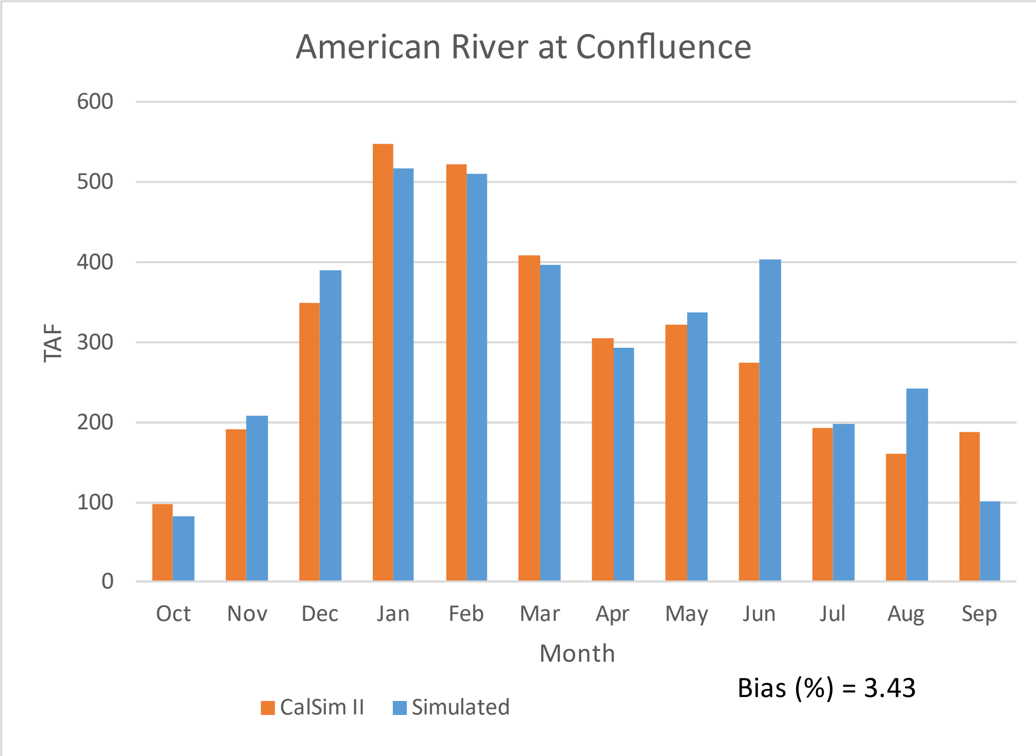


Figure A.6.6e. American River at Confluence, Average Monthly (Wet)

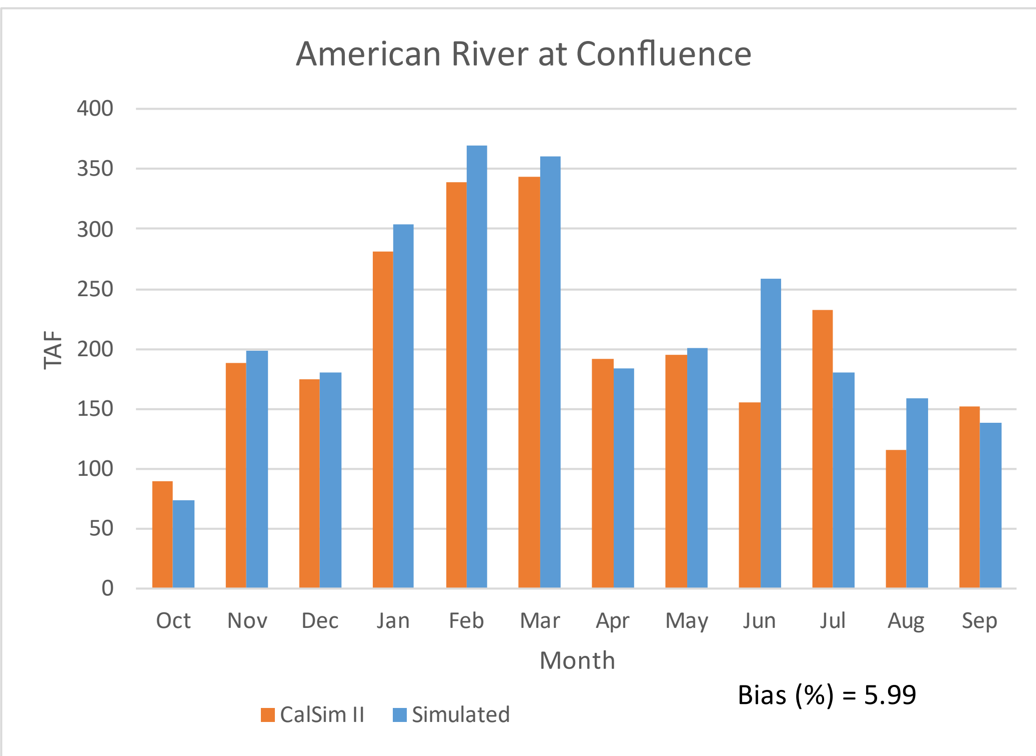


Figure A.6.6f. American River at Confluence, Average Monthly (Above Normal)

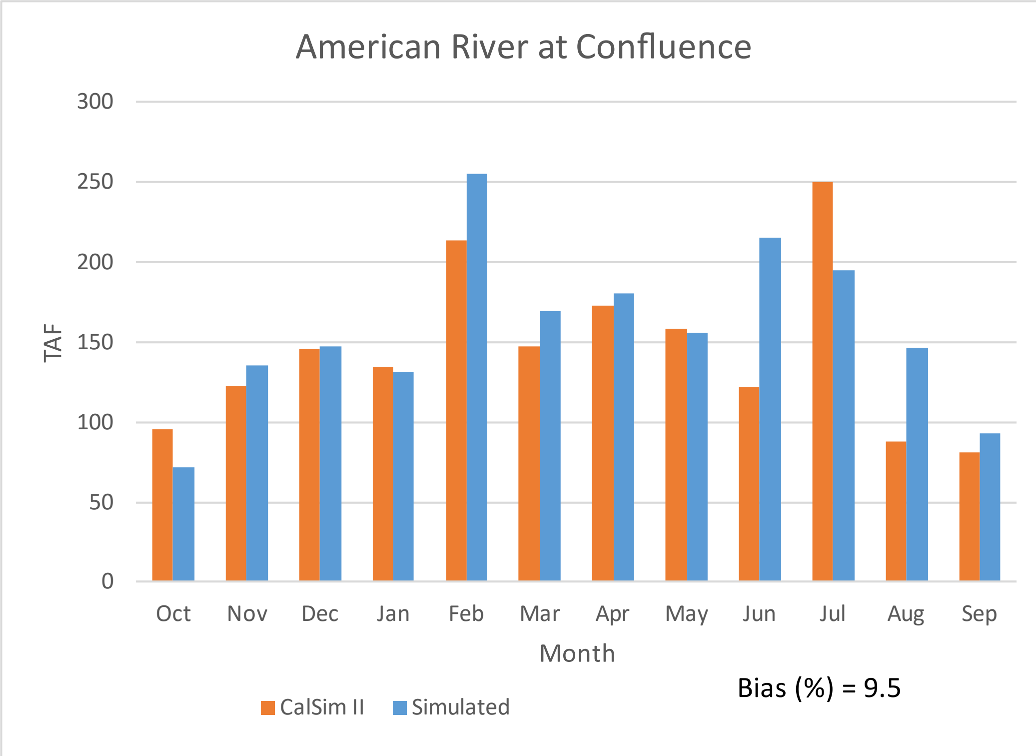


Figure A.6.6g. American River at Confluence, Average Monthly (Below Normal)

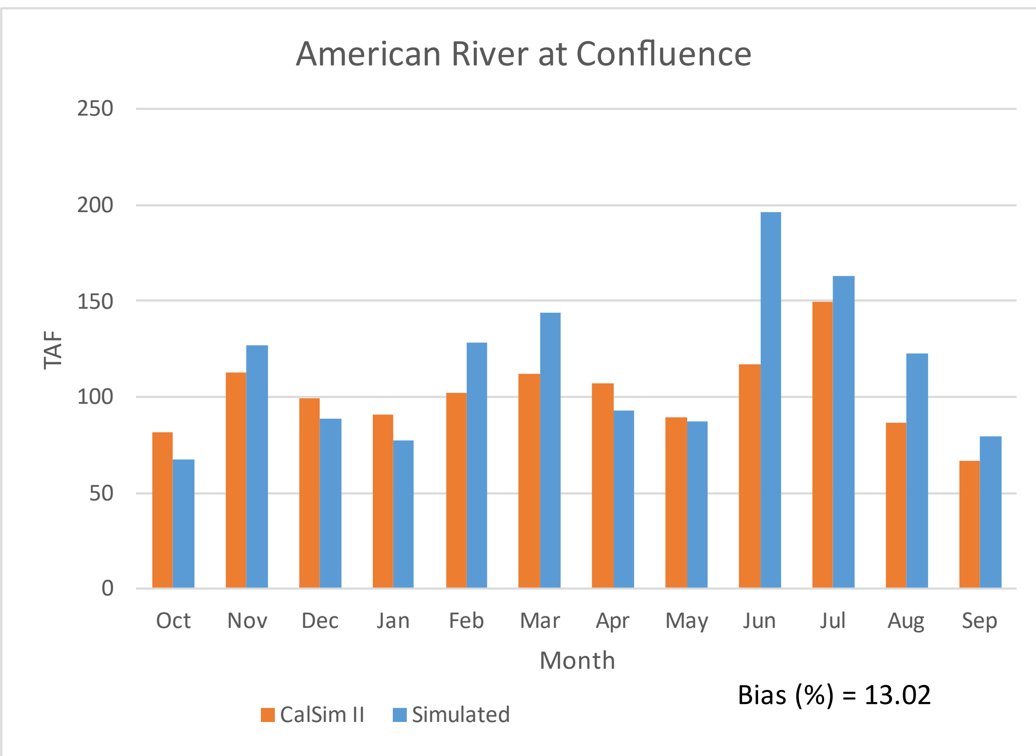


Figure A.6.6h. American River at Confluence, Average Monthly (Dry)

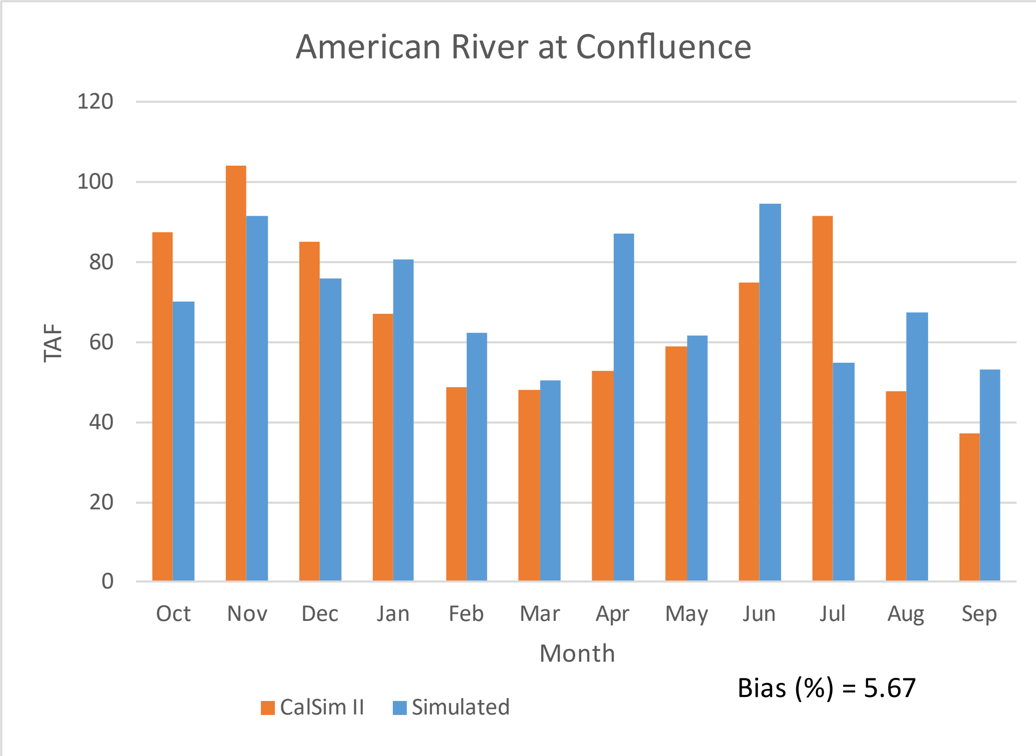


Figure A.6.6i. American River at Confluence, Average Monthly (Critical)

A.6.7 Feather River at Confluence

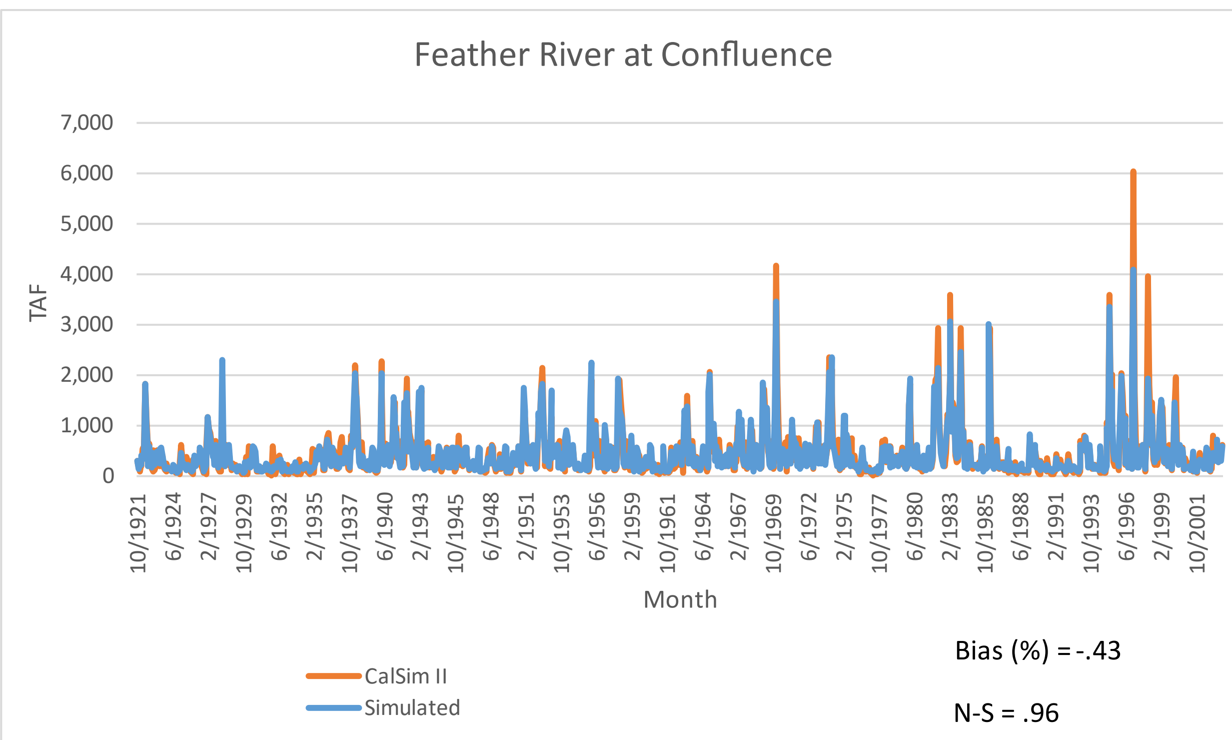


Figure A.6.7a. Feather River at Confluence, Monthly 1922 to 2003

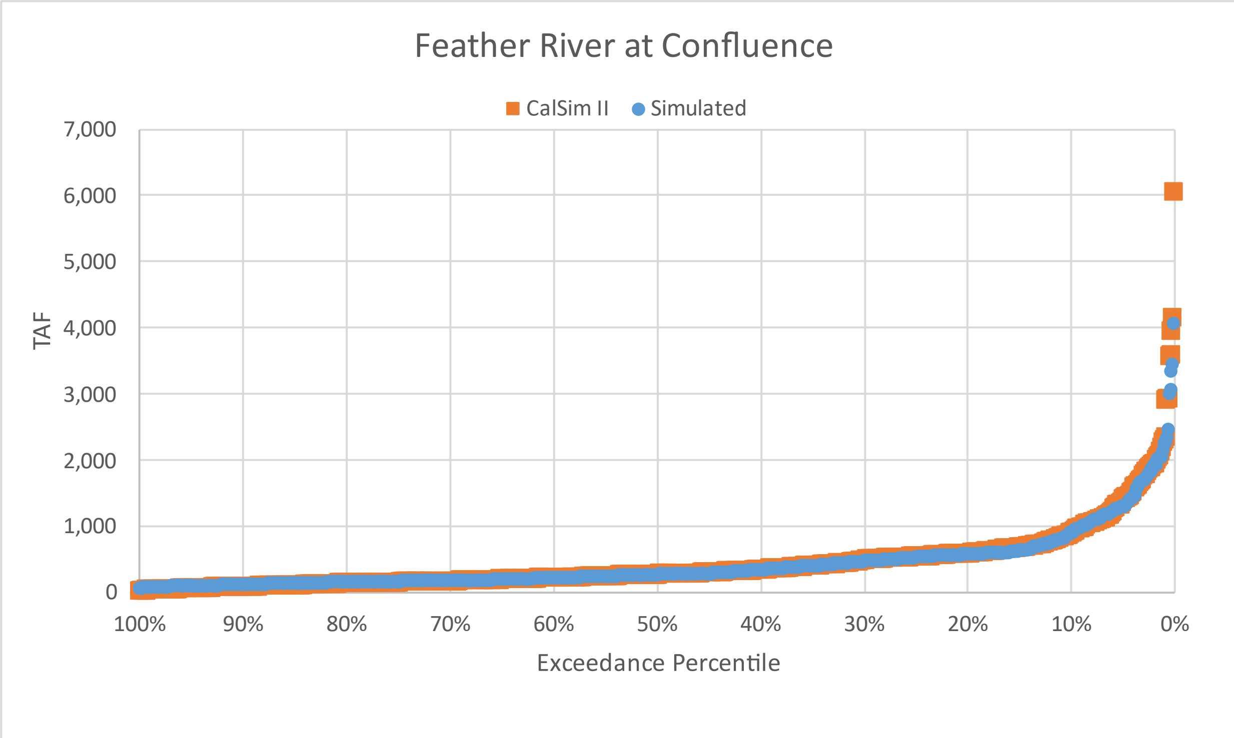


Figure A.6.7b. Feather River at Confluence, Exceedance

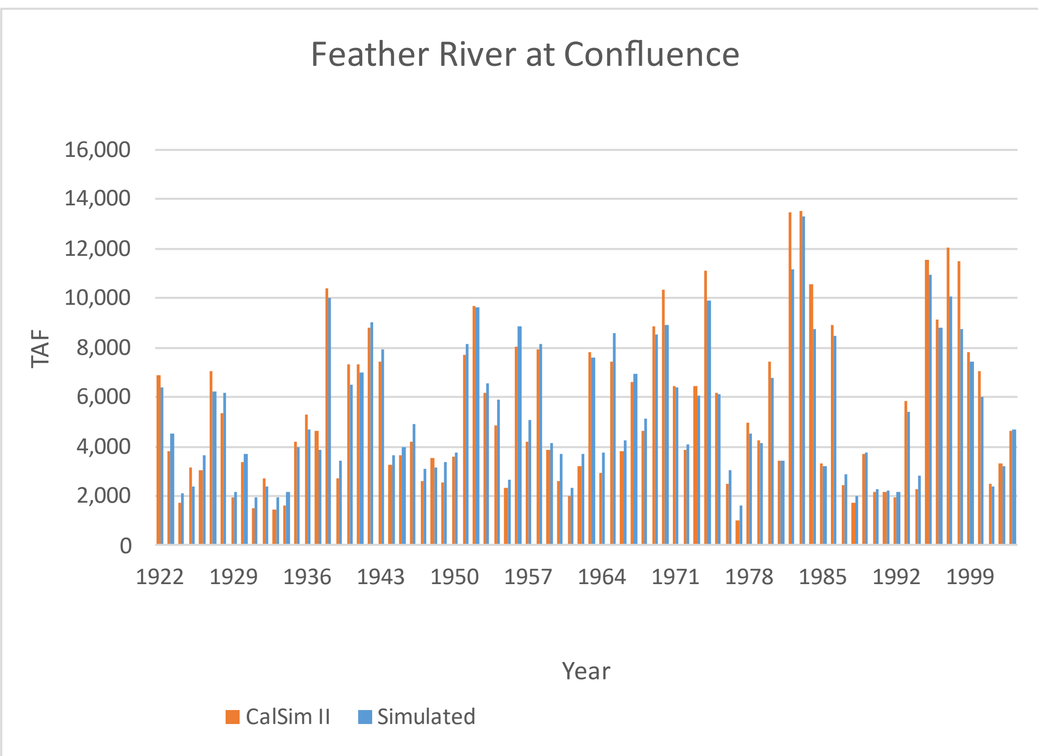


Figure A.6.7c. Feather River at Confluence, Annual 1922 to 2003

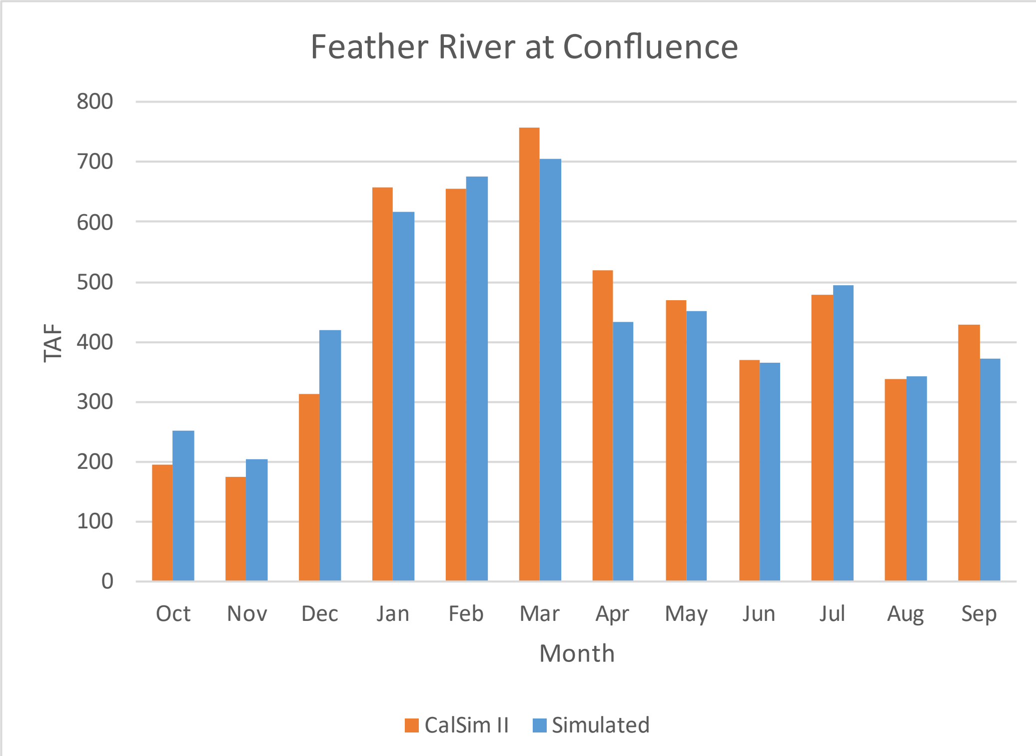


Figure A.6.7d. Feather River at Confluence, Average Monthly

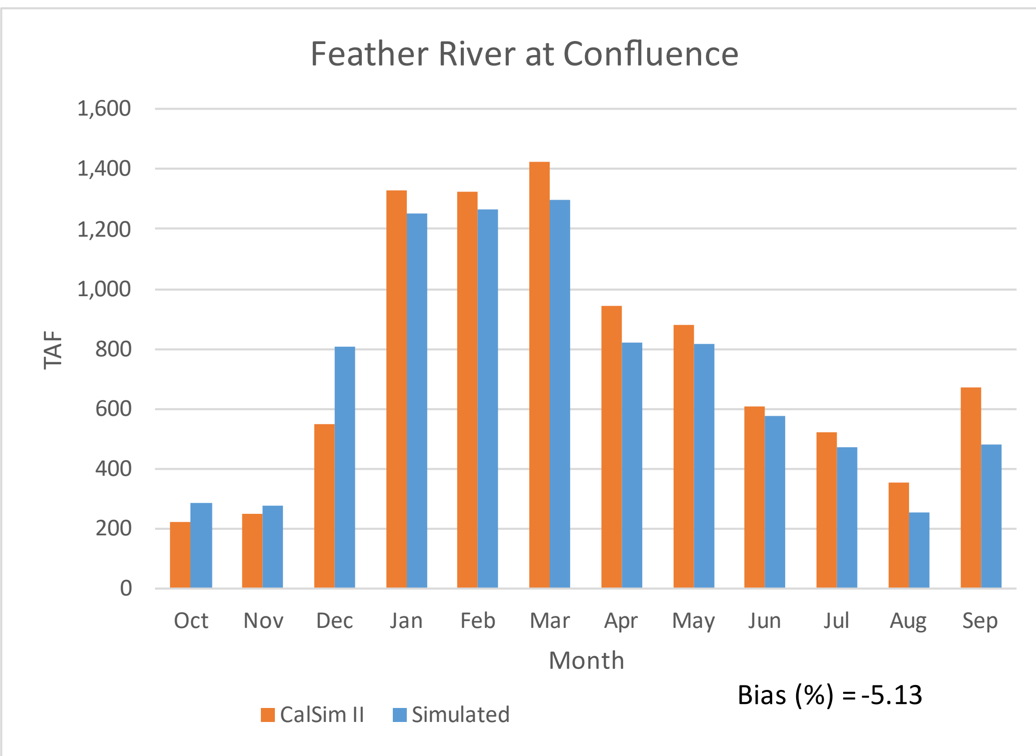


Figure A.6.7e. Feather River at Confluence, Average Monthly (Wet)

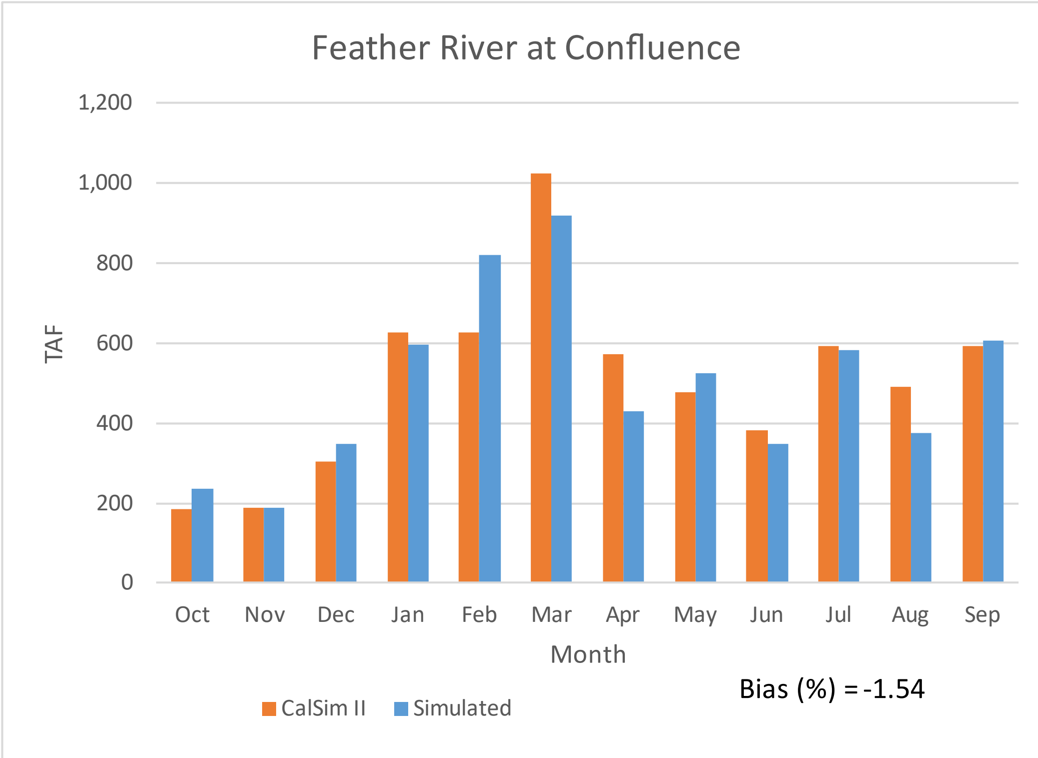


Figure A.6.7f. Feather River at Confluence, Average Monthly (Above Normal)

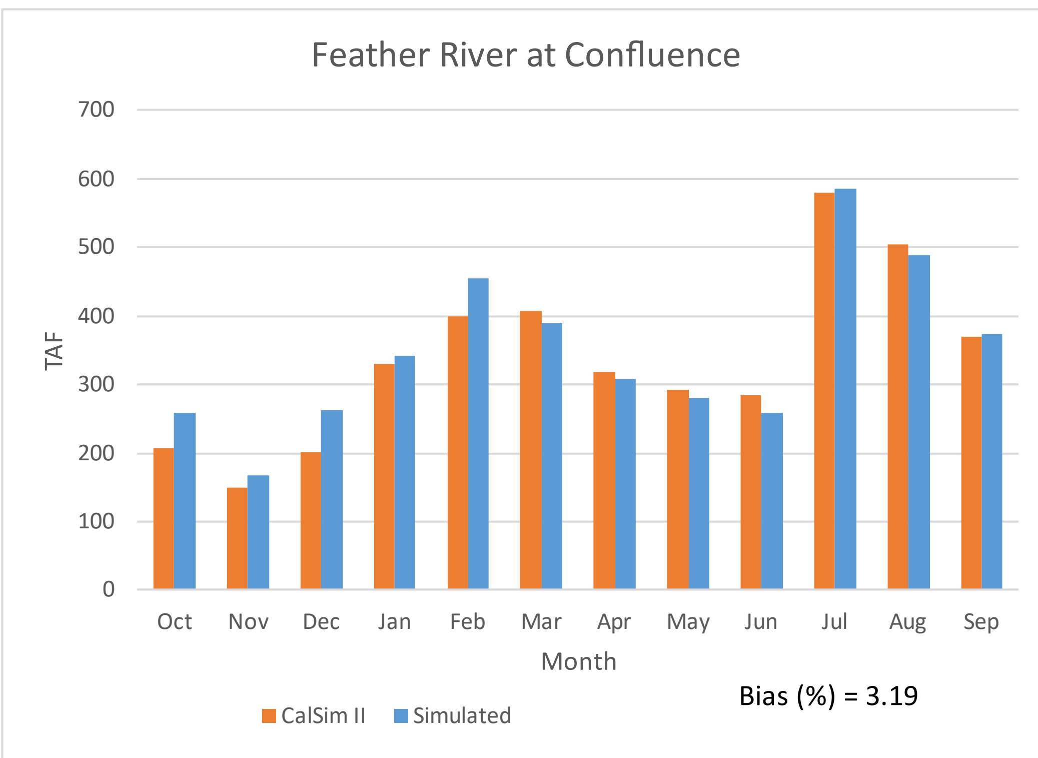


Figure A.6.7g. Feather River at Confluence, Average Monthly (Below Normal)

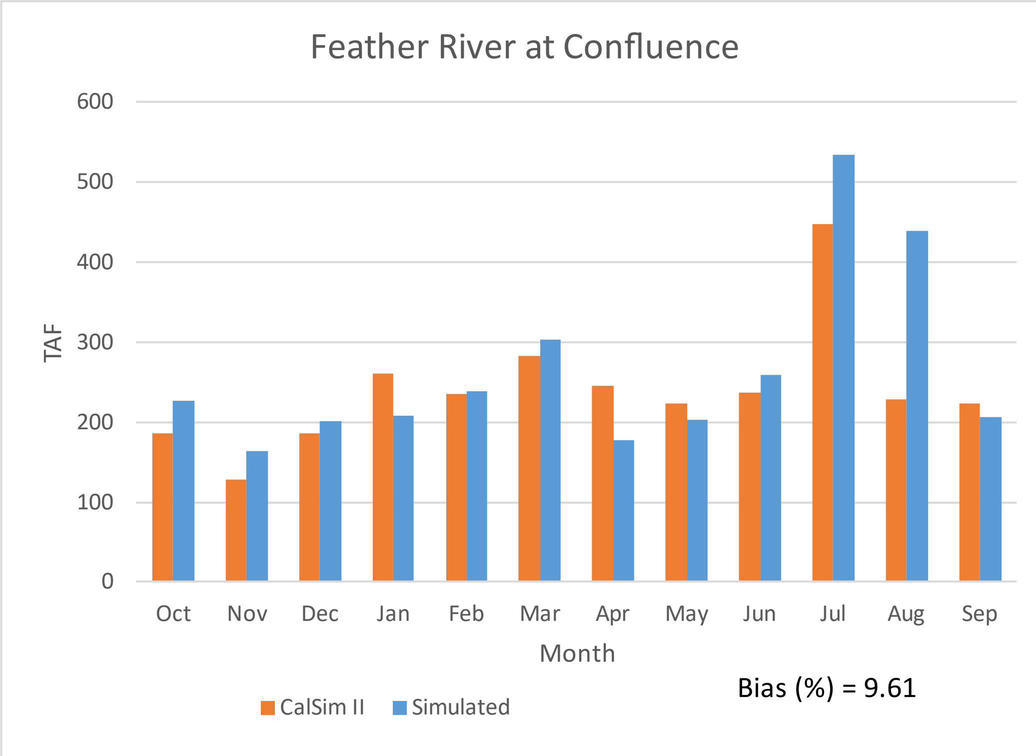


Figure A.6.7h. Feather River at Confluence, Average Monthly (Dry)

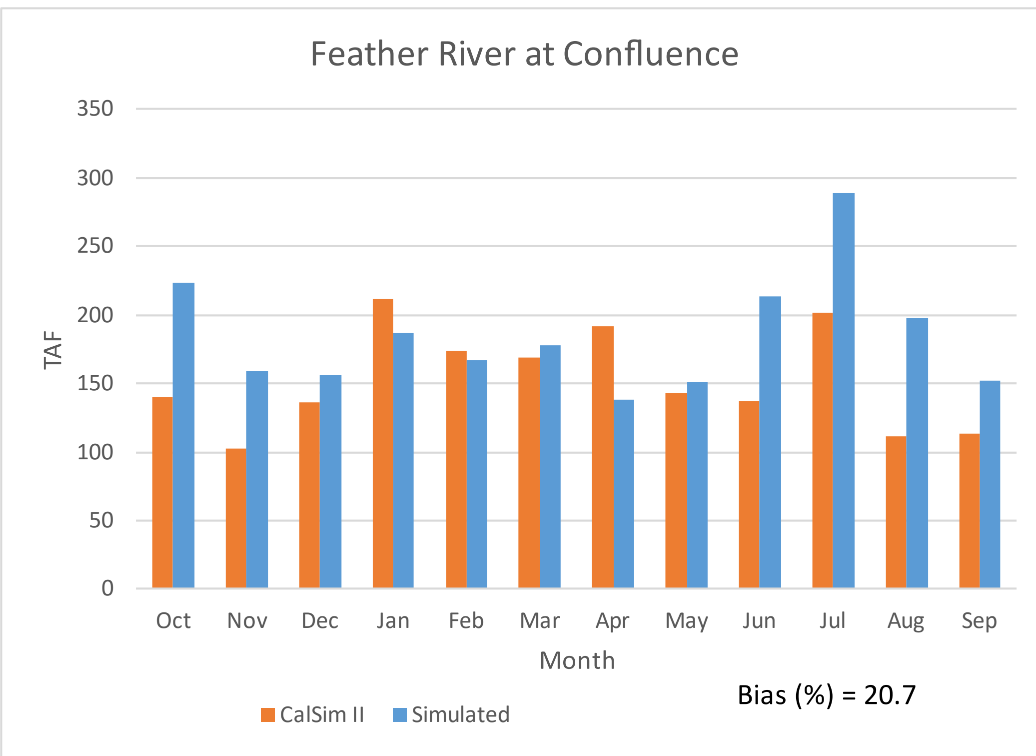


Figure A.6.7i. Feather River at Confluence, Average Monthly (Critical)

A.6.8 Sacramento River at Freeport

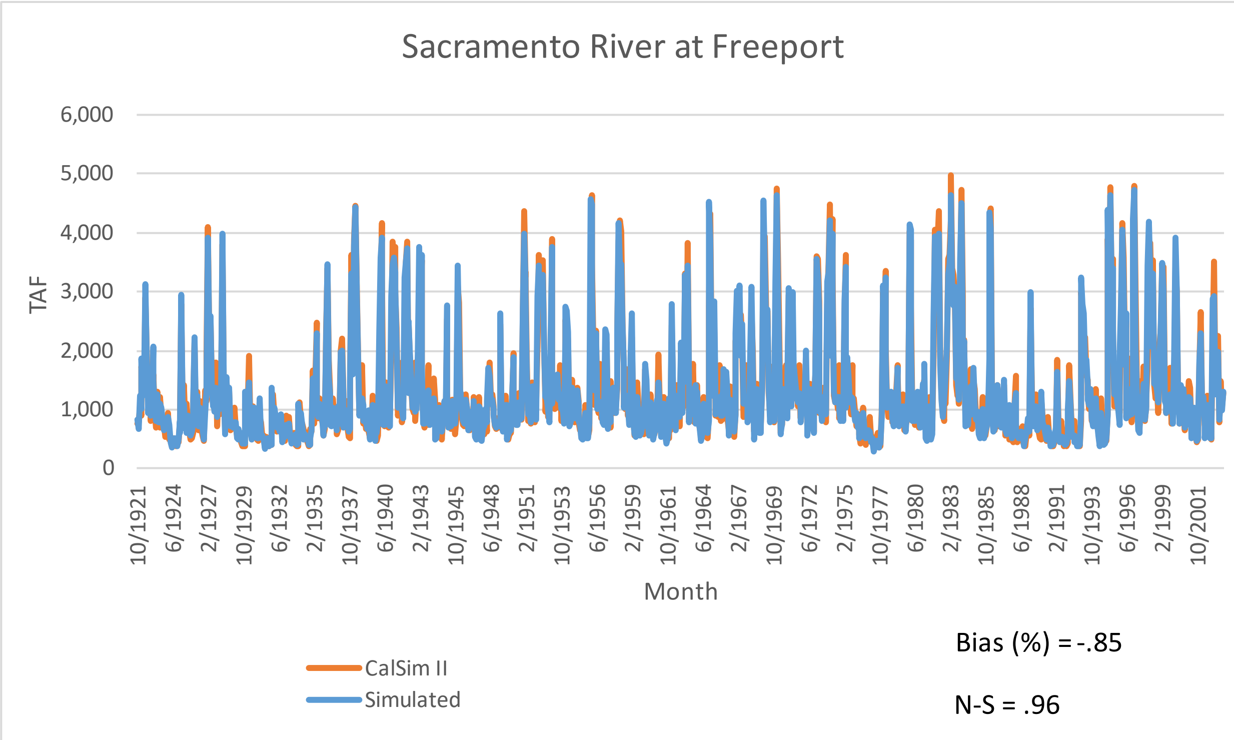


Figure A.6.8a. Sacramento River at Freeport, Monthly 1922 to 2003

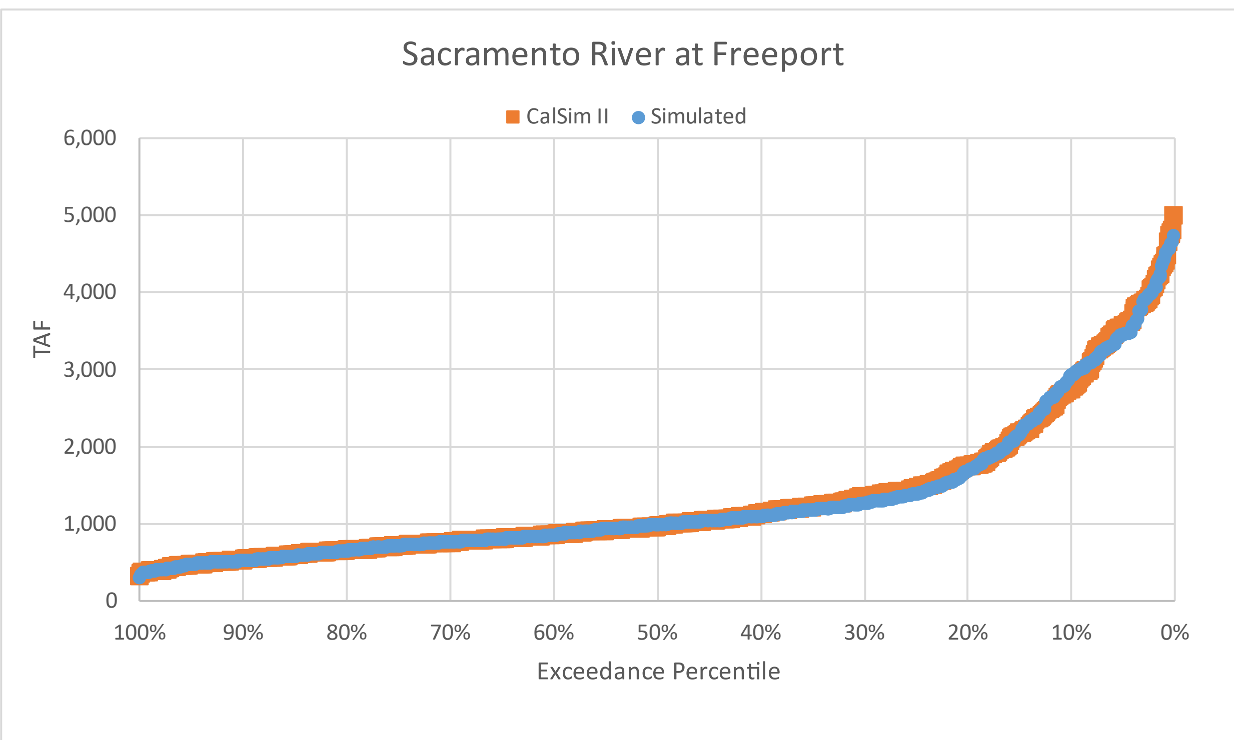


Figure A.6.8b. Sacramento River at Freeport, Exceedance

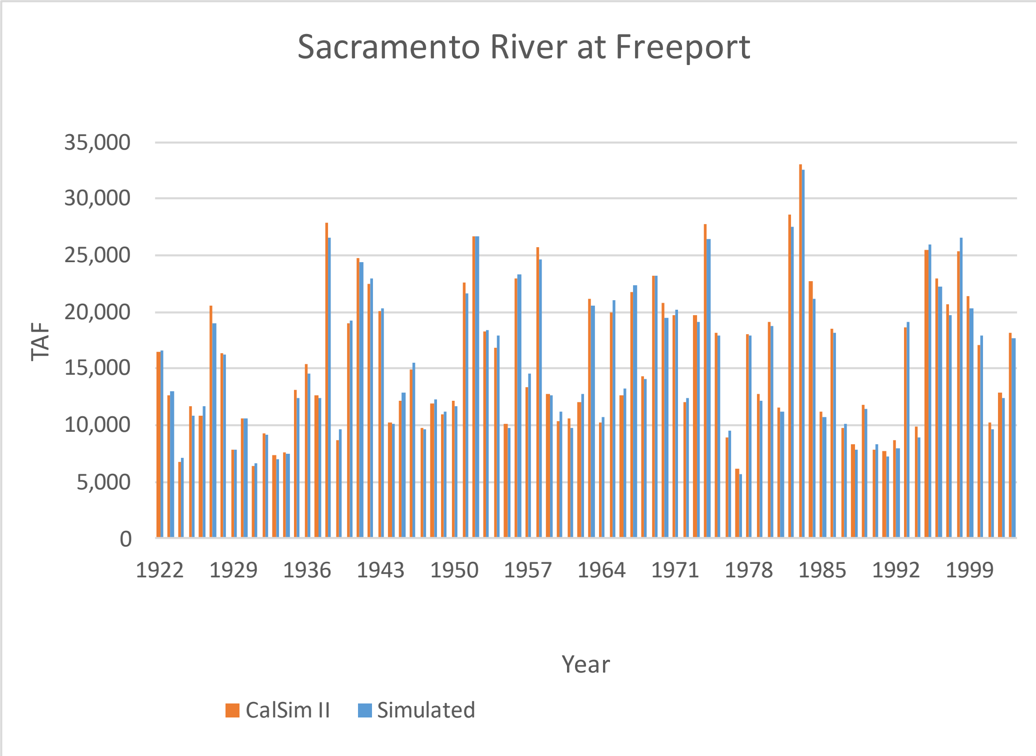


Figure A.6.8c. Sacramento River at Freeport, Annual 1922 to 2003

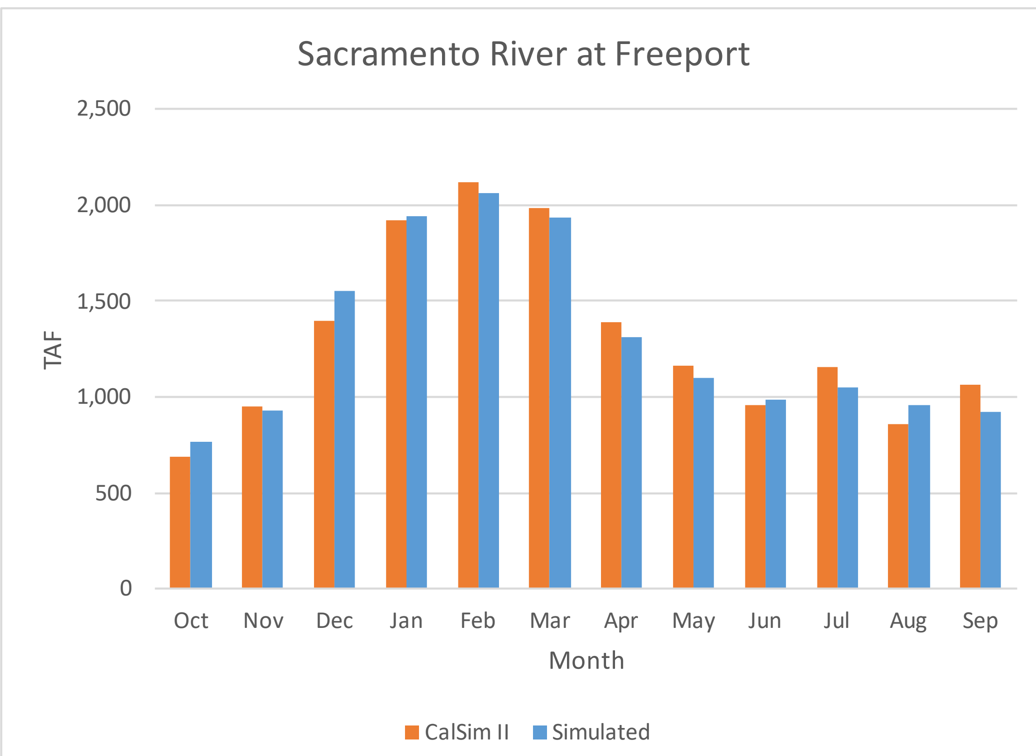


Figure A.6.8d. Sacramento River at Freeport, Average Monthly

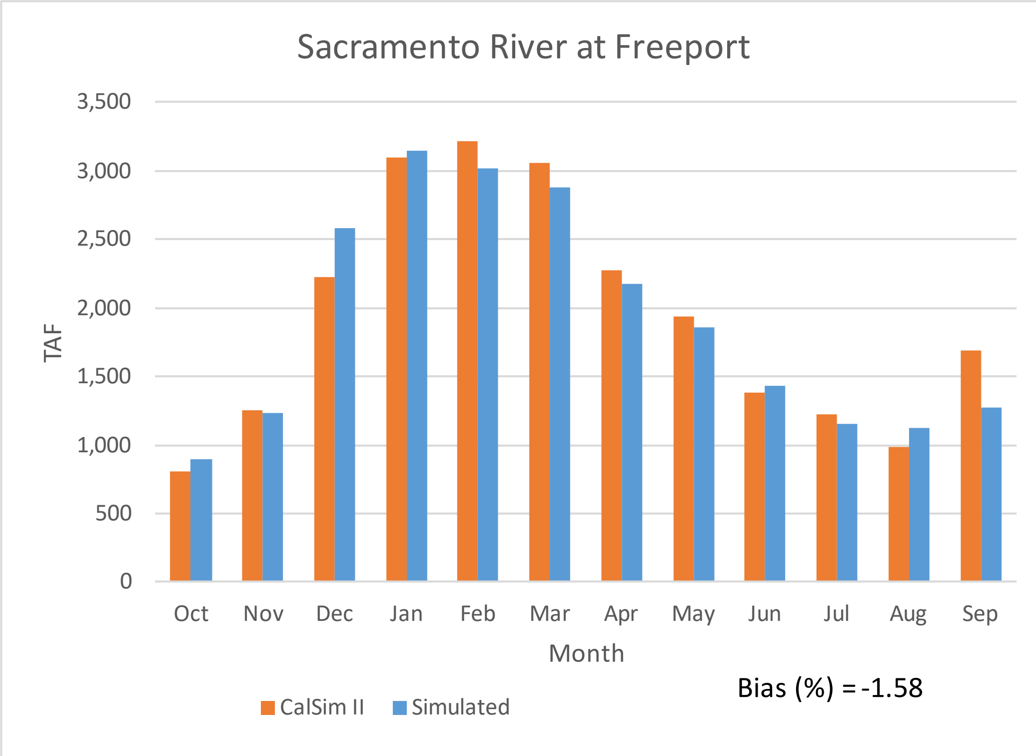


Figure A.6.8e. Sacramento River at Freeport, Average Monthly (Wet)

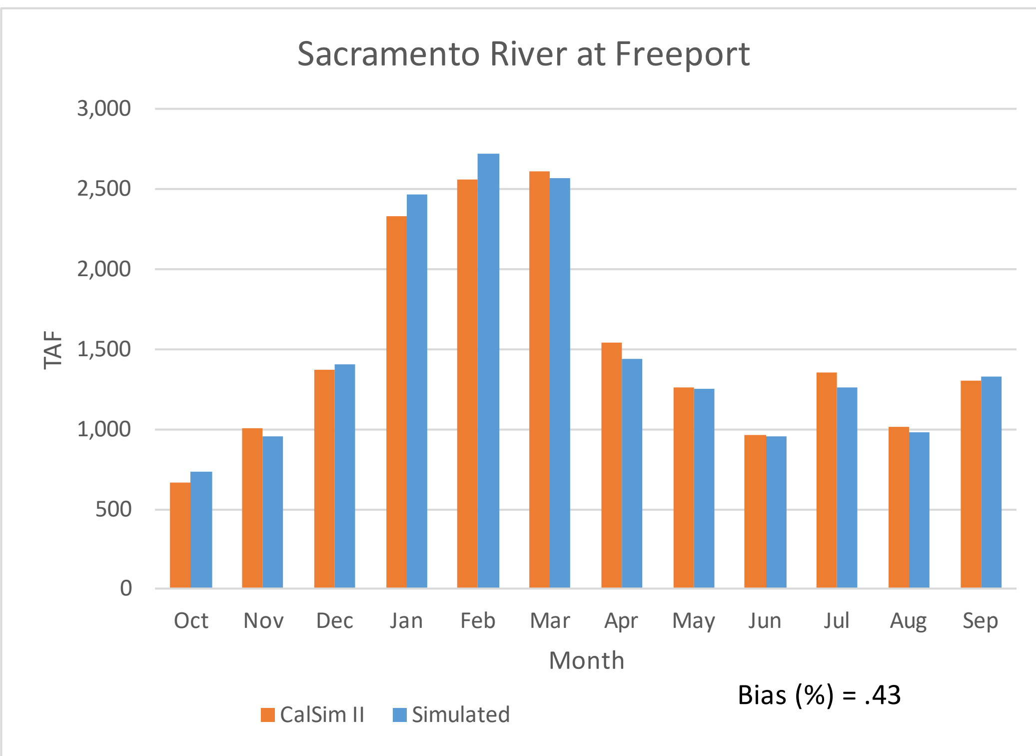


Figure A.6.8f. Sacramento River at Freeport, Average Monthly (Above Normal)

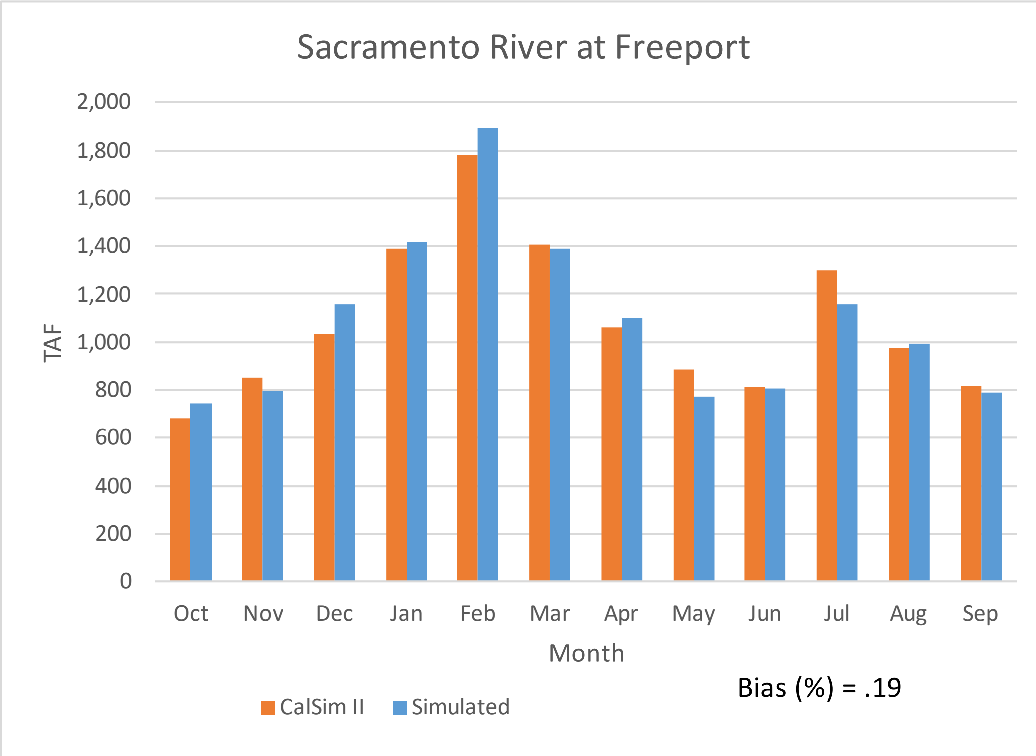


Figure A.6.8g. Sacramento River at Freeport, Average Monthly (Below Normal)

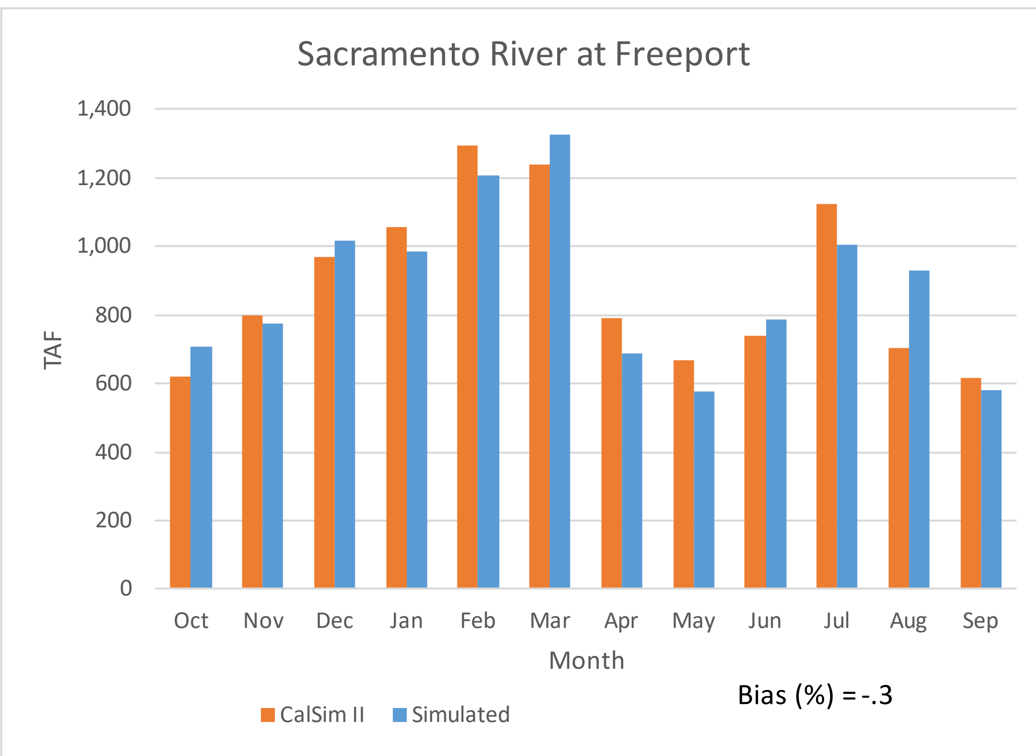


Figure A.6.8h. Sacramento River at Freeport, Average Monthly (Dry)

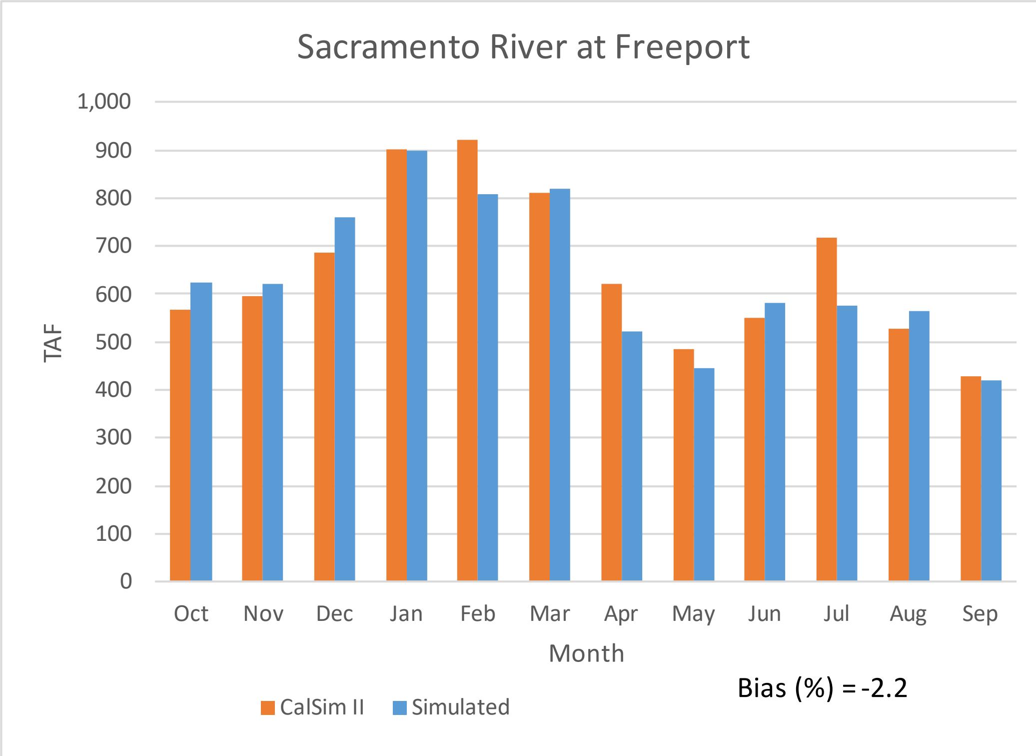


Figure A.6.8i. Sacramento River at Freeport, Average Monthly (Critical)

A.6.9 Delta Inflow

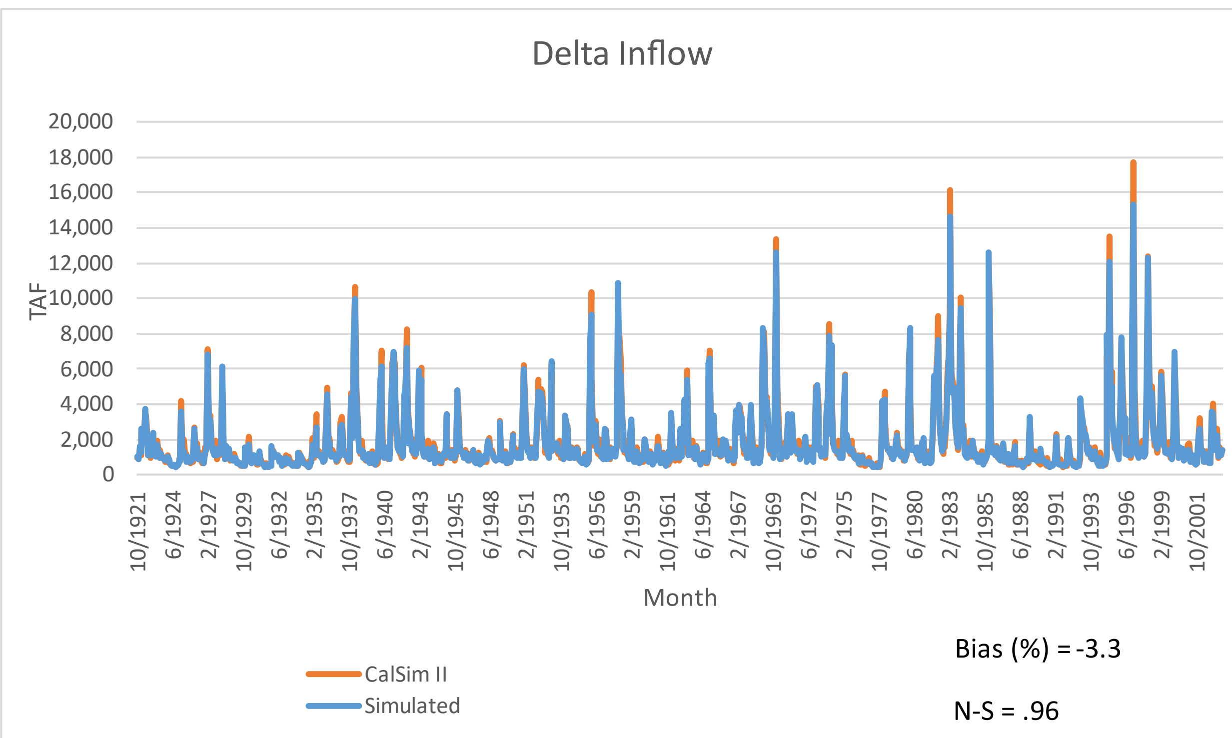


Figure A.6.9a. Delta Inflow, Monthly 1922 to 2003

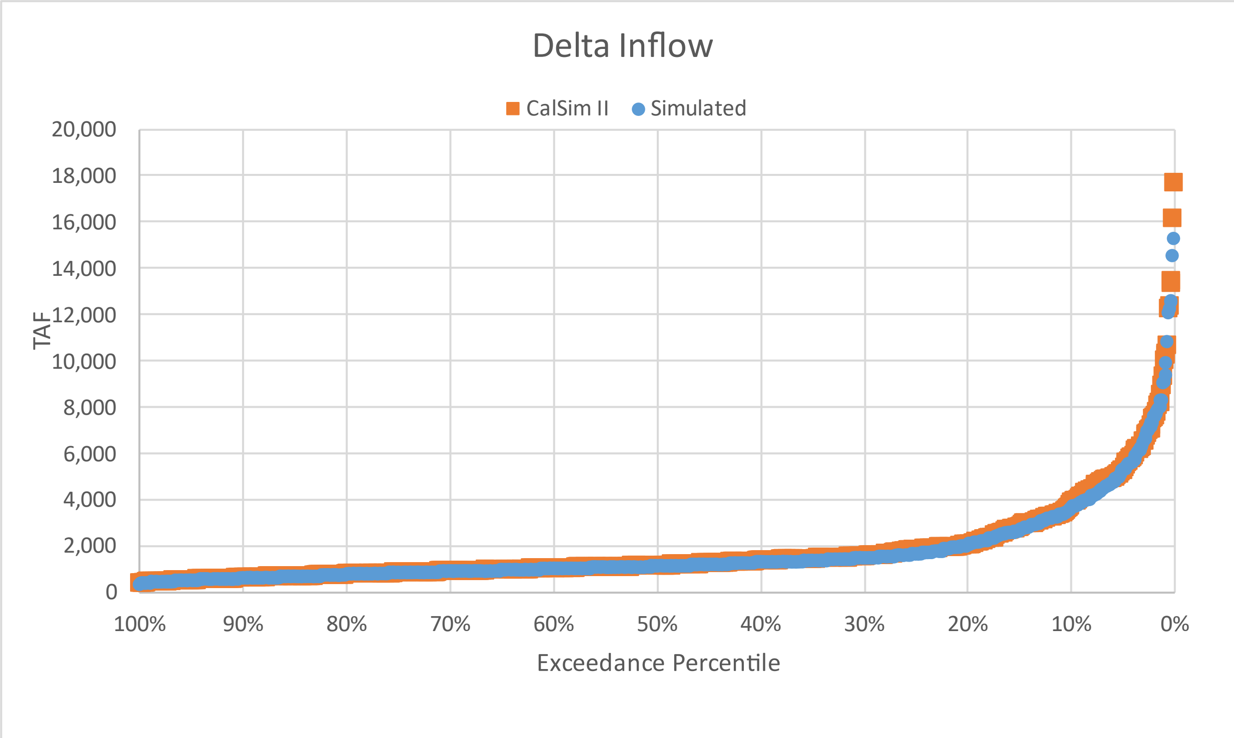


Figure A.6.9b. Delta Inflow, Exceedance

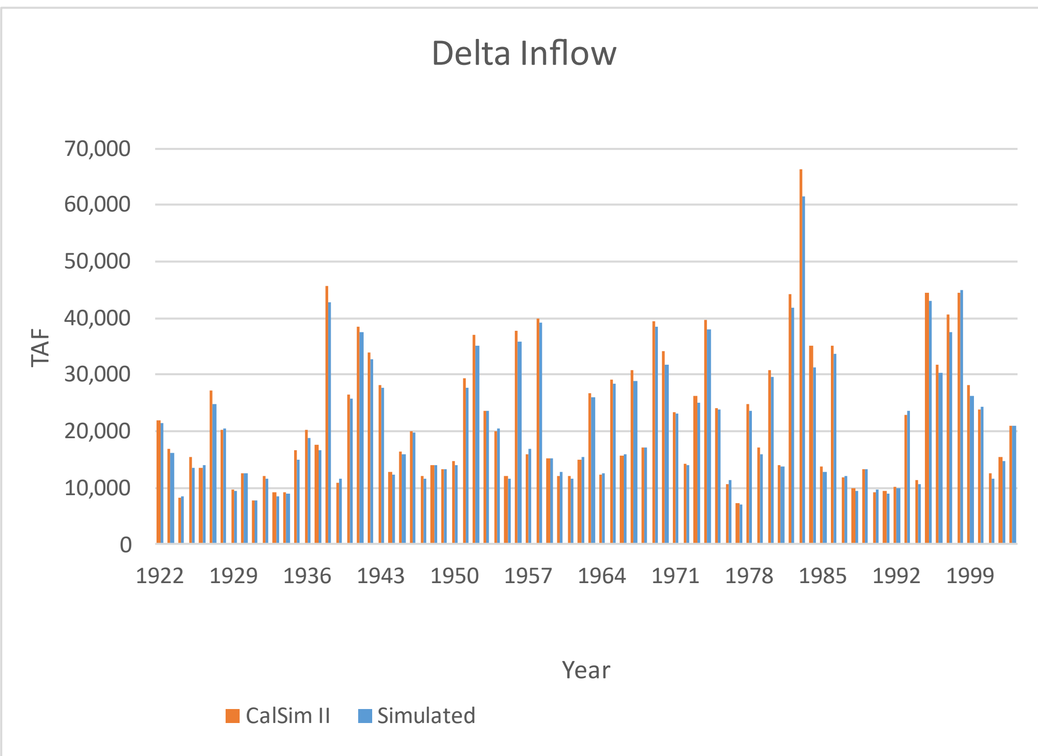


Figure A.6.9c. Delta Inflow, Annual 1922 to 2003

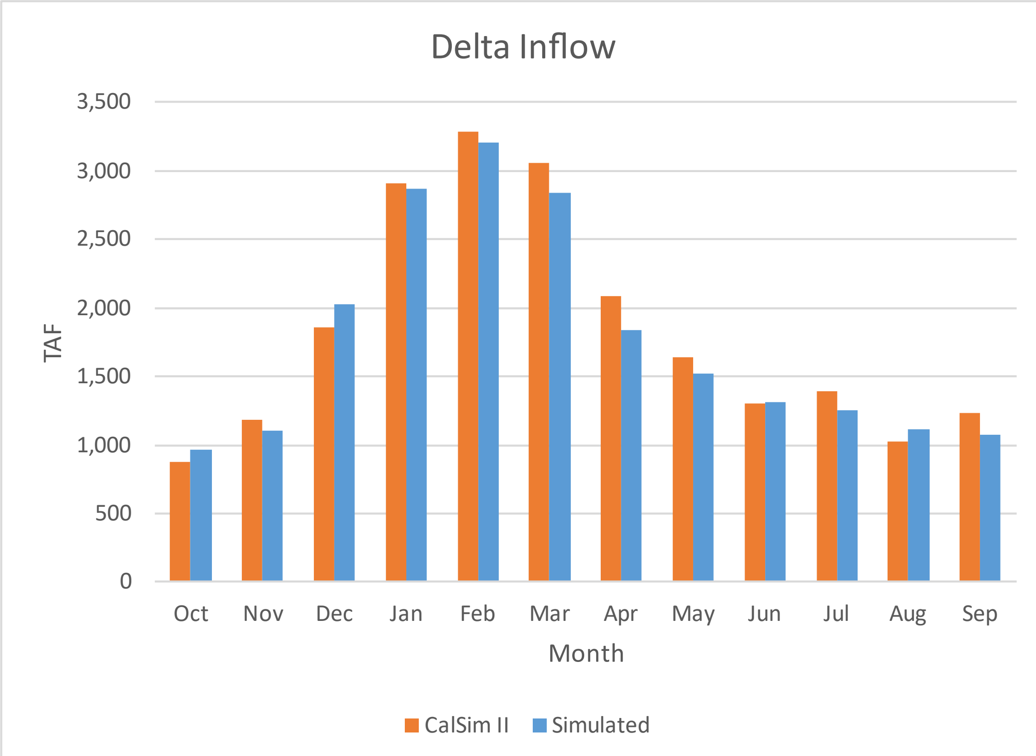


Figure A.6.9d. Delta Inflow, Average Monthly

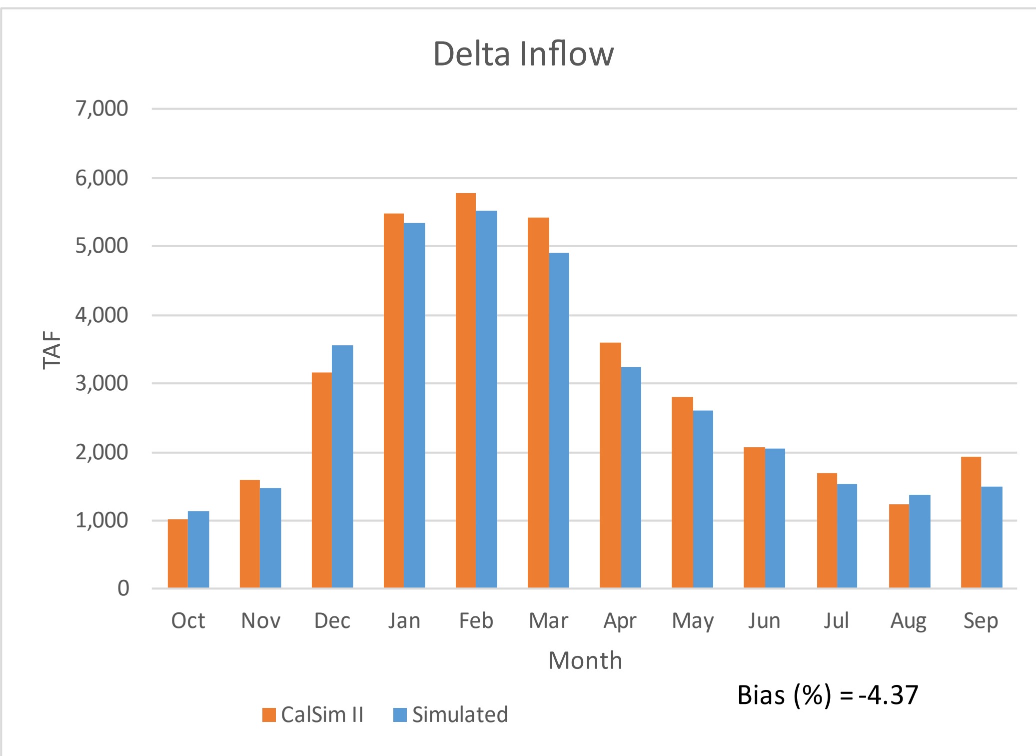


Figure A.6.9e. Delta Inflow, Average Monthly (Wet)

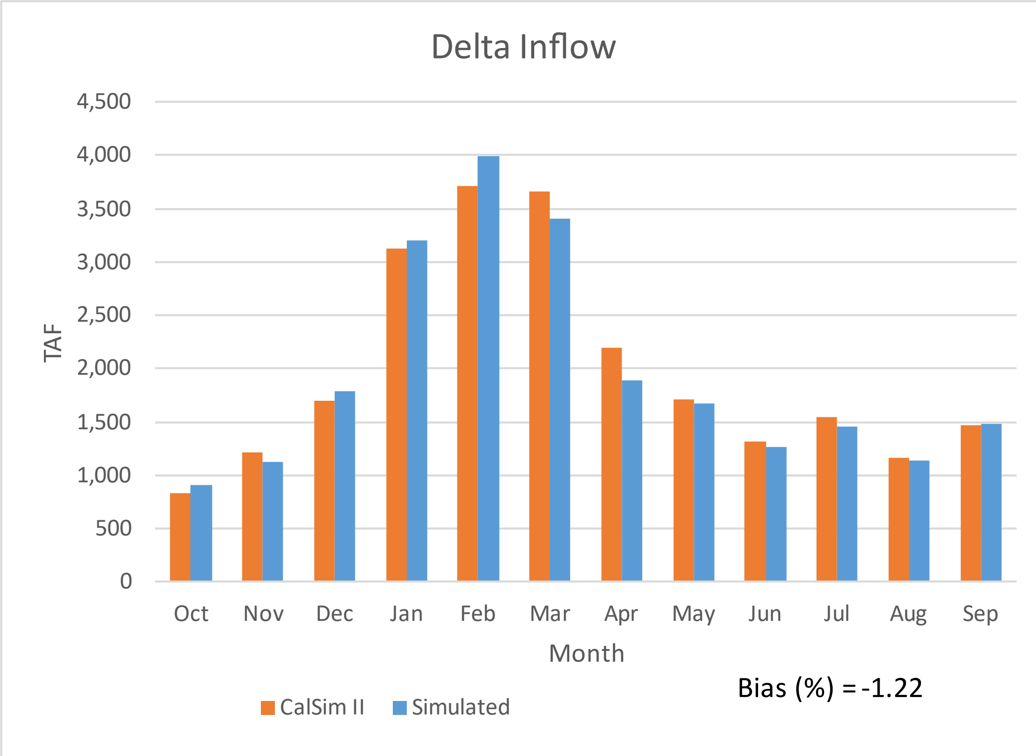


Figure A.6.9f. Delta Inflow, Average Monthly (Above Normal)

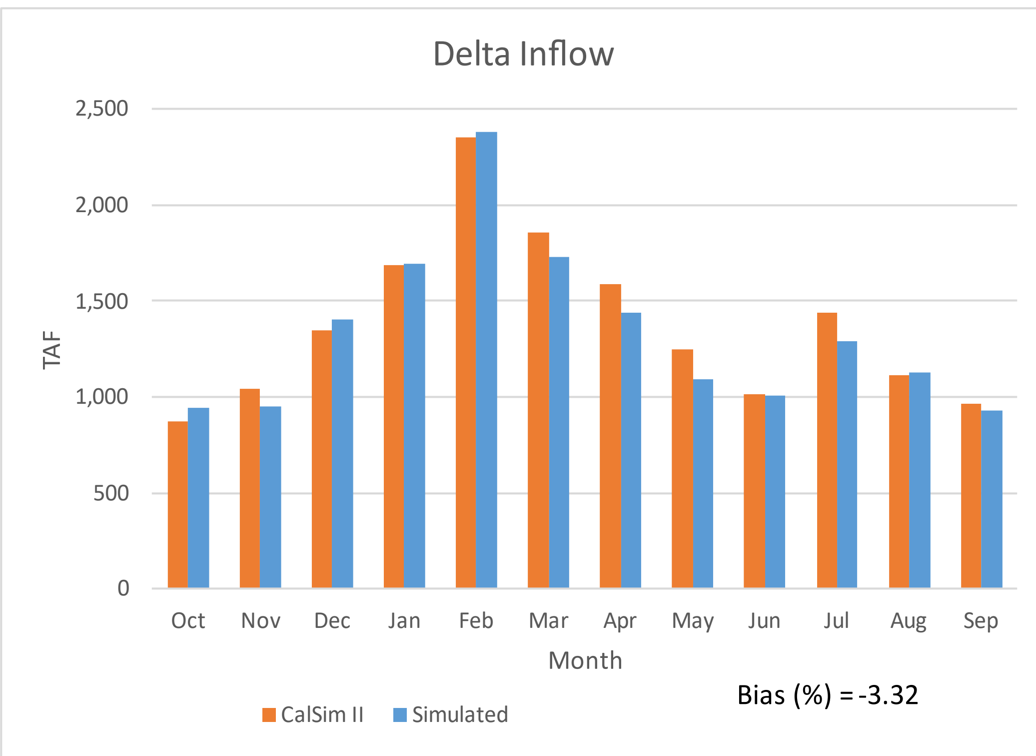


Figure A.6.9g. Delta Inflow, Average Monthly (Below Normal)

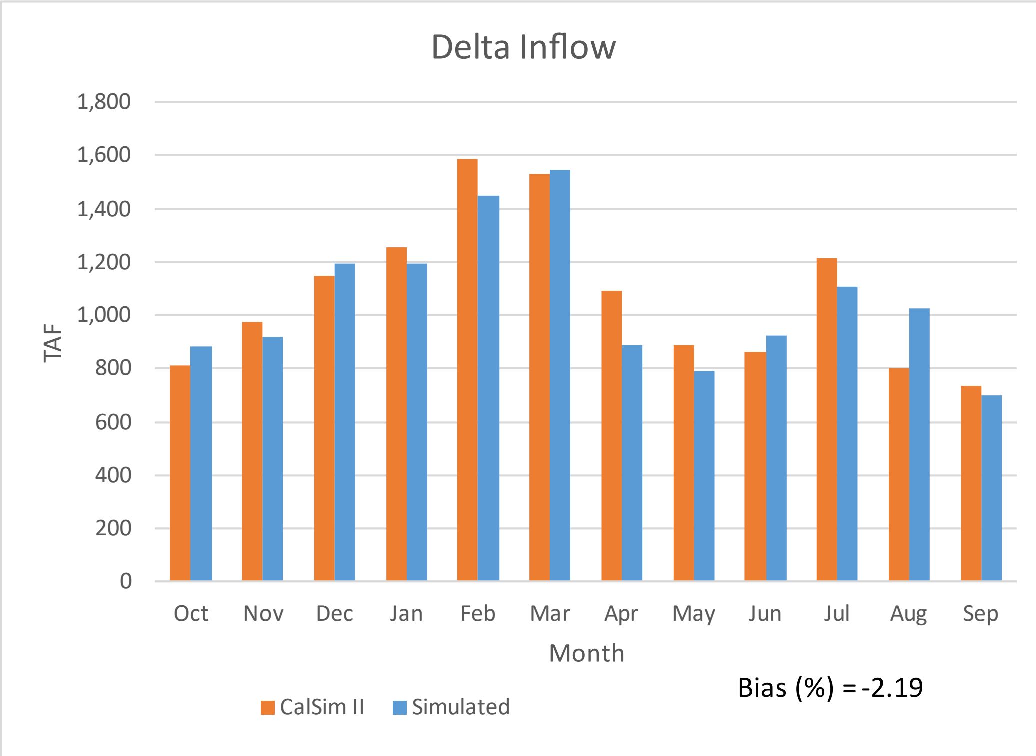


Figure A.6.9h. Delta Inflow, Average Monthly (Dry)

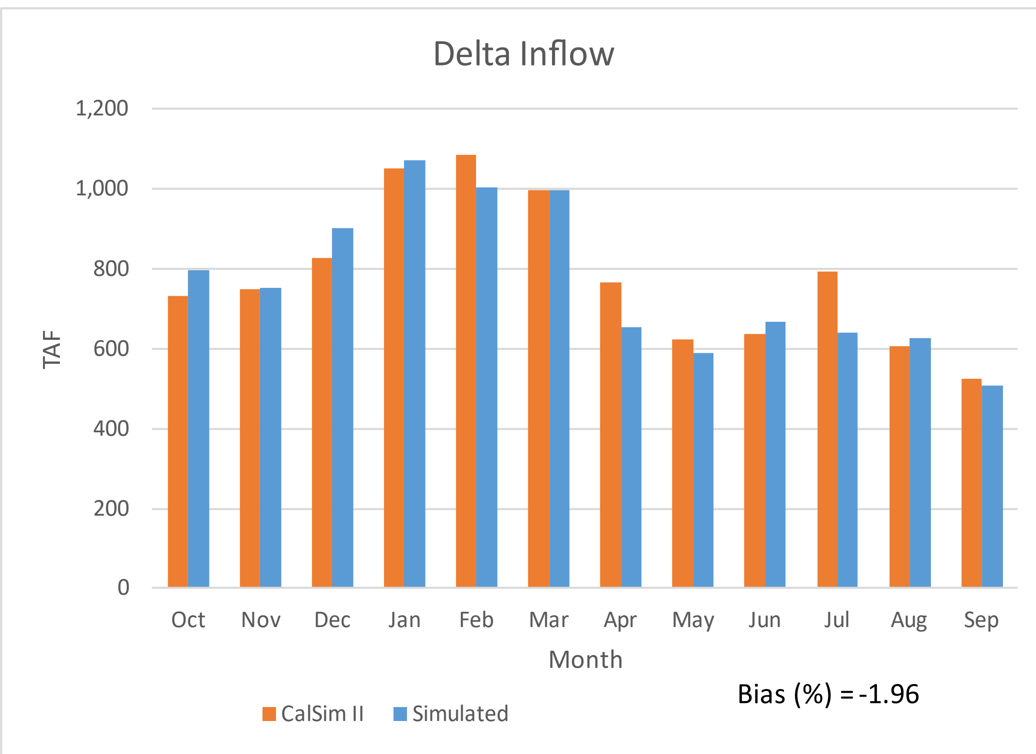


Figure A.6.9i. Delta Inflow, Average Monthly (Critical)

A.6.10 CVP Delta Exports

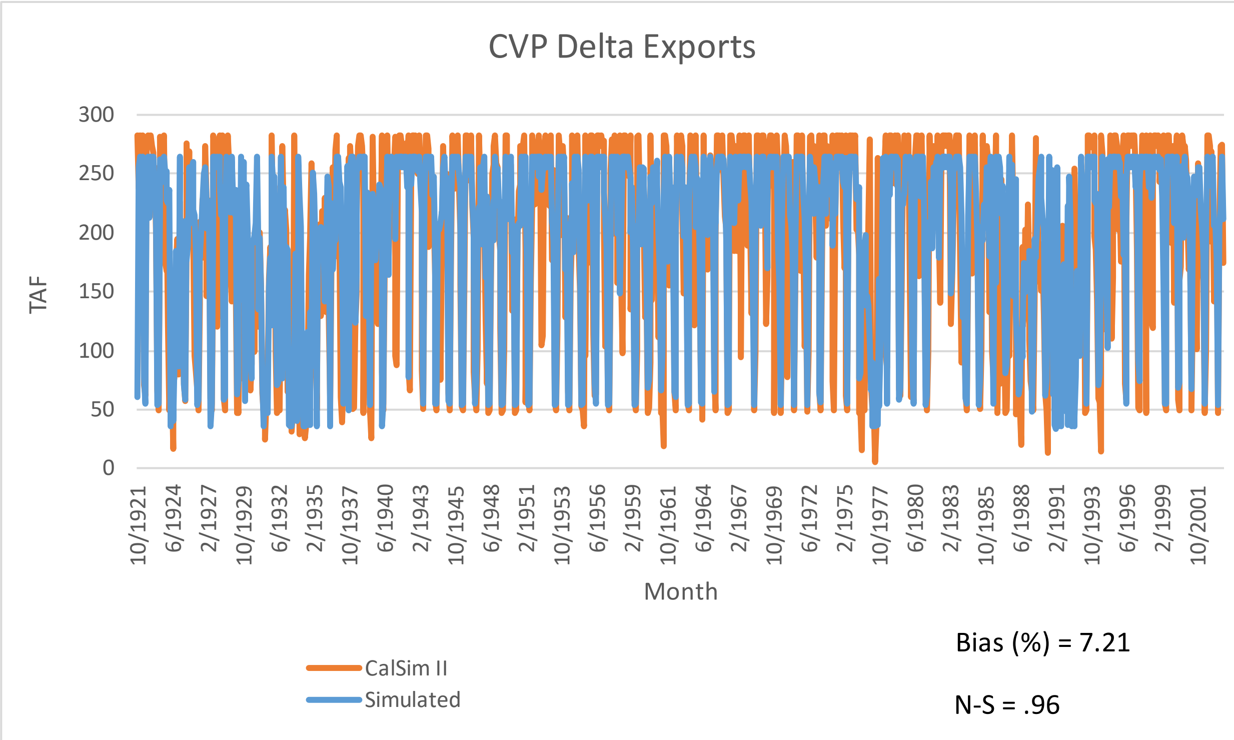


Figure A.6.10a. CVP Delta Exports, Monthly 1922 to 2003

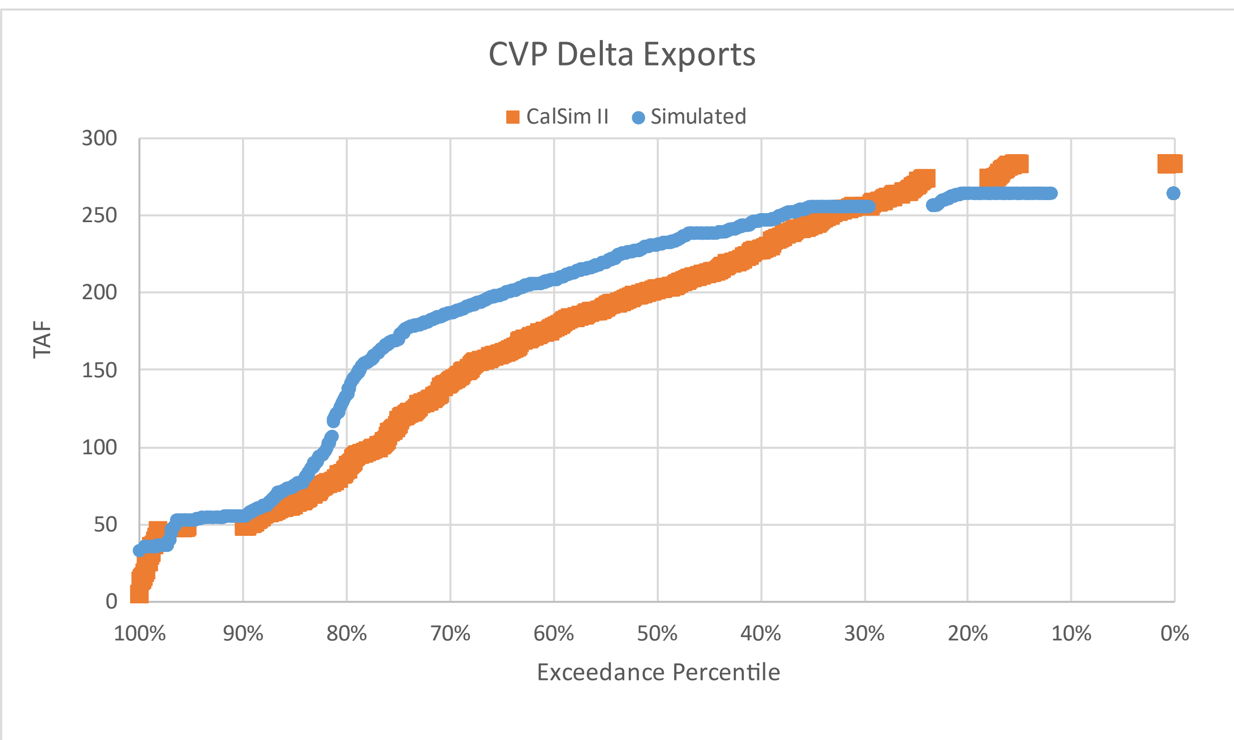


Figure A.6.10b. CVP Delta Exports, Exceedance

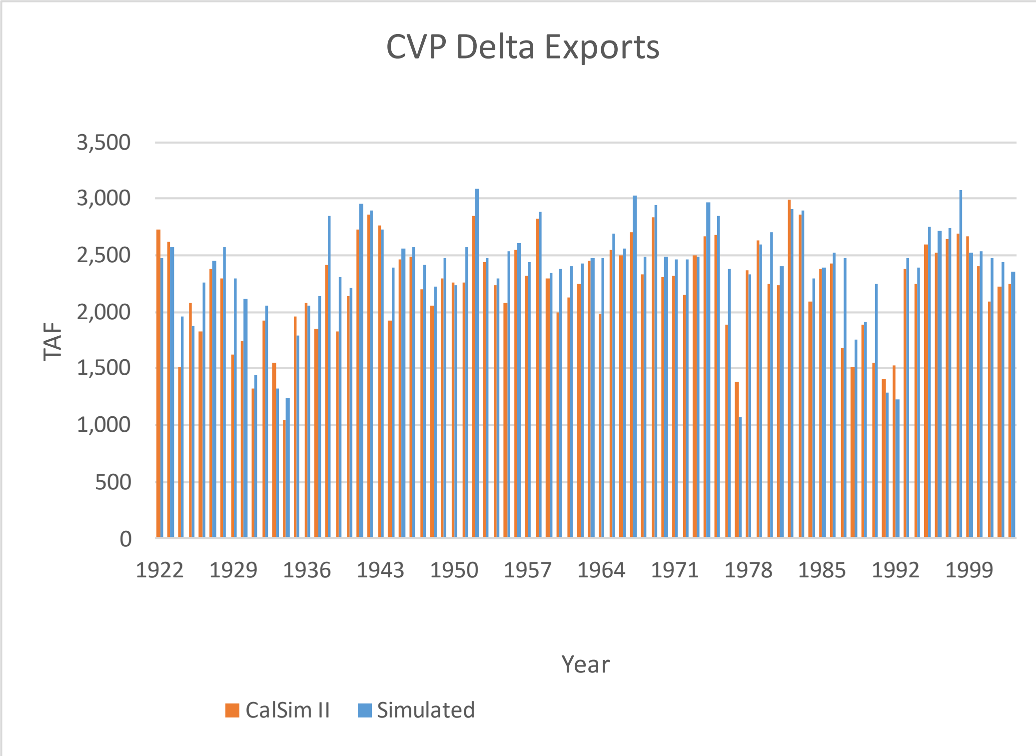


Figure A.6.10c. CVP Delta Exports, Annual 1922 to 2003

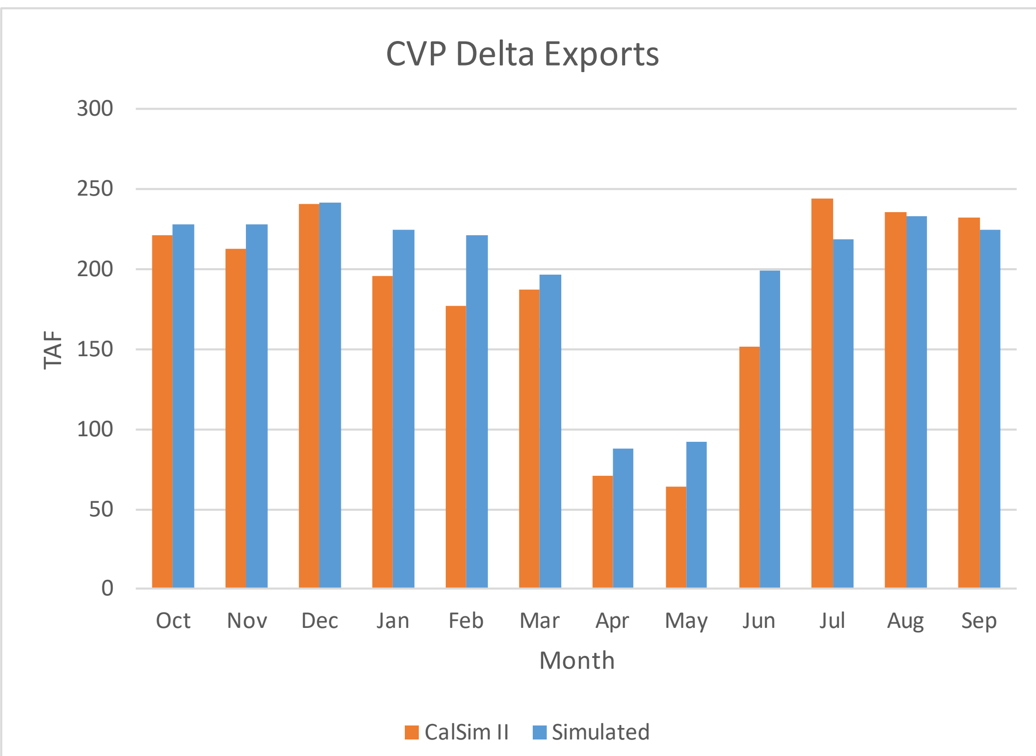


Figure A.6.10d. CVP Delta Exports, Average Monthly

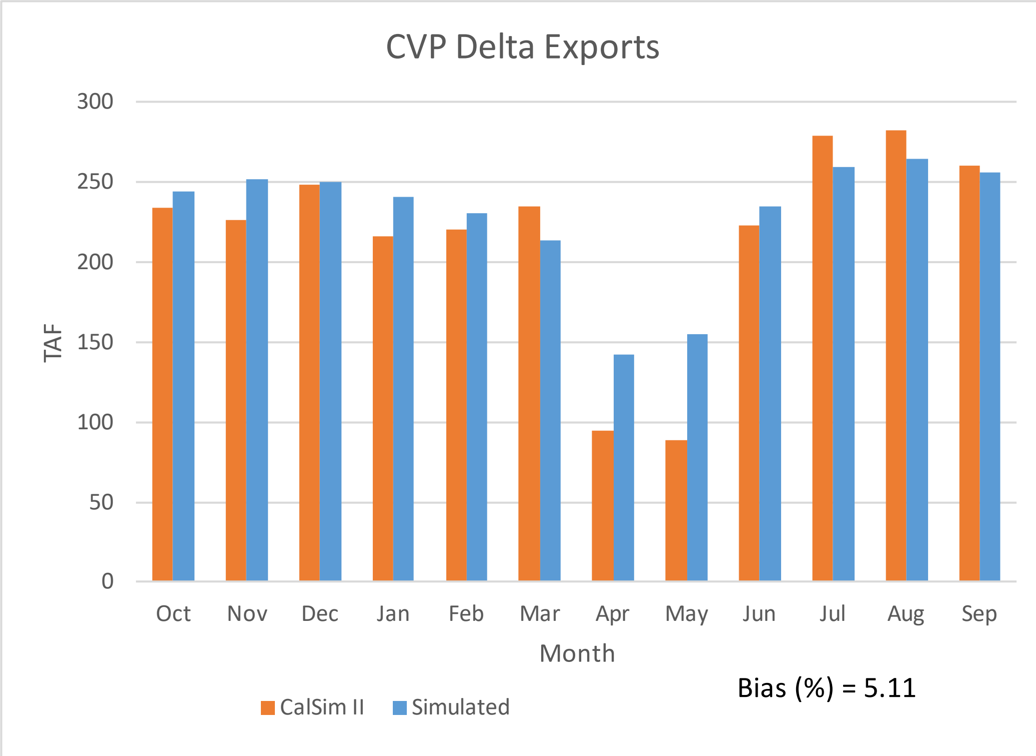


Figure A.6.10e. CVP Delta Exports, Average Monthly (Wet)

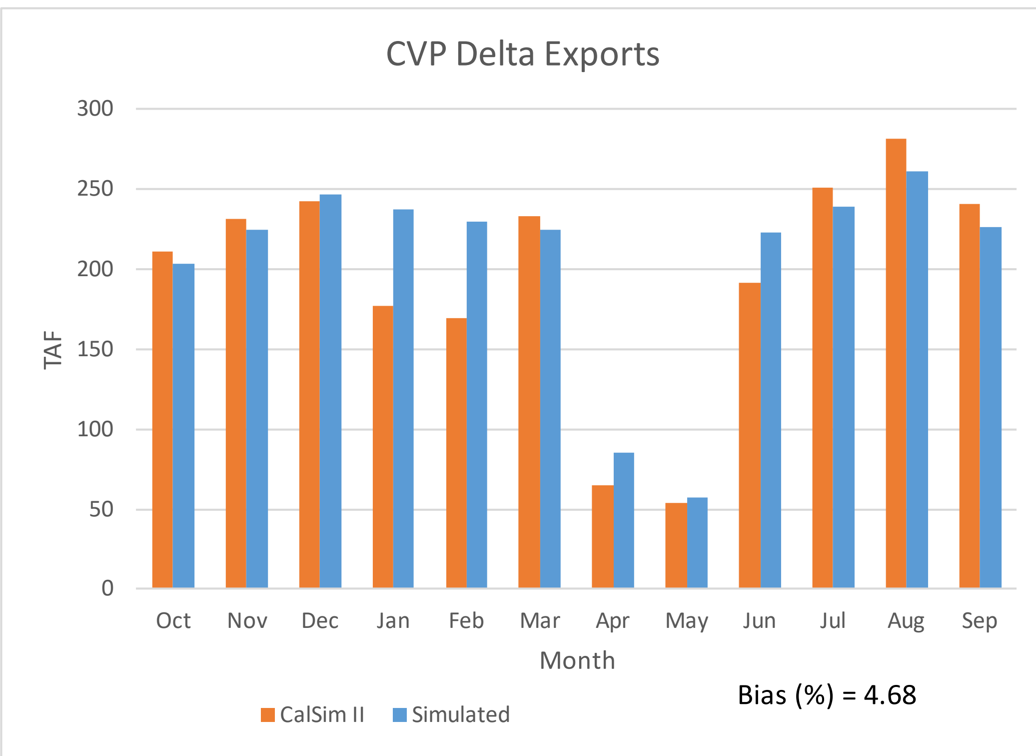


Figure A.6.10f. CVP Delta Exports, Average Monthly (Above Normal)

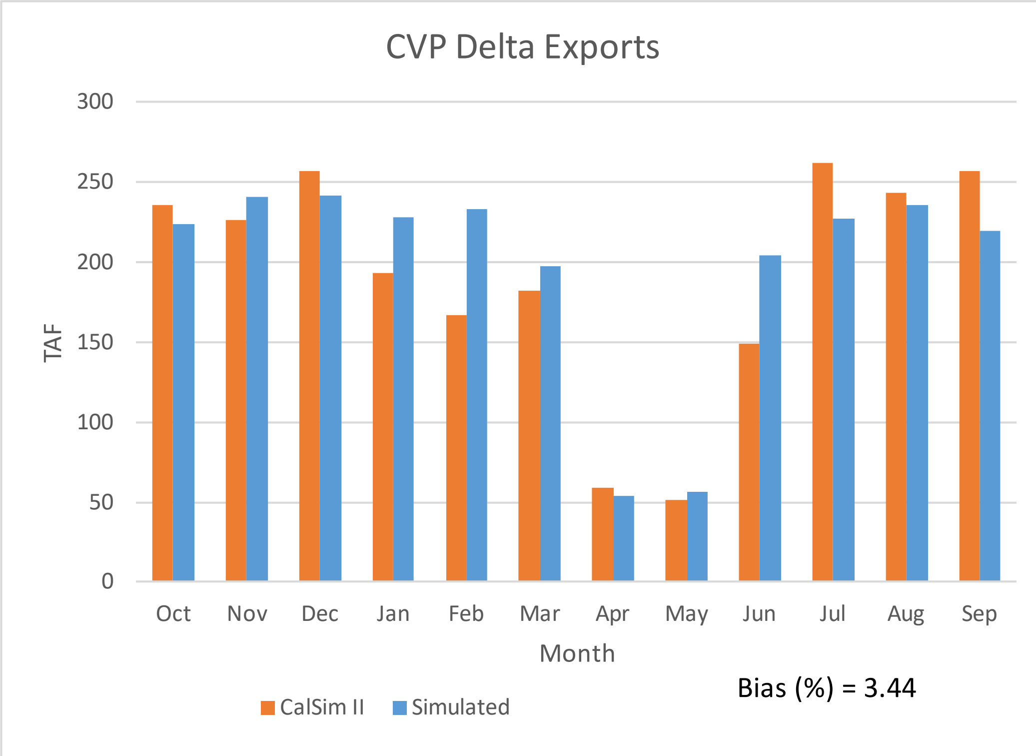


Figure A.6.10g. CVP Delta Exports, Average Monthly (Below Normal)

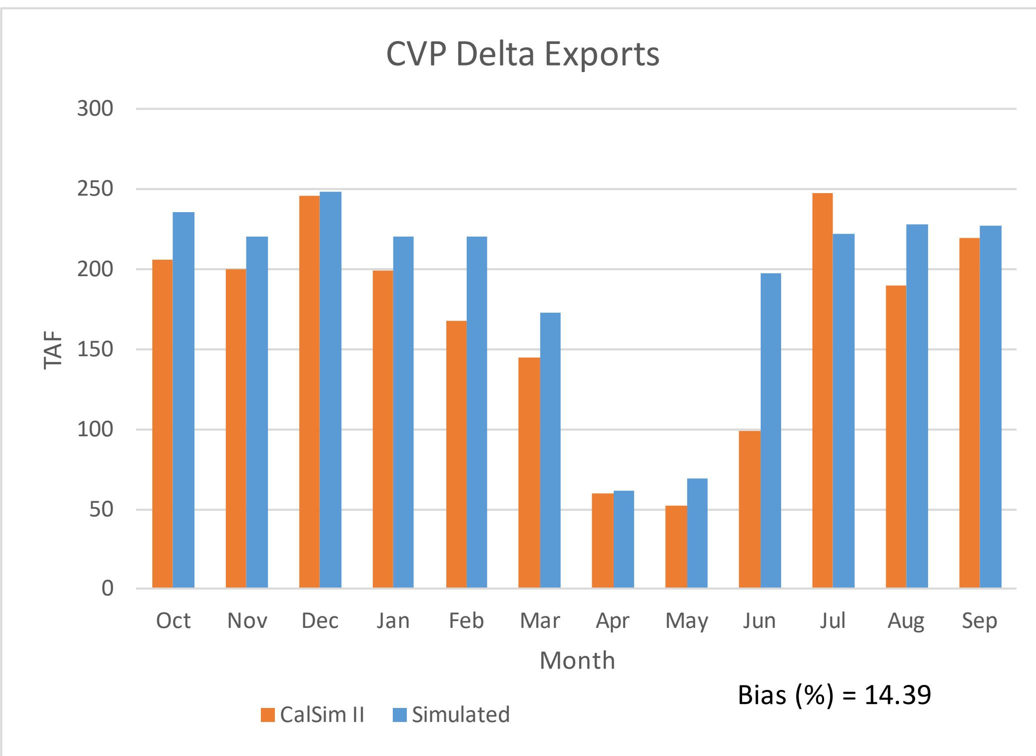


Figure A.6.10h. CVP Delta Exports, Average Monthly (Dry)

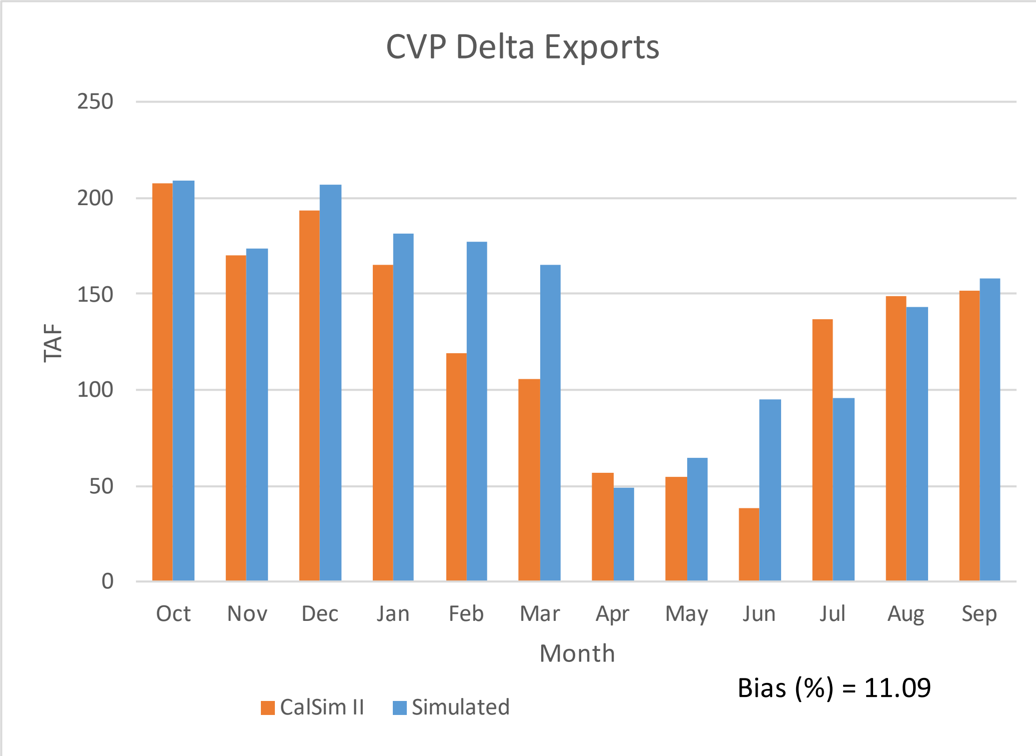


Figure A.6.10i. CVP Delta Exports, Average Monthly (Critical)

A.6.11 SWP Delta Exports

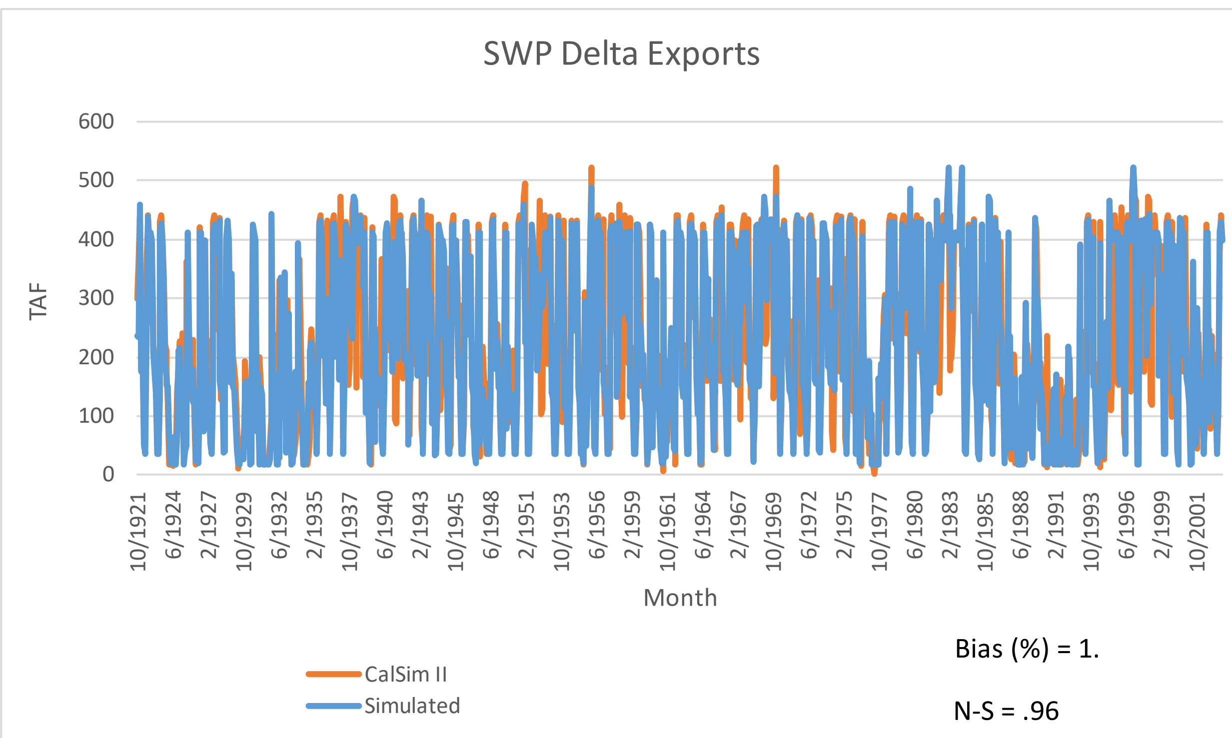


Figure A.6.11a. SWP Delta Exports, Monthly 1922 to 2003

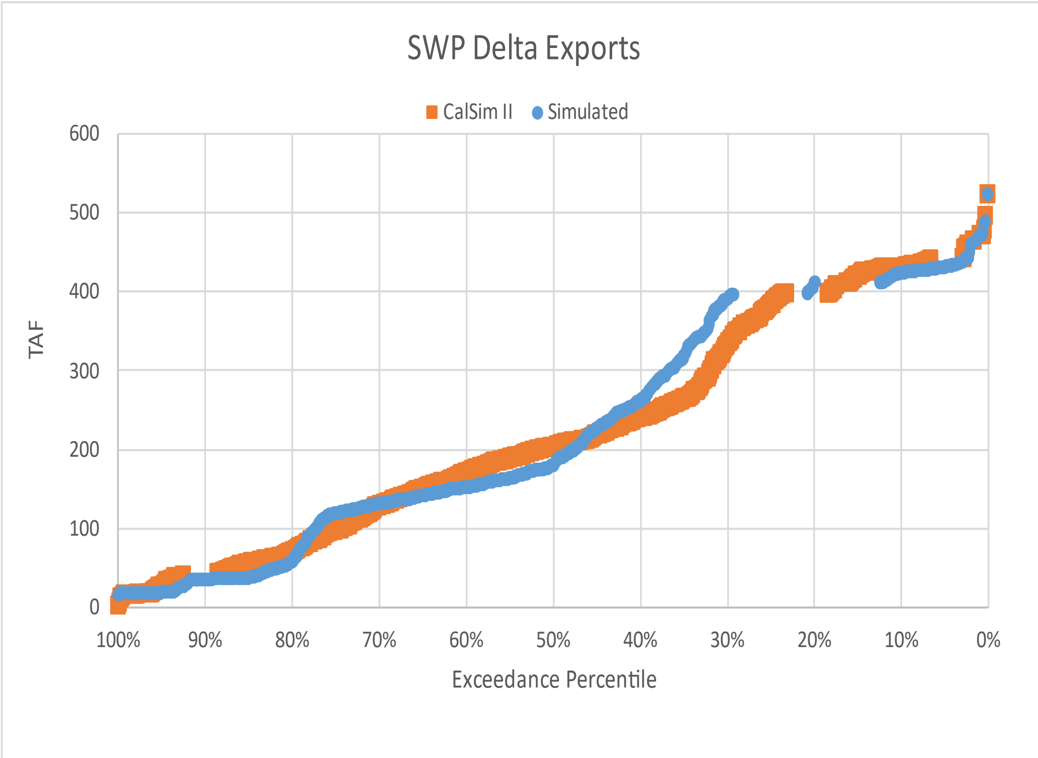


Figure A.6.11b. SWP Delta Exports, Exceedance

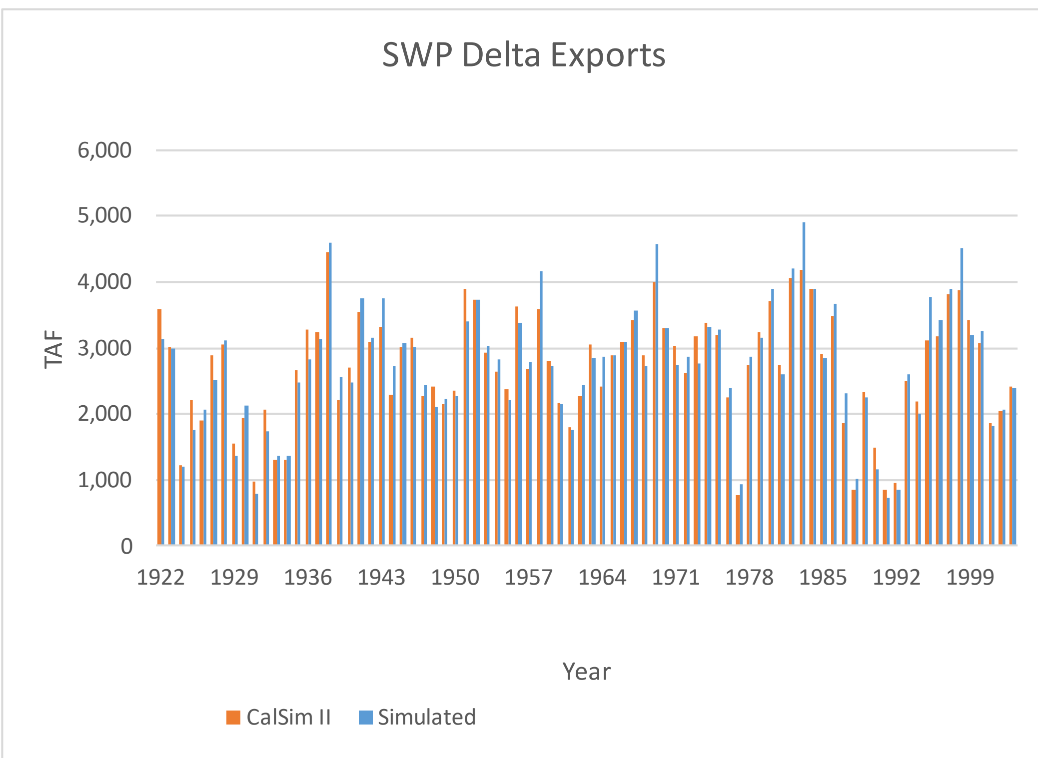


Figure A.6.11c. SWP Delta Exports, Annual 1922 to 2003

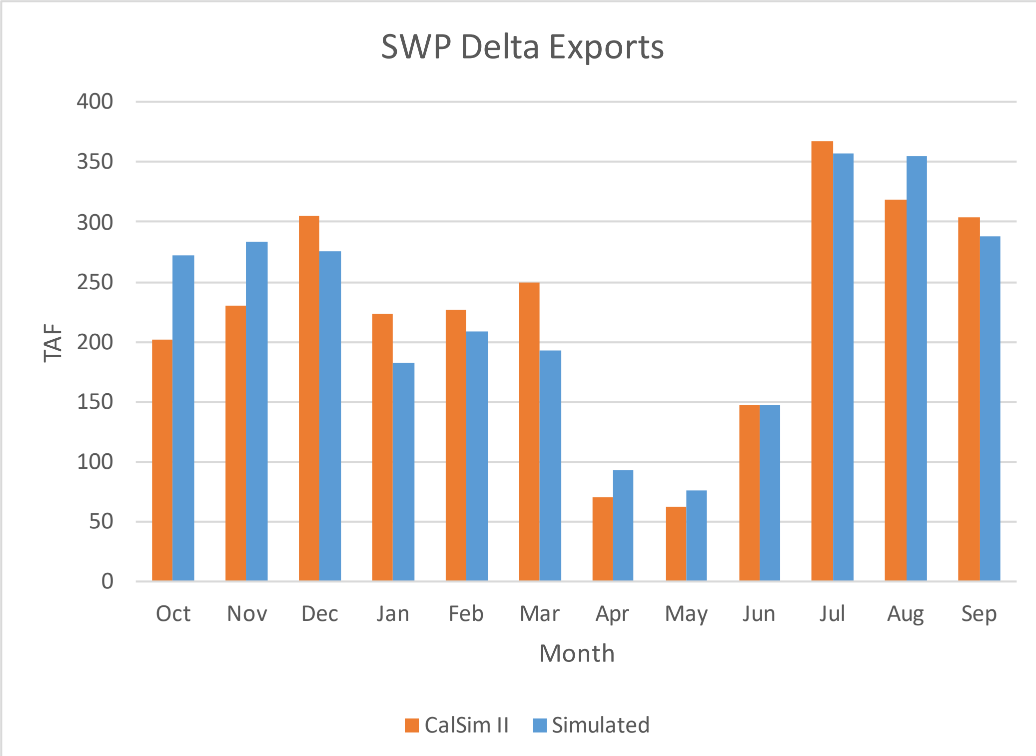


Figure A.6.11d. SWP Delta Exports, Average Monthly

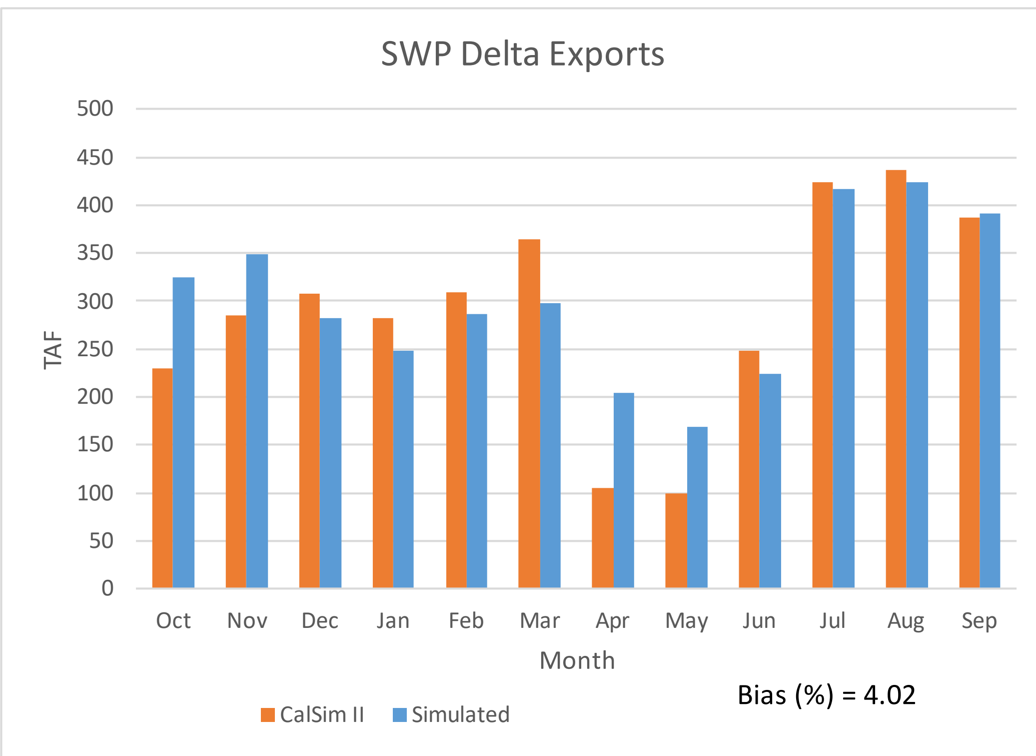


Figure A.6.11e. SWP Delta Exports, Average Monthly (Wet)

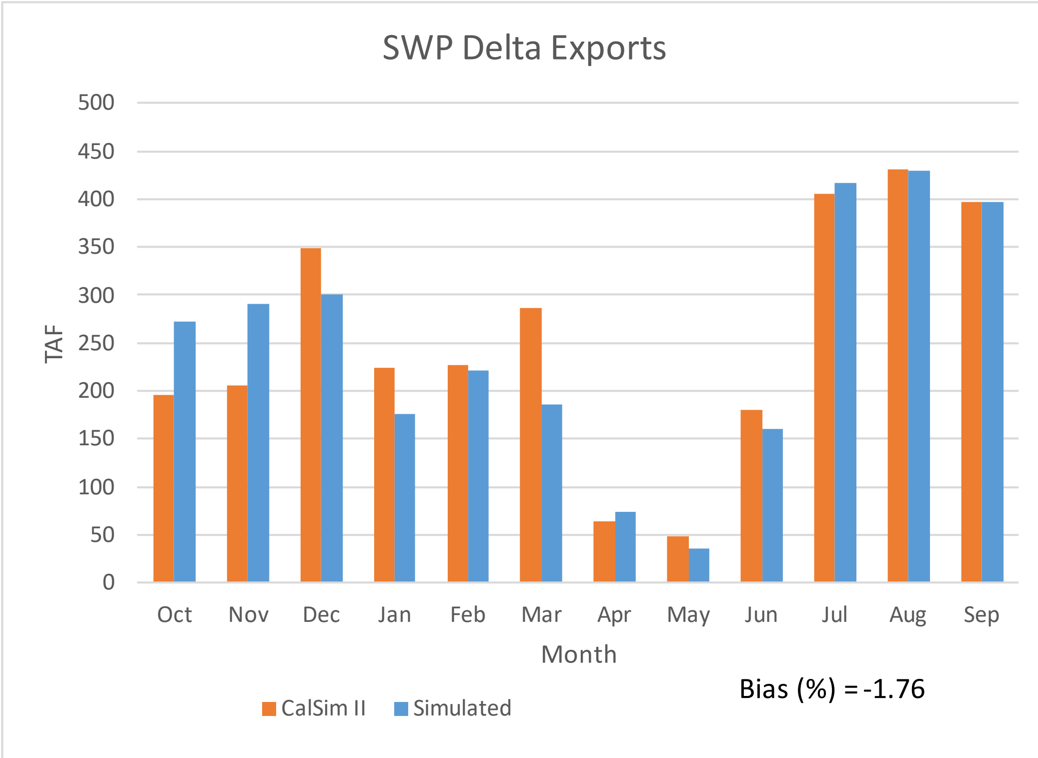


Figure A.6.11f. SWP Delta Exports, Average Monthly (Above Normal)

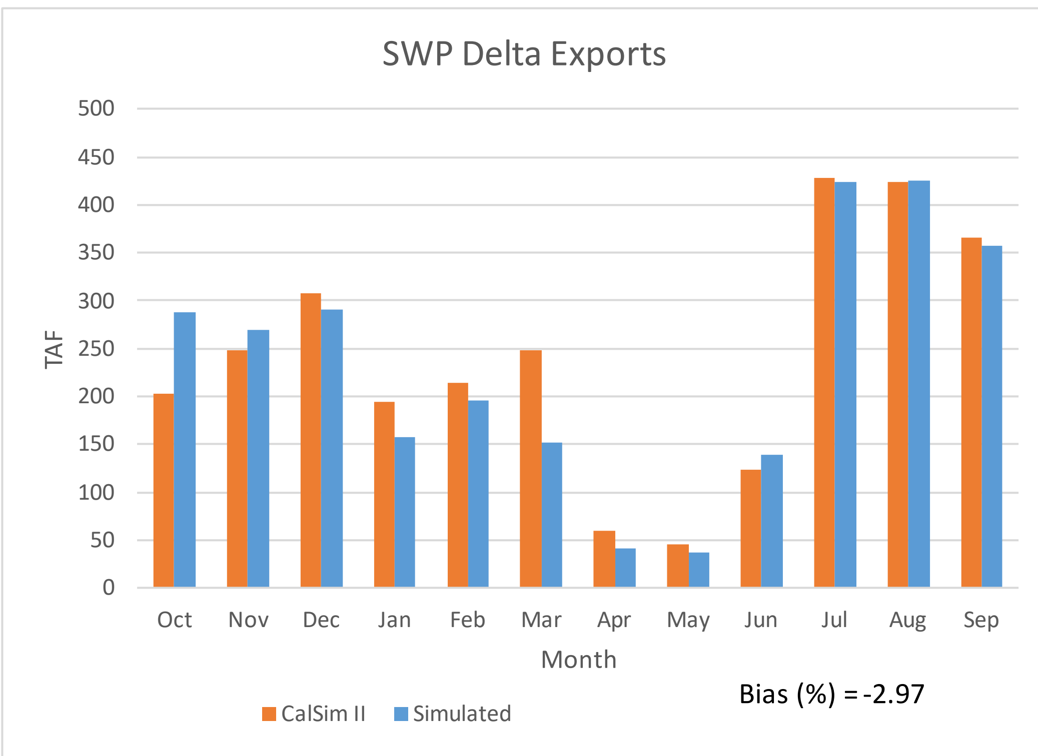


Figure A.6.11g. SWP Delta Exports, Average Monthly (Below Normal)

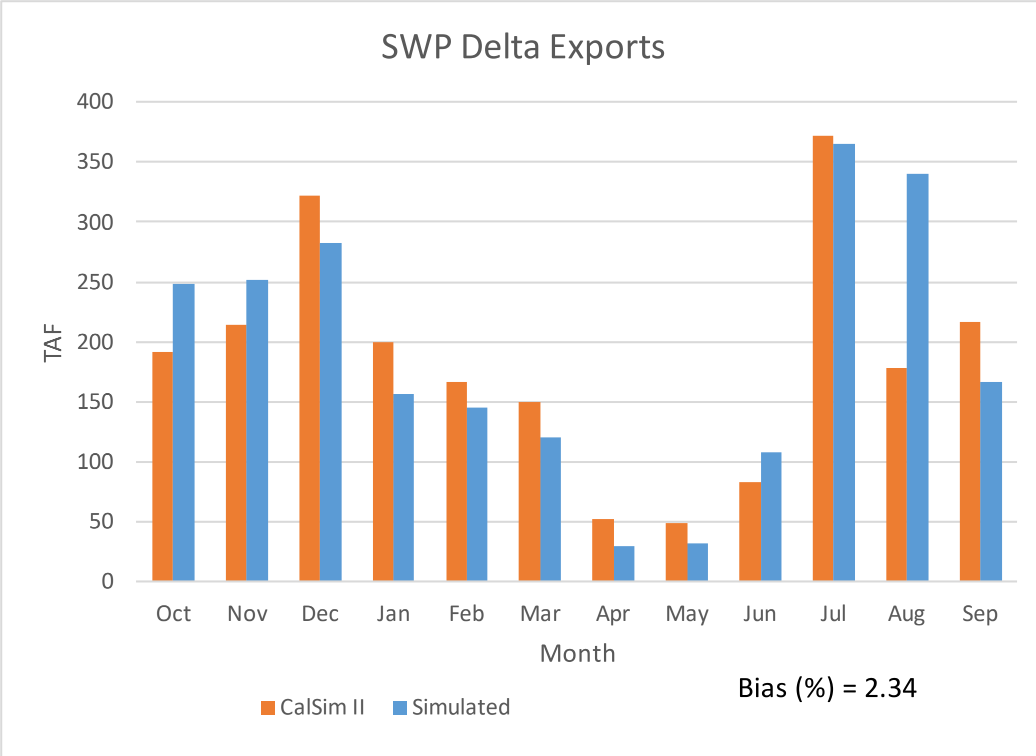


Figure A.6.11h. SWP Delta Exports, Average Monthly (Dry)

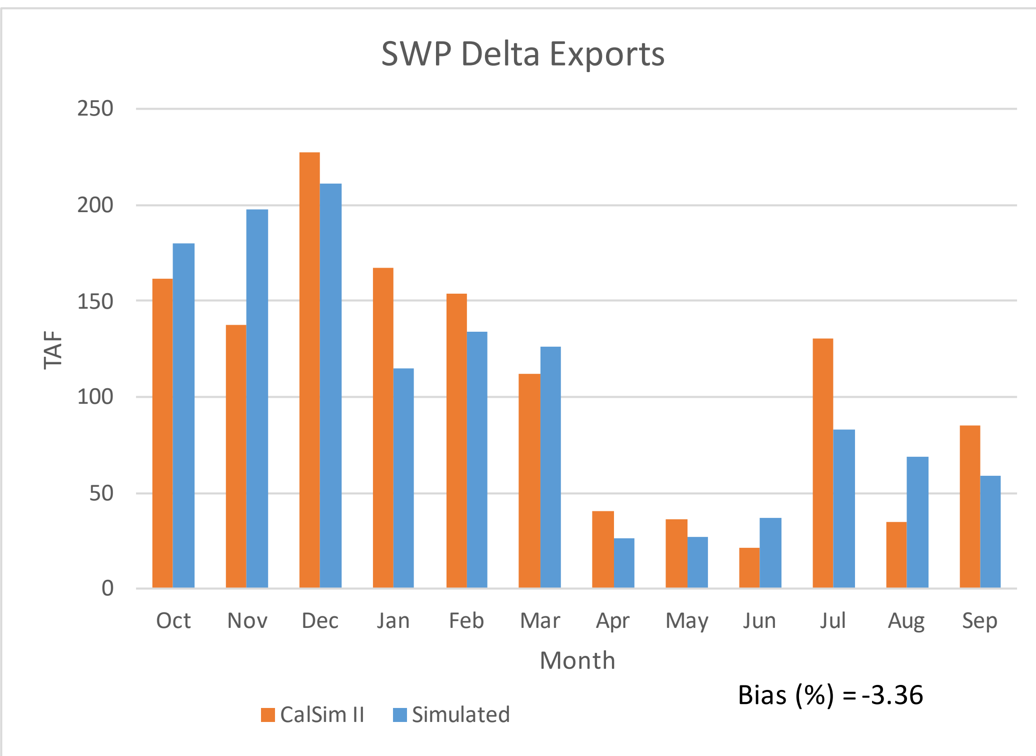


Figure A.6.11i. SWP Delta Exports, Average Monthly (Critical)

A.6.12 Combined Delta Exports

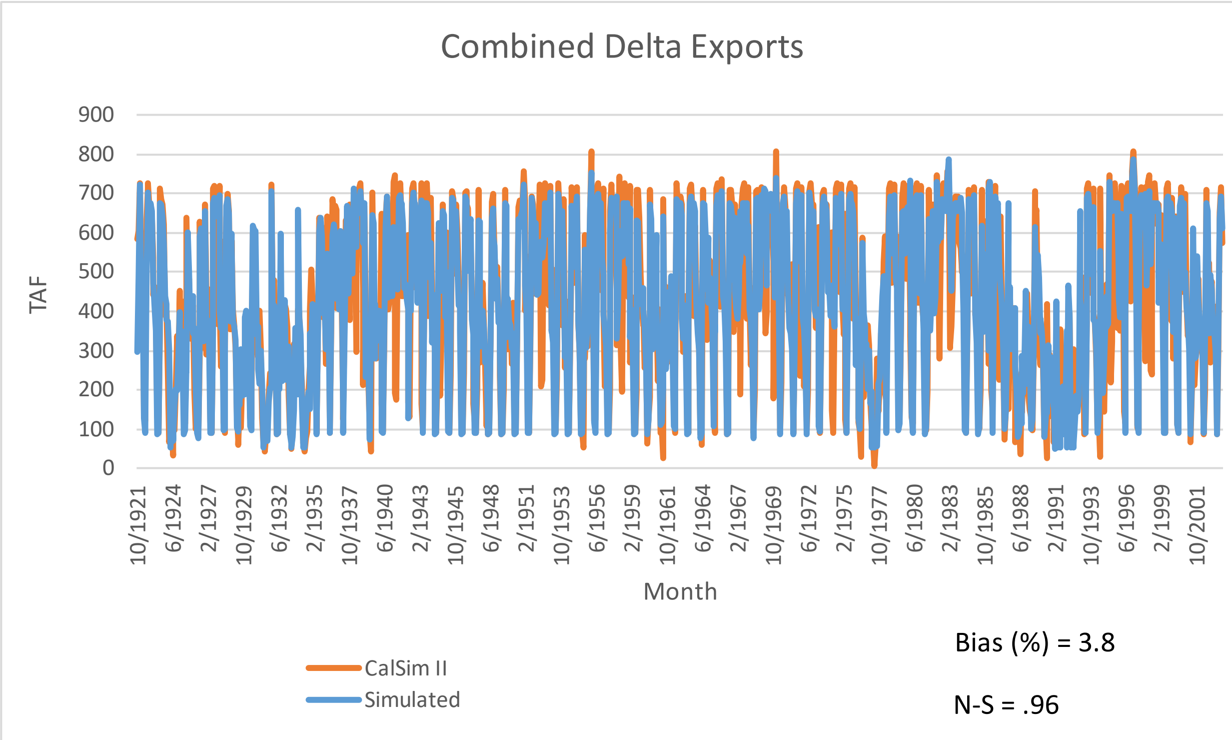


Figure A.6.12a. Combined Delta Exports, Monthly 1922 to 2003

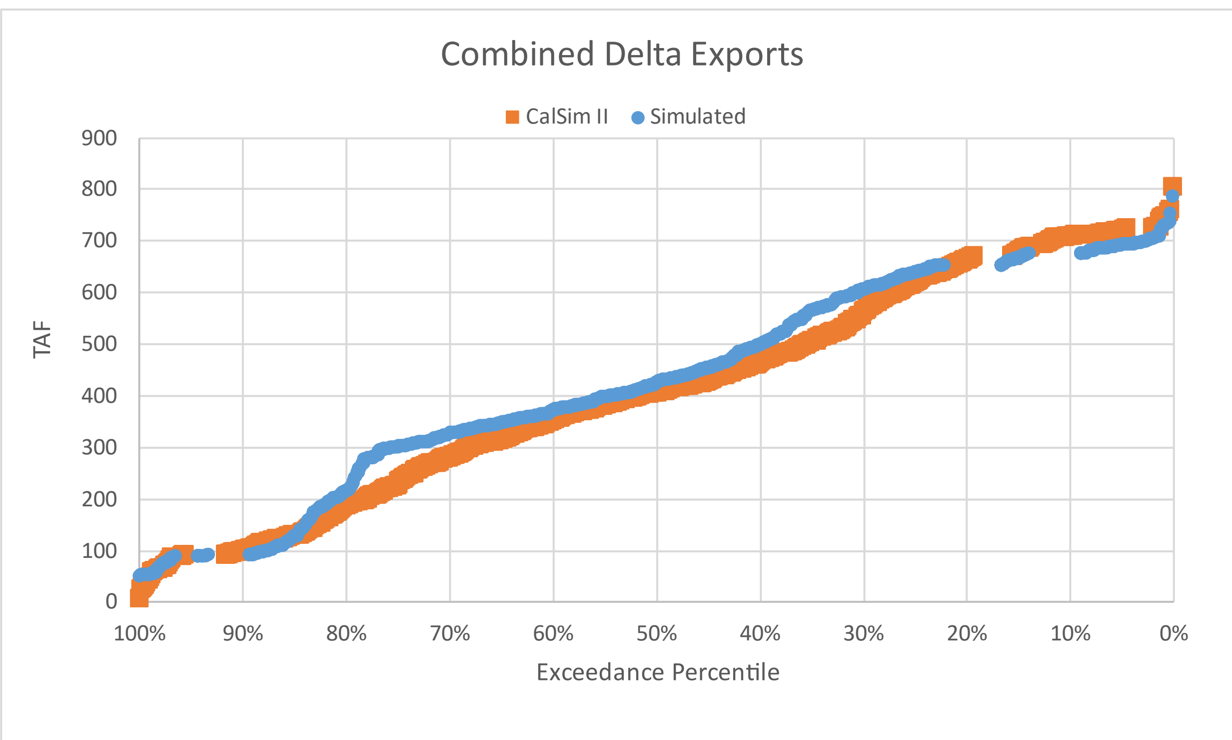


Figure A.6.12b. Combined Delta Exports, Exceedance

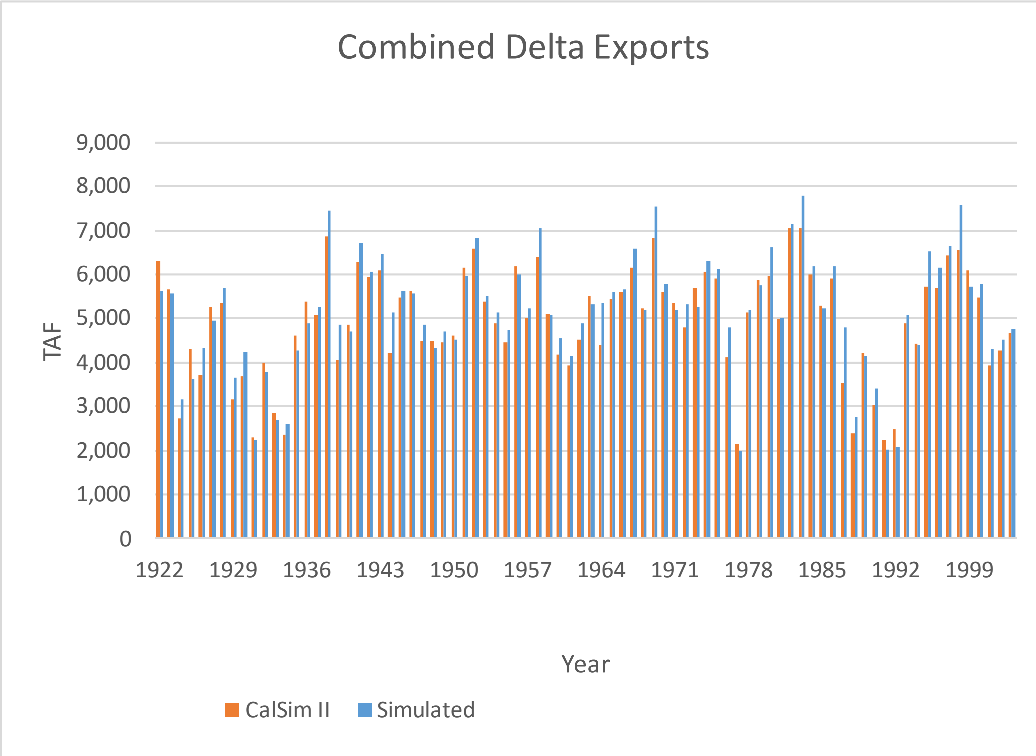


Figure A.6.12c. Combined Delta Exports, Annual 1922 to 2003

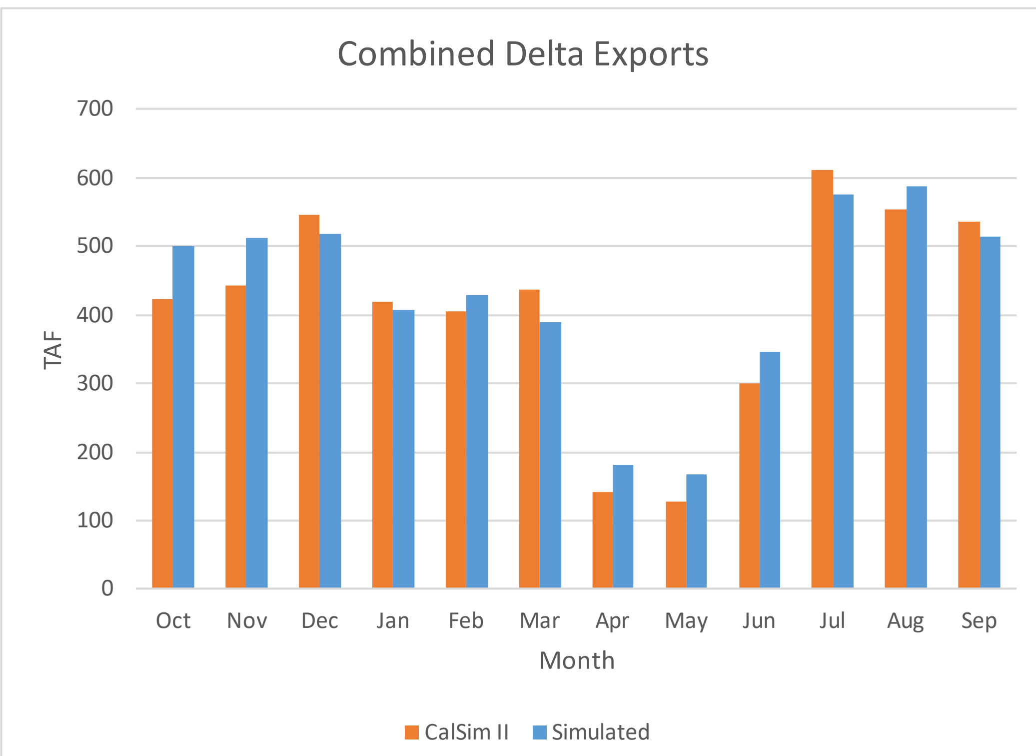


Figure A.6.12d. Combined Delta Exports, Average Monthly

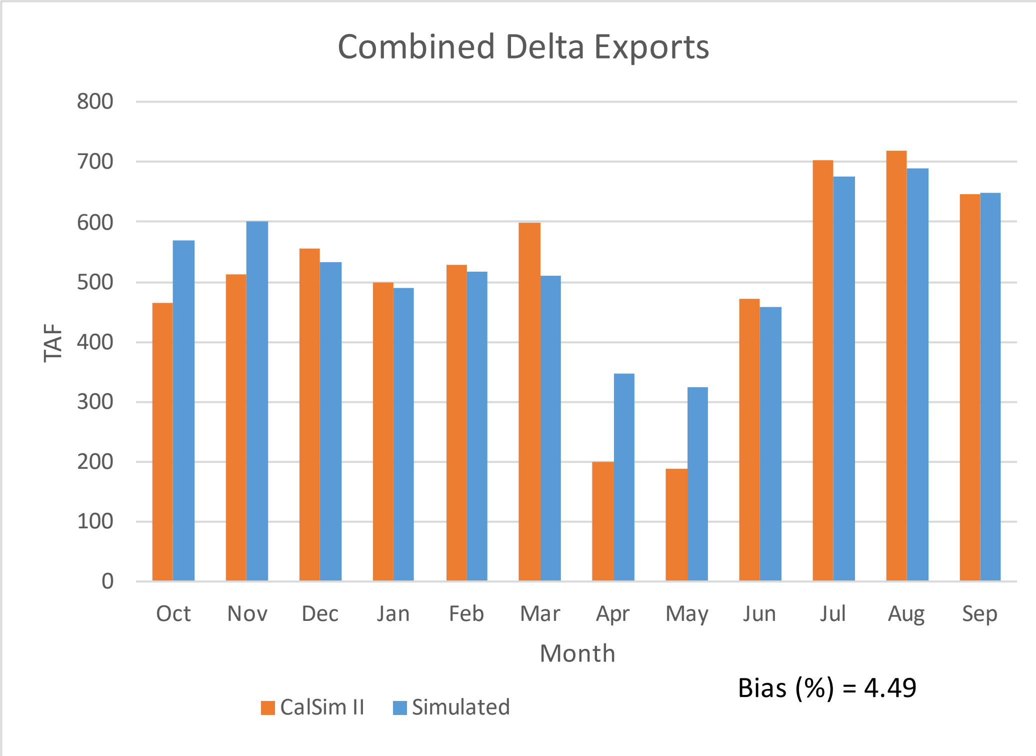


Figure A.6.12e. Combined Delta Exports, Average Monthly (Wet)

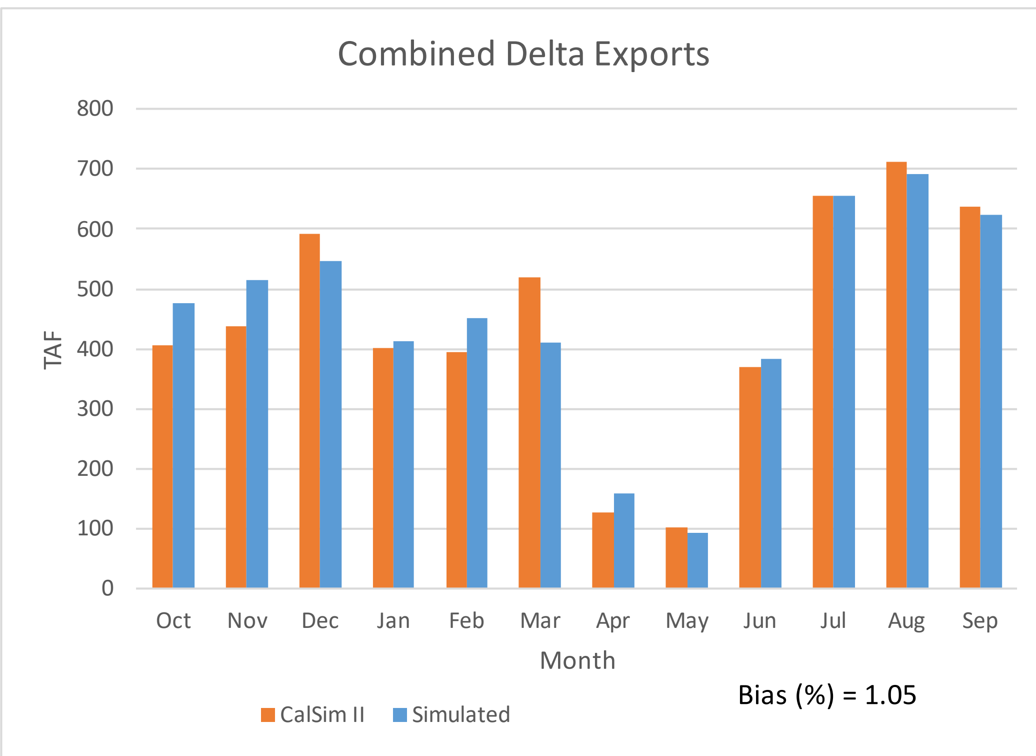


Figure A.6.12f. Combined Delta Exports, Average Monthly (Above Normal)

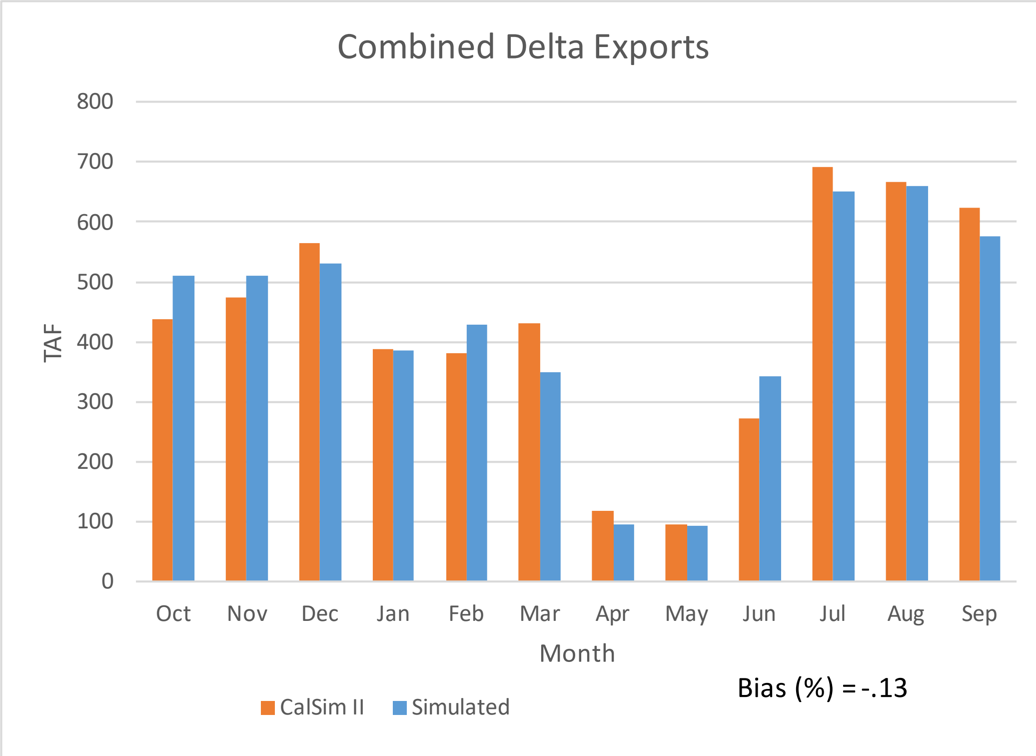


Figure A.6.12g. Combined Delta Exports, Average Monthly (Below Normal)

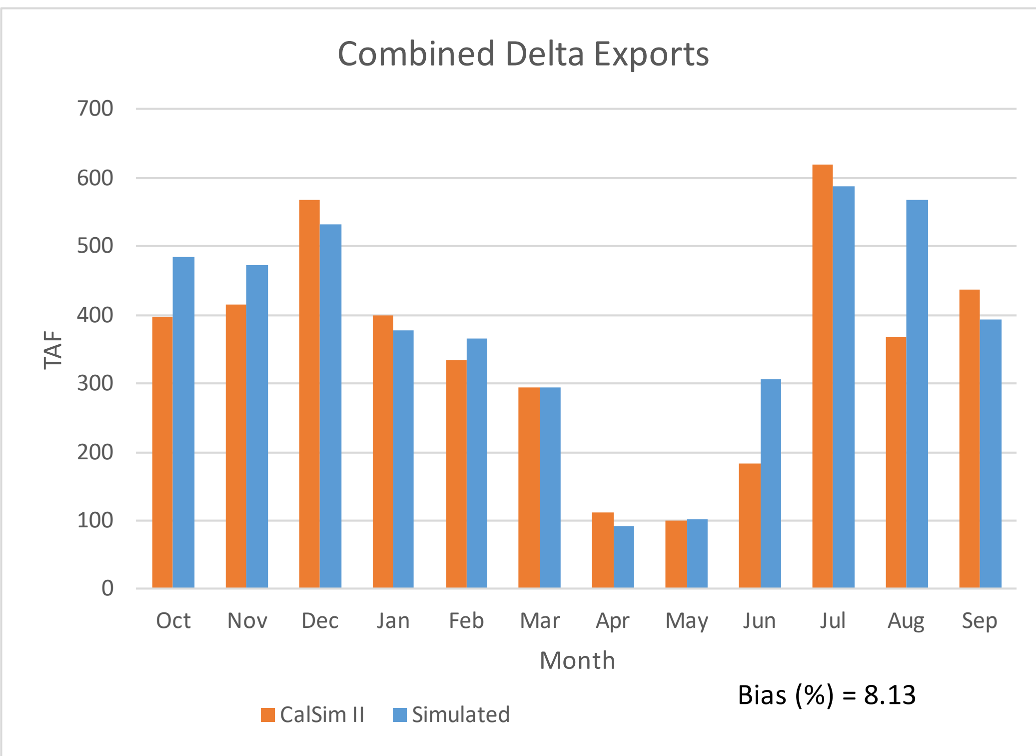


Figure A.6.12h. Combined Delta Exports, Average Monthly (Dry)

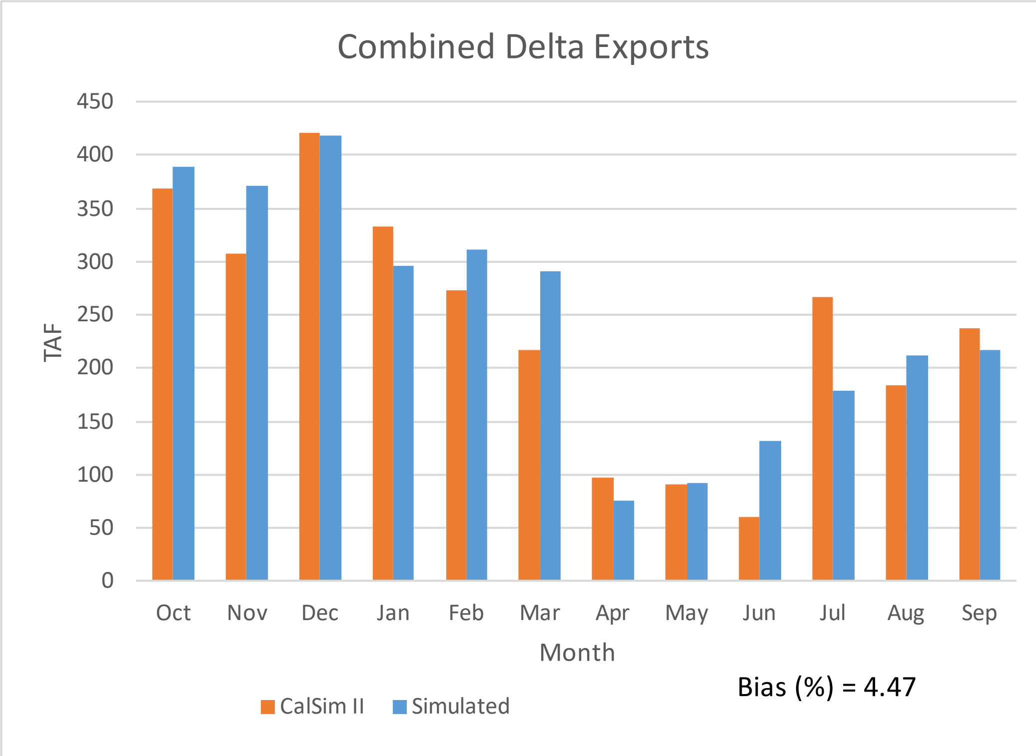


Figure A.6.12i. Combined Delta Exports, Average Monthly (Critical)

A.6.13 Required Delta Outflow (Salinity, X2, MRDO)

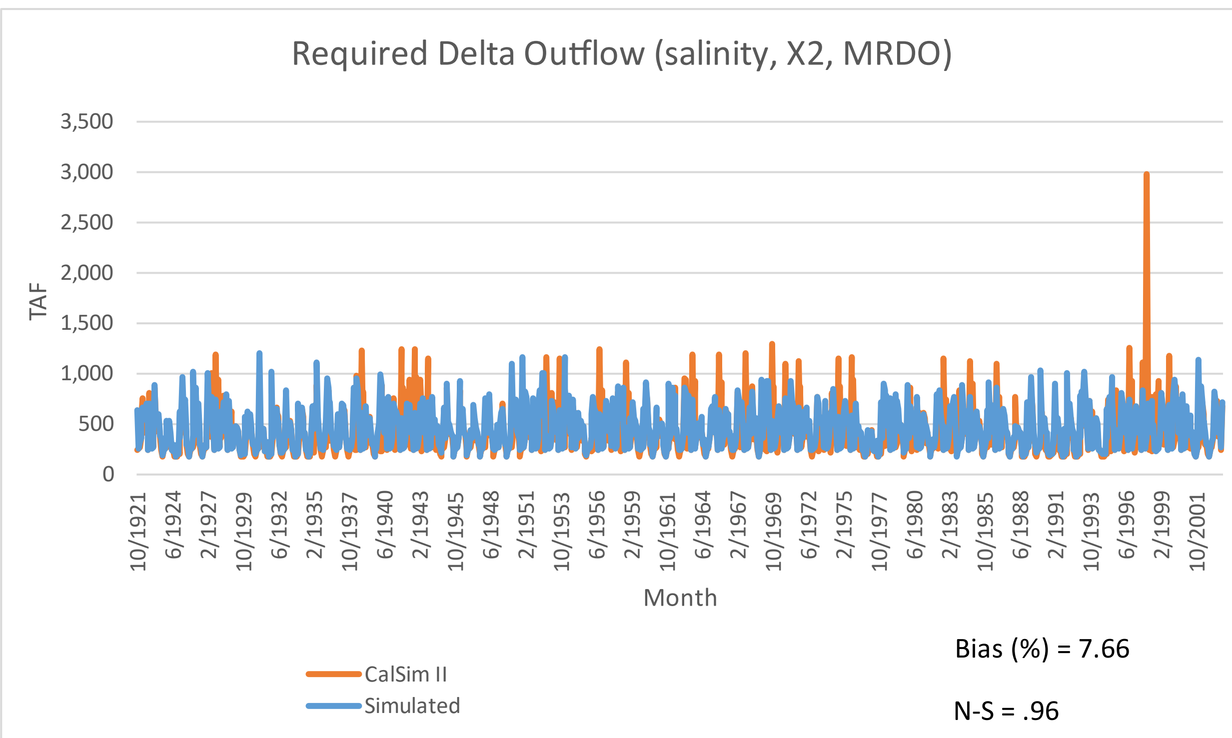


Figure A.6.13a. Required Delta Outflow (salinity, X2, MRDO), Monthly 1922 to 2003

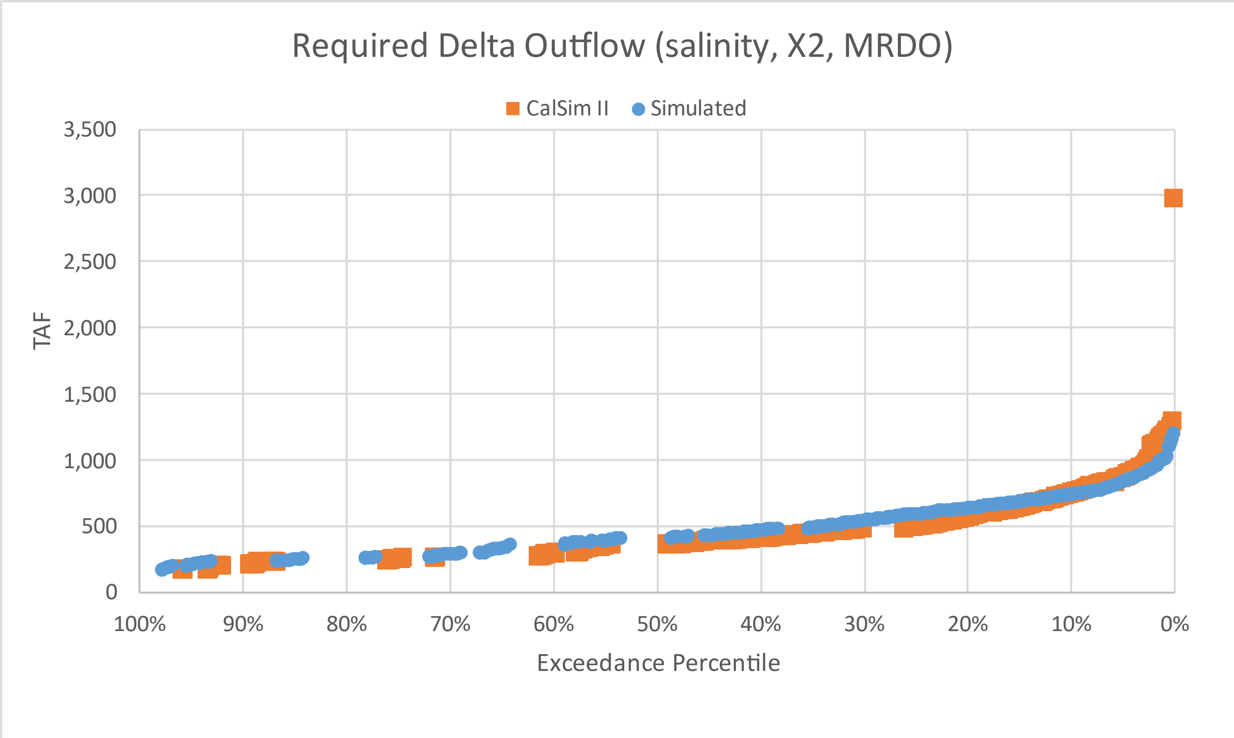


Figure A.6.13b. Required Delta Outflow (salinity, X2, MRDO), Exceedance

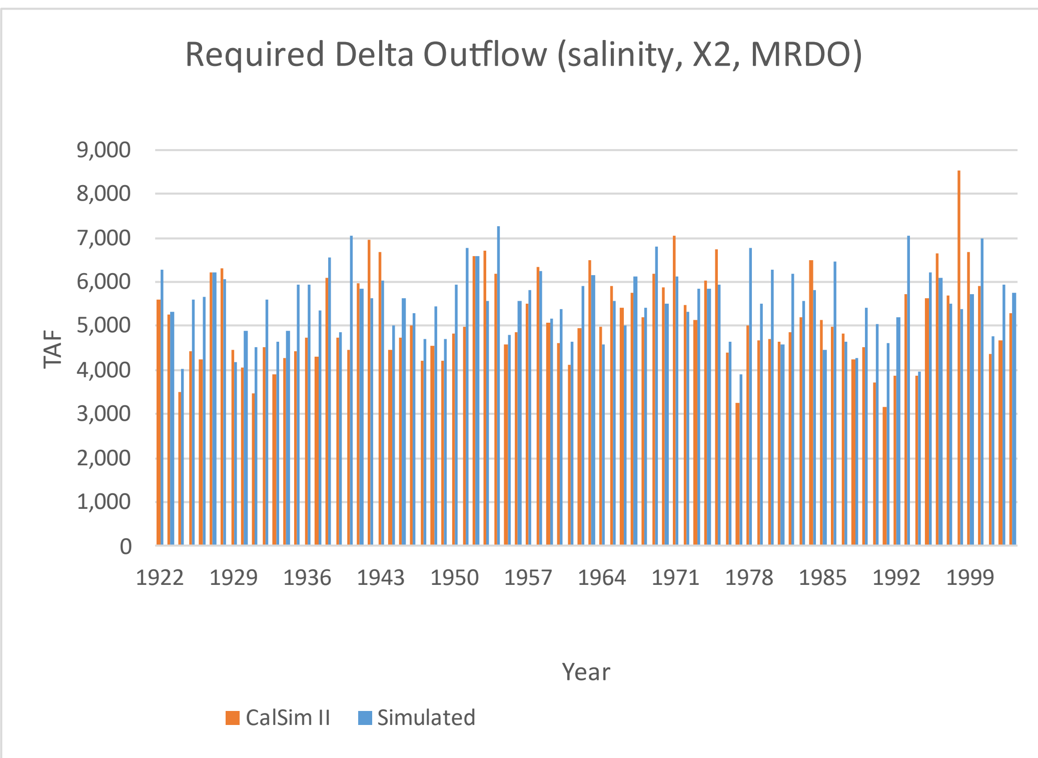


Figure A.6.13c. Required Delta Outflow (salinity, X2, MRDO), Annual 1922 to 2003

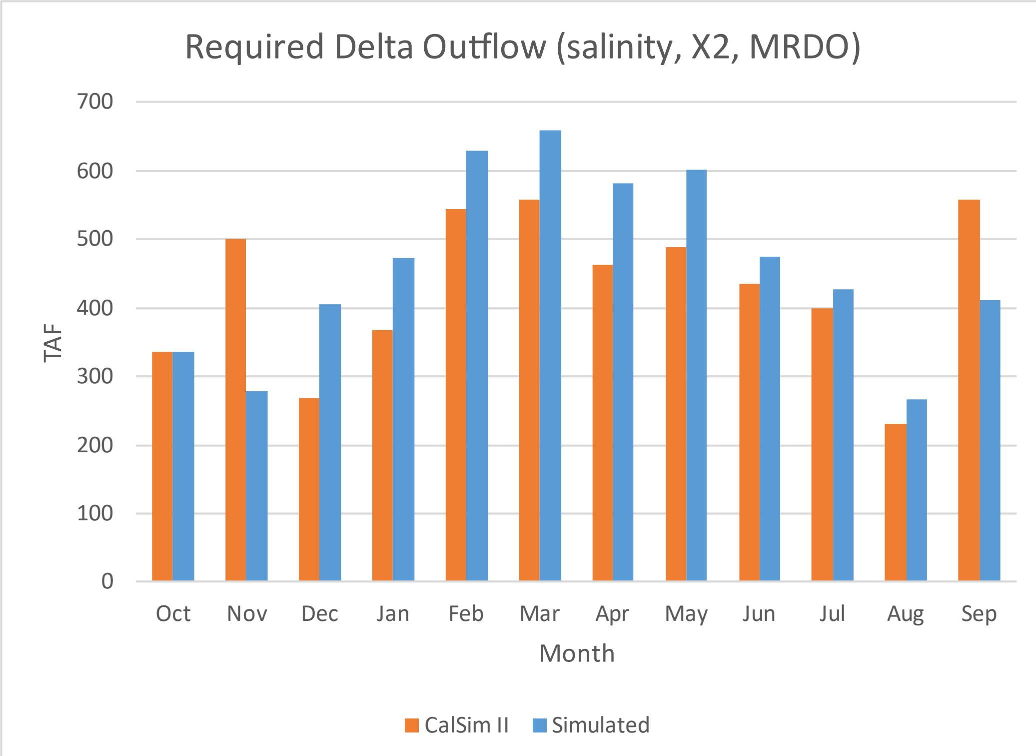


Figure A.6.13d. Required Delta Outflow (salinity, X2, MRDO), Average Monthly

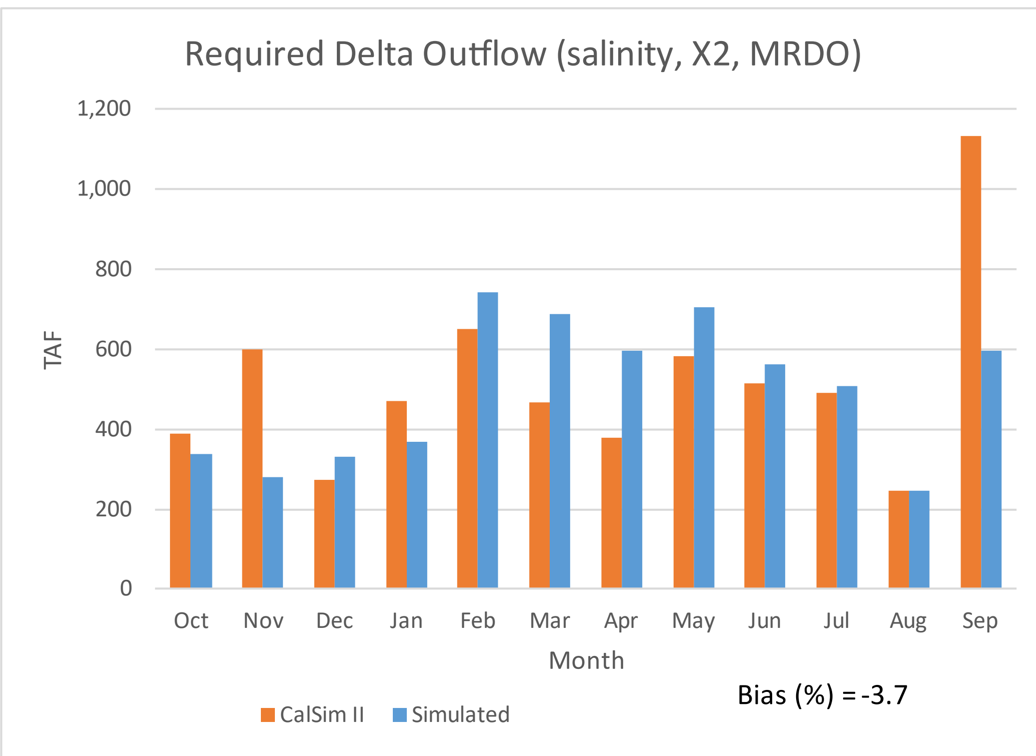


Figure A.6.13e. Required Delta Outflow (salinity, X2, MRDO), Average Monthly (Wet)

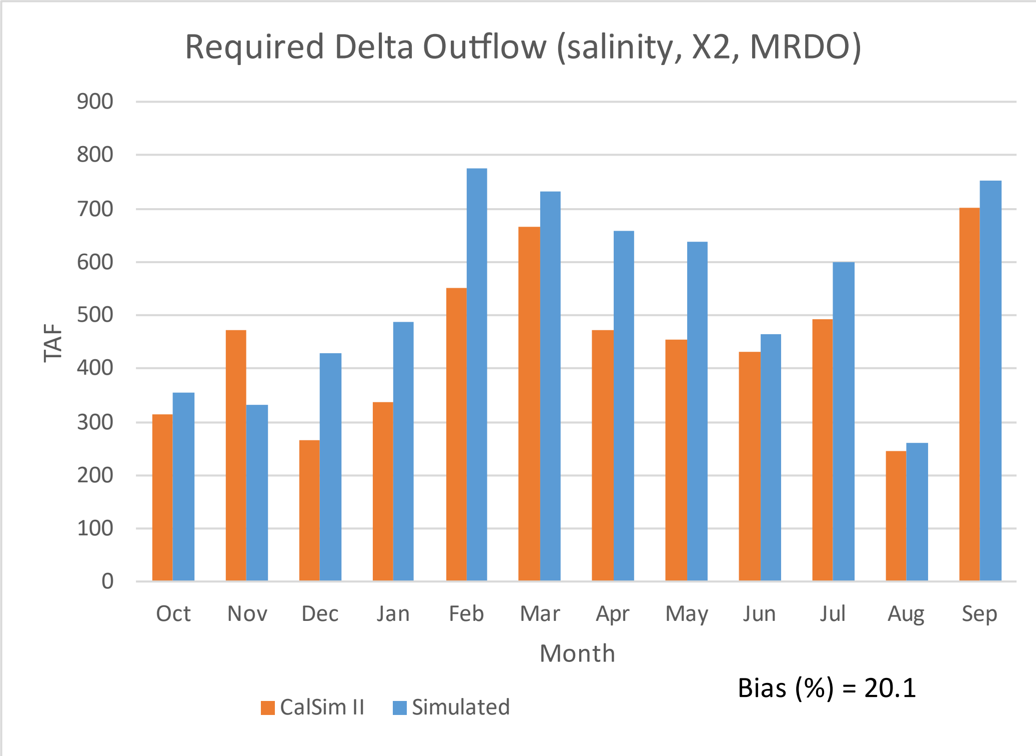


Figure A.6.13f. Required Delta Outflow (salinity, X2, MRDO), Average Monthly (Above Normal)

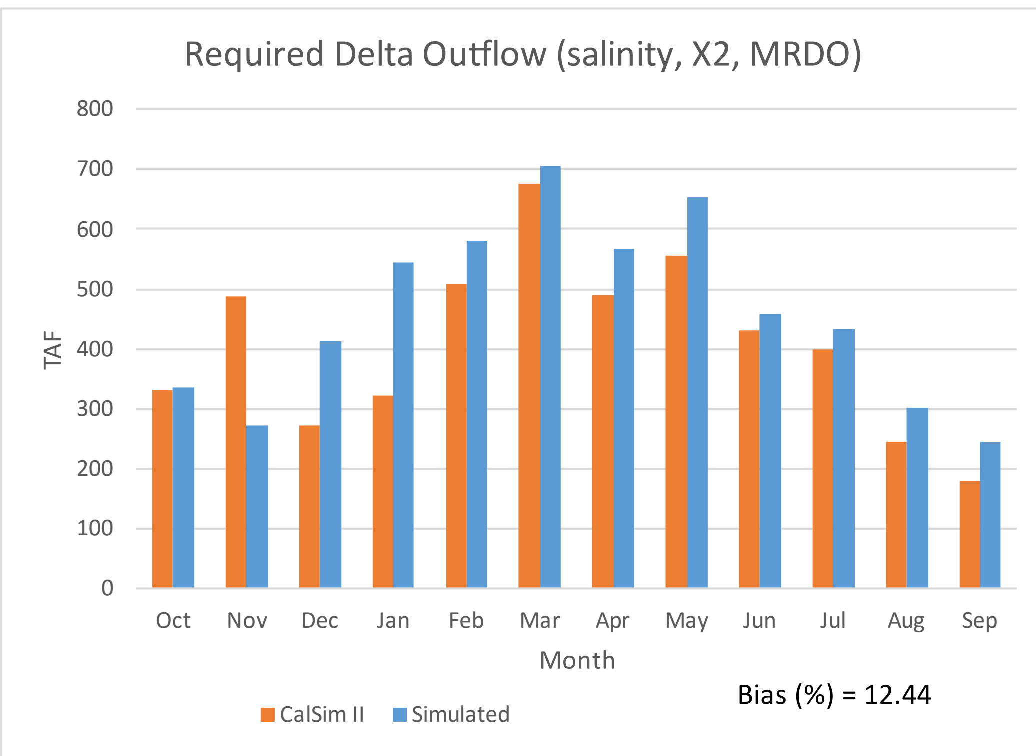


Figure A.6.13g. Required Delta Outflow (salinity, X2, MRDO), Average Monthly (Below Normal)

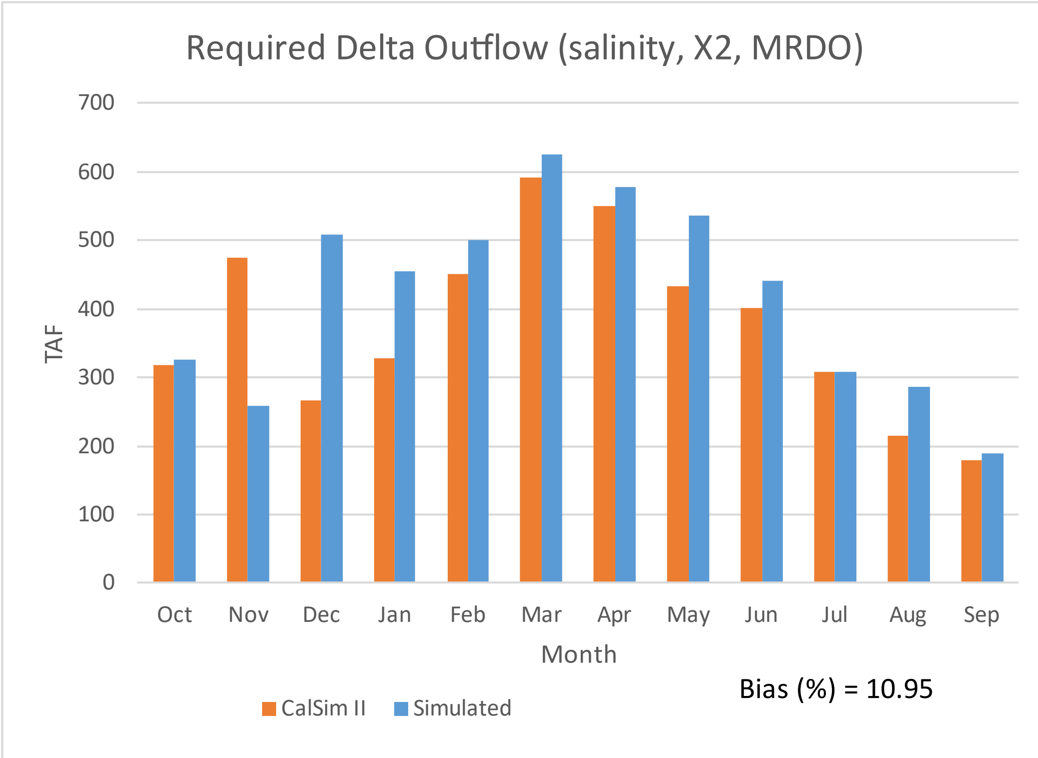


Figure A.6.13h. Required Delta Outflow (salinity, X2, MRDO), Average Monthly (Dry)

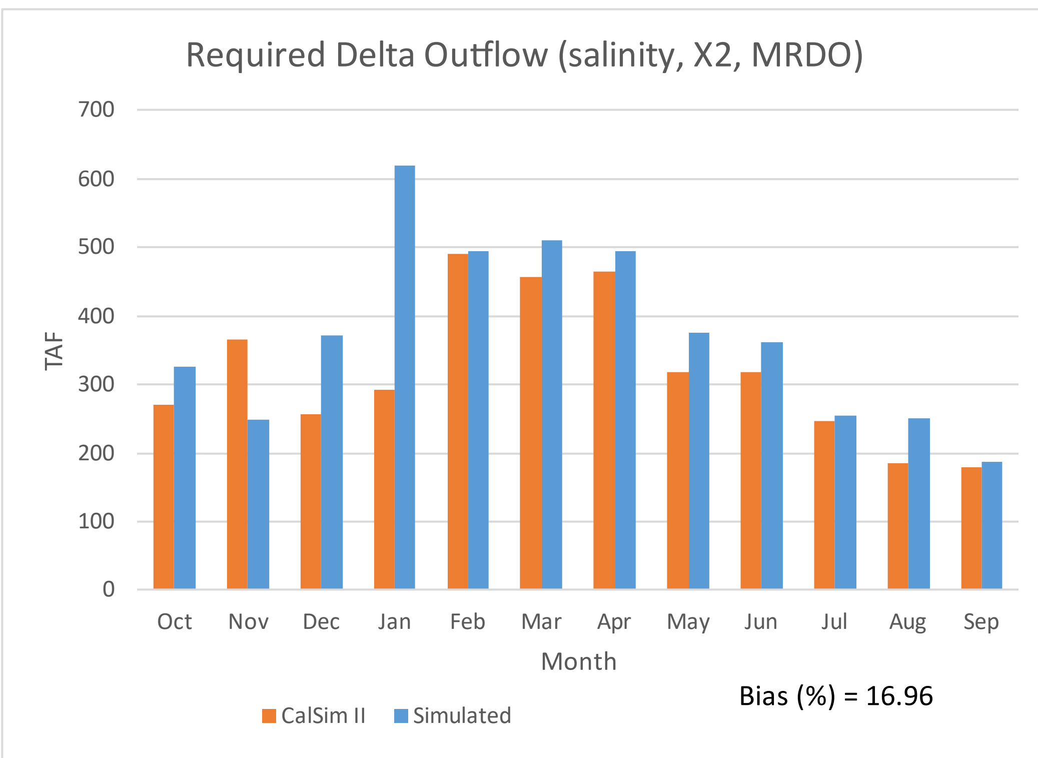


Figure A.6.13i. Required Delta Outflow (salinity, X2, MRDO), Average Monthly (Critical)

A.6.14 Surplus Delta Outflow

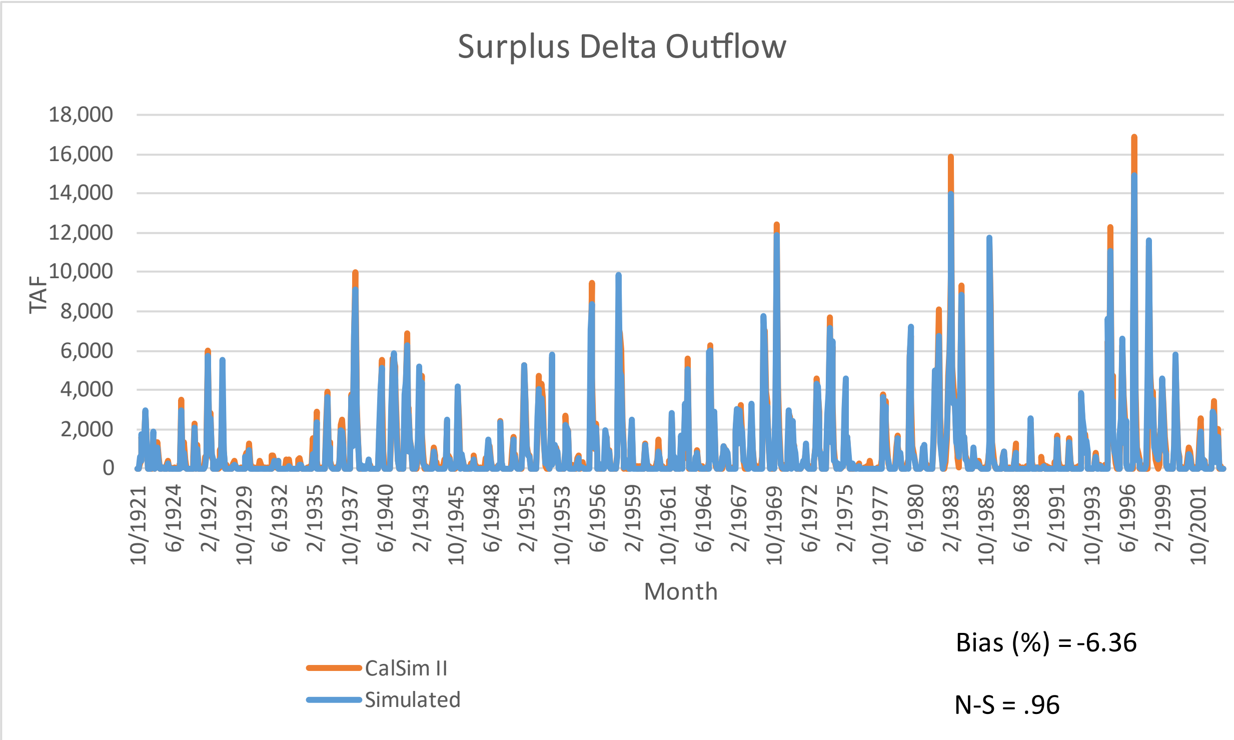


Figure A.6.14a. Surplus Delta Outflow, Monthly 1922 to 2003

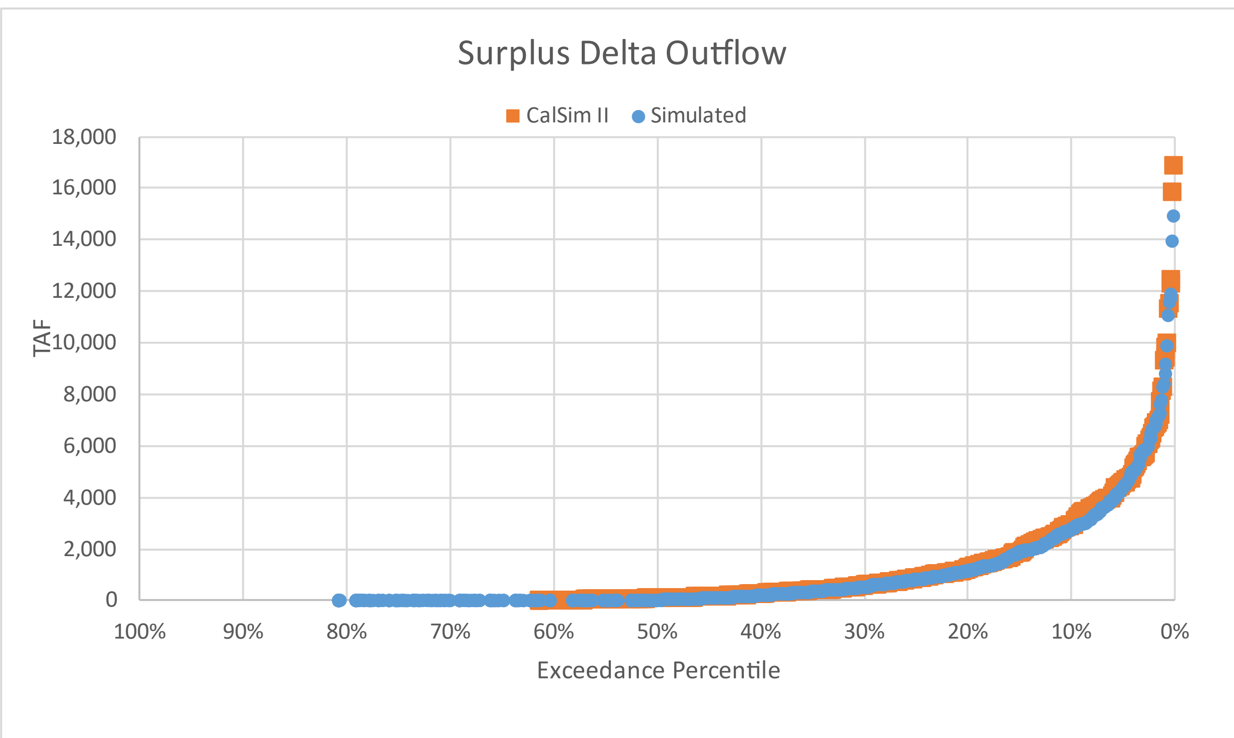


Figure A.6.14b. Surplus Delta Outflow, Exceedance

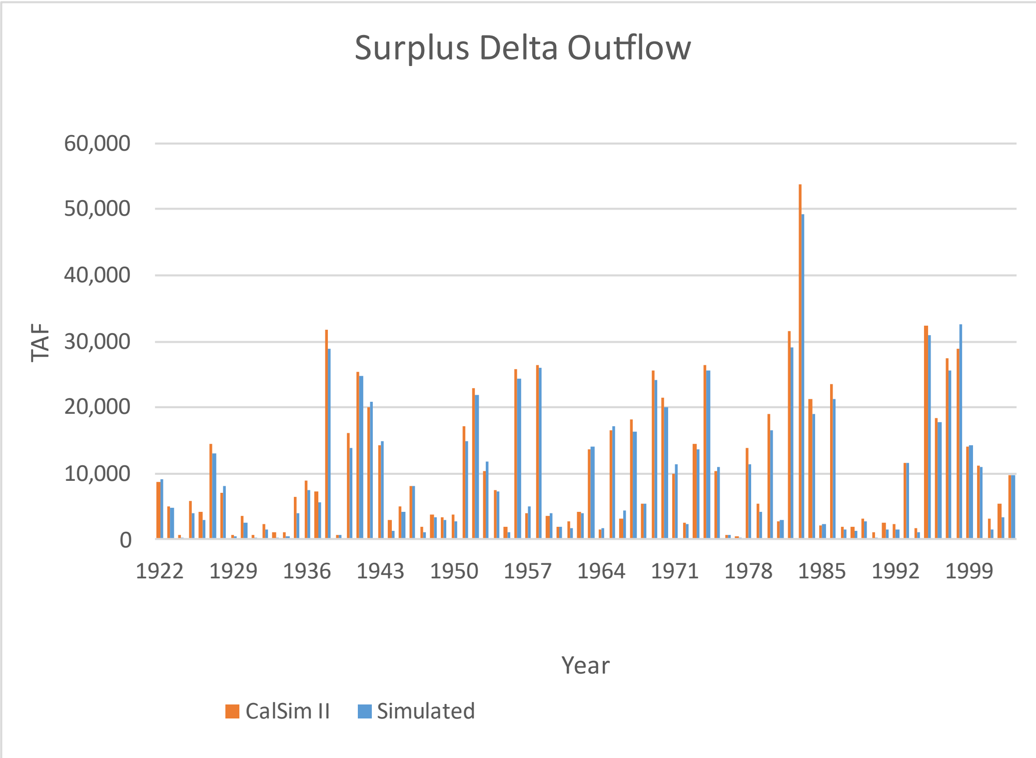


Figure A.6.14c. Surplus Delta Outflow, Annual 1922 to 2003

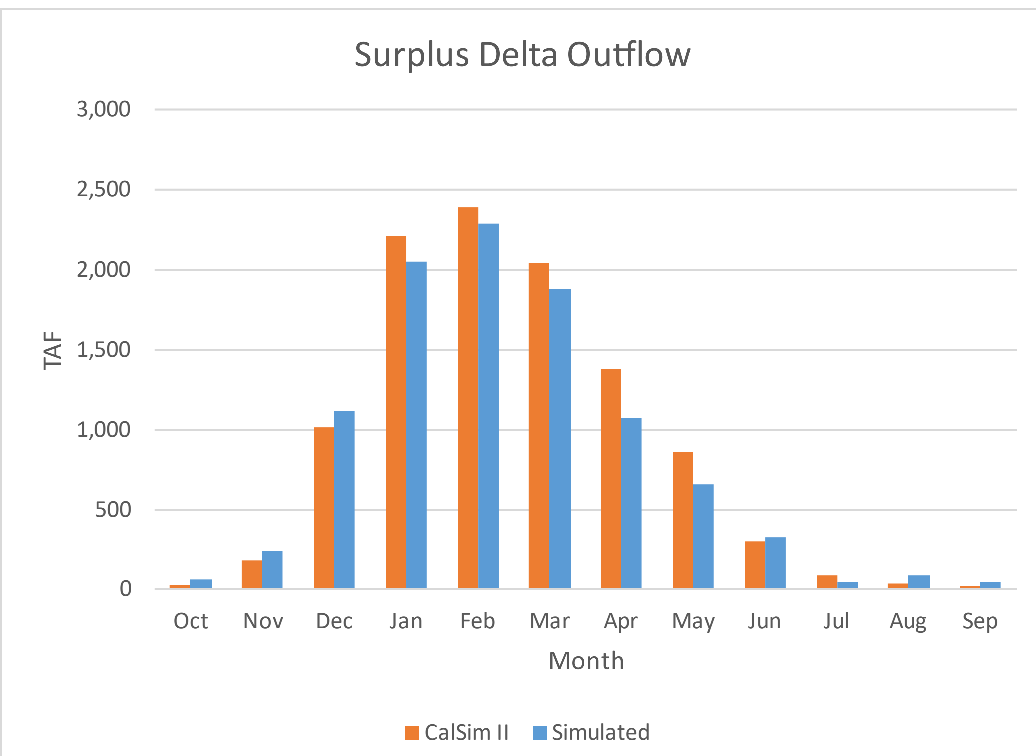


Figure A.6.14d. Surplus Delta Outflow, Average Monthly

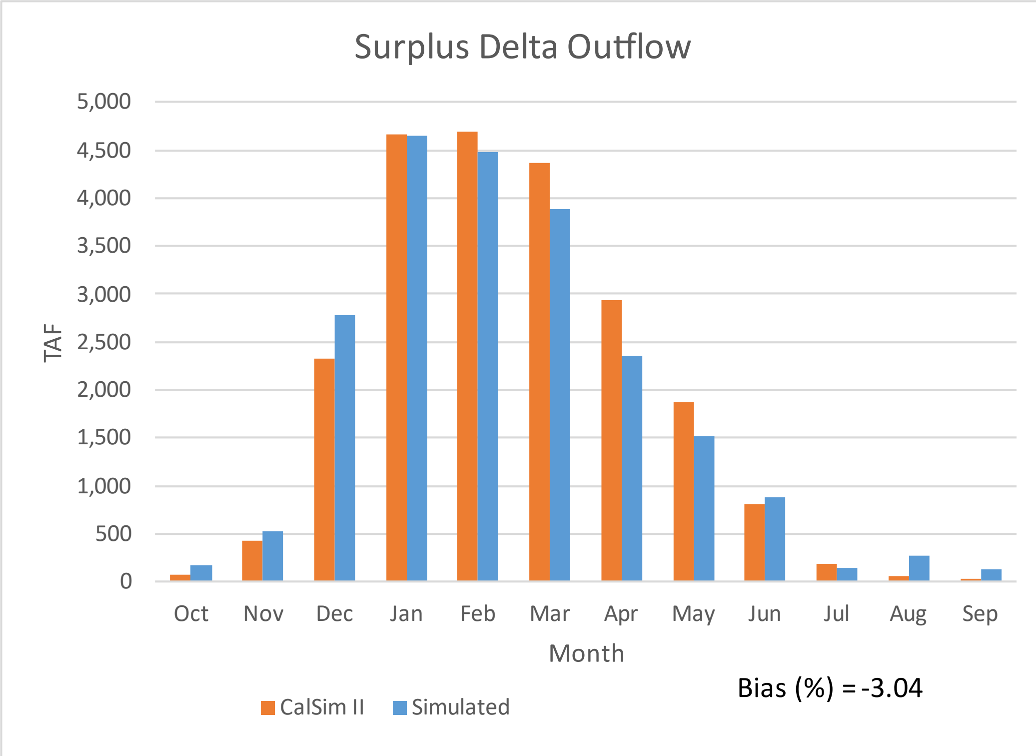


Figure A.6.14e. Surplus Delta Outflow, Average Monthly (Wet)

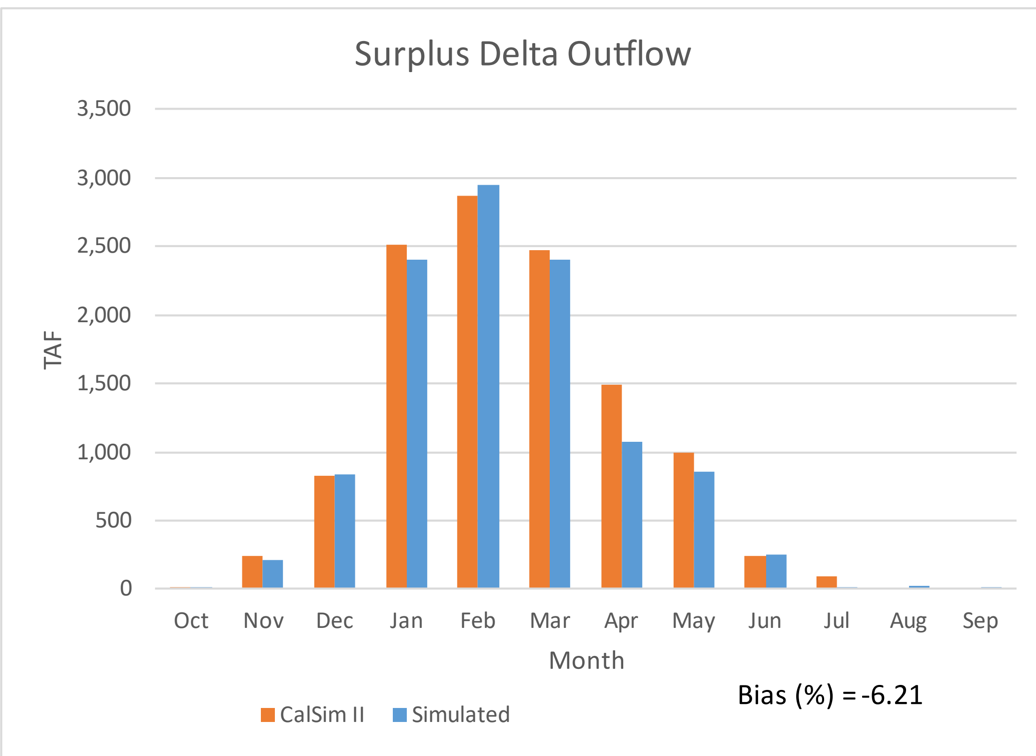


Figure A.6.14f. Surplus Delta Outflow, Average Monthly (Above Normal)

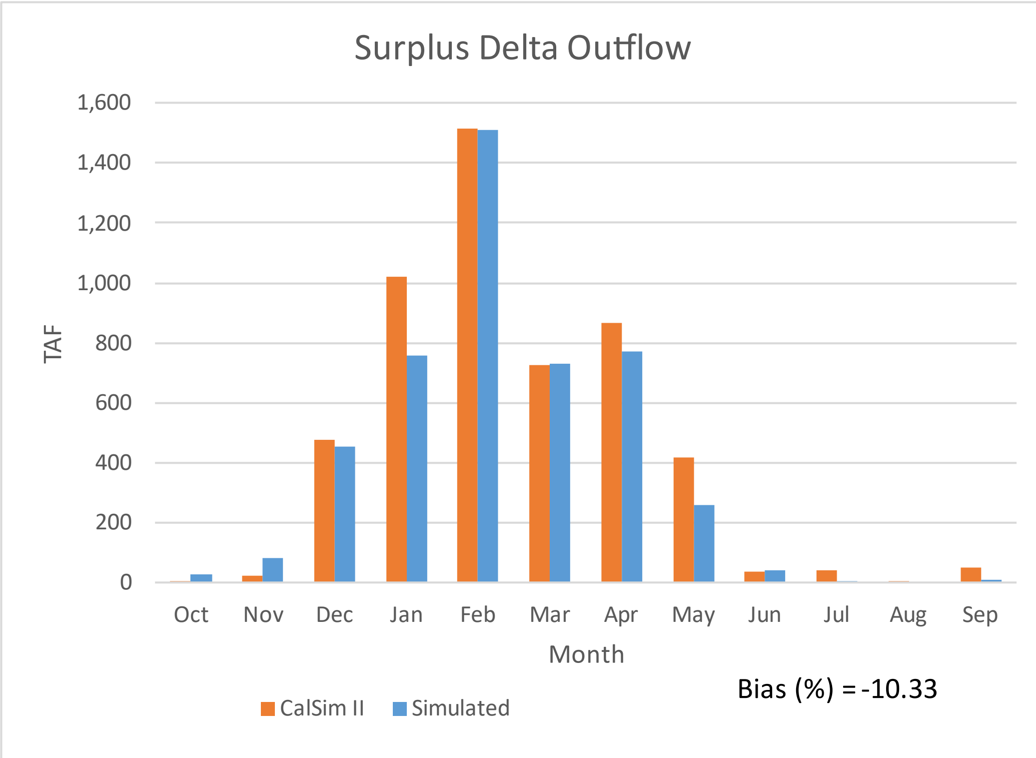


Figure A.6.14g. Surplus Delta Outflow, Average Monthly (Below Normal)

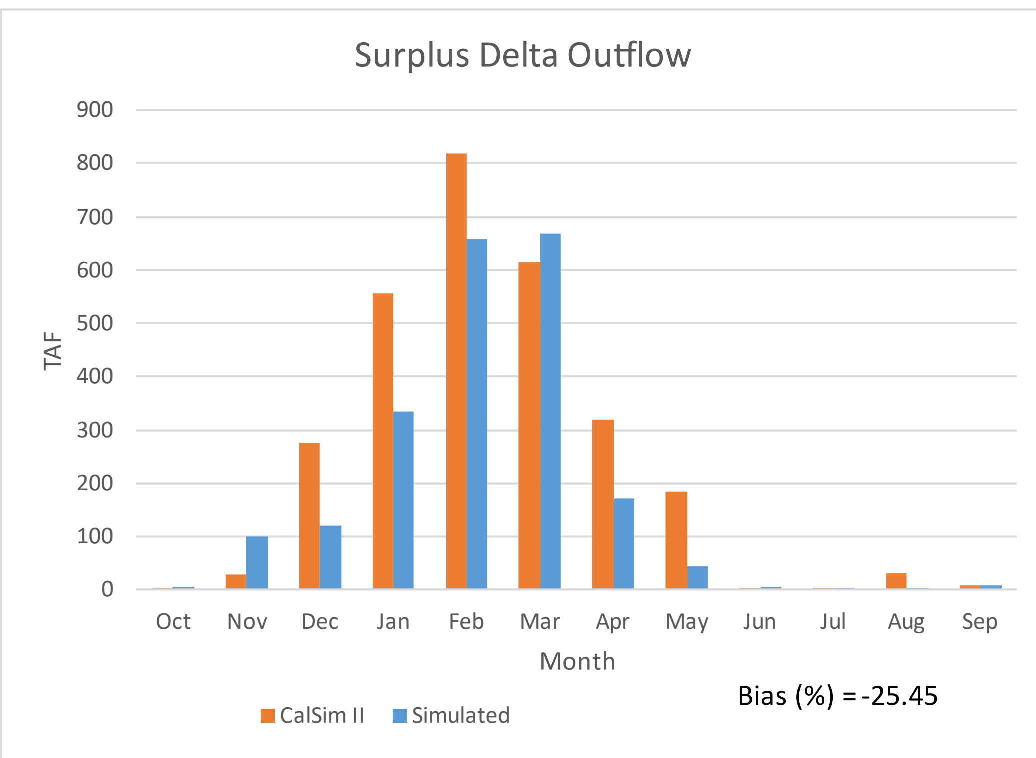


Figure A.6.14h. Surplus Delta Outflow, Average Monthly (Dry)

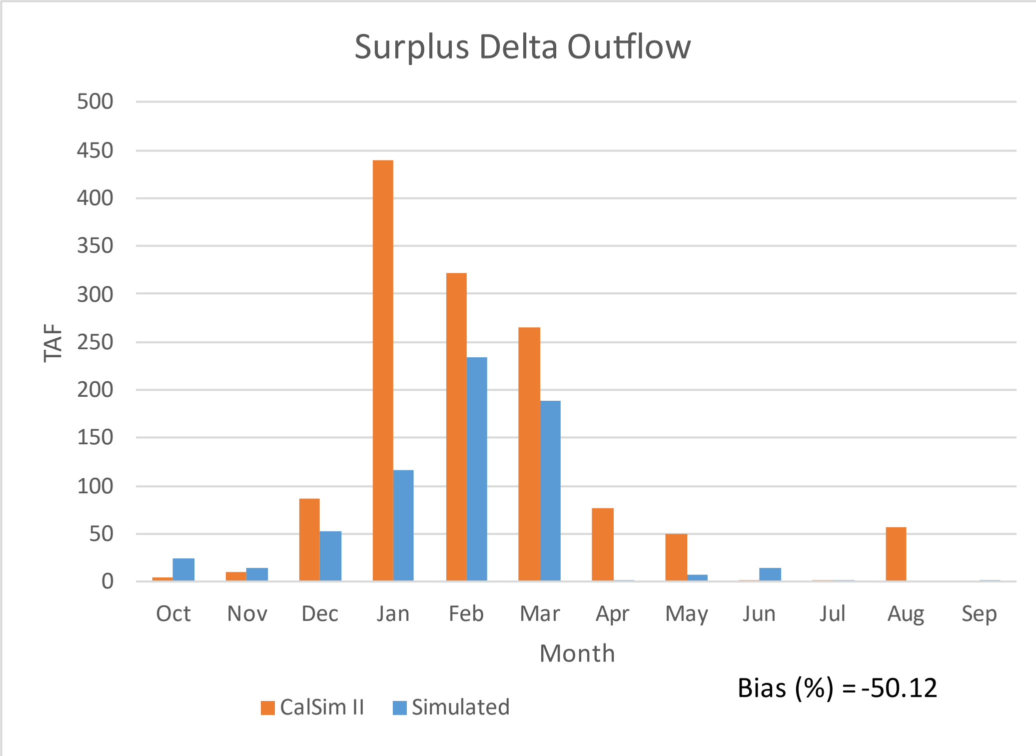


Figure A.6.14i. Surplus Delta Outflow, Average Monthly (Critical)

A.7 Project Operations Validation (Historical)

An extensive set of logic was developed to represent CVP-SWP operations in SacWAM. A description of this logic is found in chapters 7 and 8 of the main report. This section compares CVP-SWP SacWAM simulated operations to historical data for water years 2010-2015. This period follows the release of the 2008 USFWS biological opinion and the 2009 NMFS biological opinion on long-term CVP and SWP operations, which have a very significant impact on project operations. These biological opinions are simulated in SacWAM. Similar to the SacWAM comparison to CalSim II (Section B.6), the comparison presented here focuses on the main components of CVP-SWP operations, as follows:

1. CVP storage north-of-Delta
2. SWP storage north-of-Delta (Oroville)
3. CVP storage south-of-Delta (San Luis)
4. SWP storage south-of-Delta (San Luis)
5. Trinity River imports
6. American River flow at Fair Oaks
7. Feather River flow at Gridley
8. Sacramento River flow at Freeport
9. Delta inflow

10. CVP Delta Exports
11. SWP Delta Exports
12. CVP-SWP Exports Combined
13. Net Delta Outflow

For each of these components, graphs of model results are presented in the form of monthly values, average monthly values, annual values, and monthly exceedance for water years 1922-2003. Values for bias and Nash-Sutcliffe efficiency are also provided. Positive values of bias correspond with larger values simulated by SacWAM in comparison to historical.

SacWAM simulates a 'fixed level of development' in which land use conditions, water control facilities, contracts, and regulatory requirement remain constant over the period of simulation. The model does not simulate many specific actions that occurred in response to the extremely dry conditions of 2014 and 2015, including land fallowing, water transfers, and temporary urgent change petitions (TUCP).

A.7.1 CVP NOD Storage

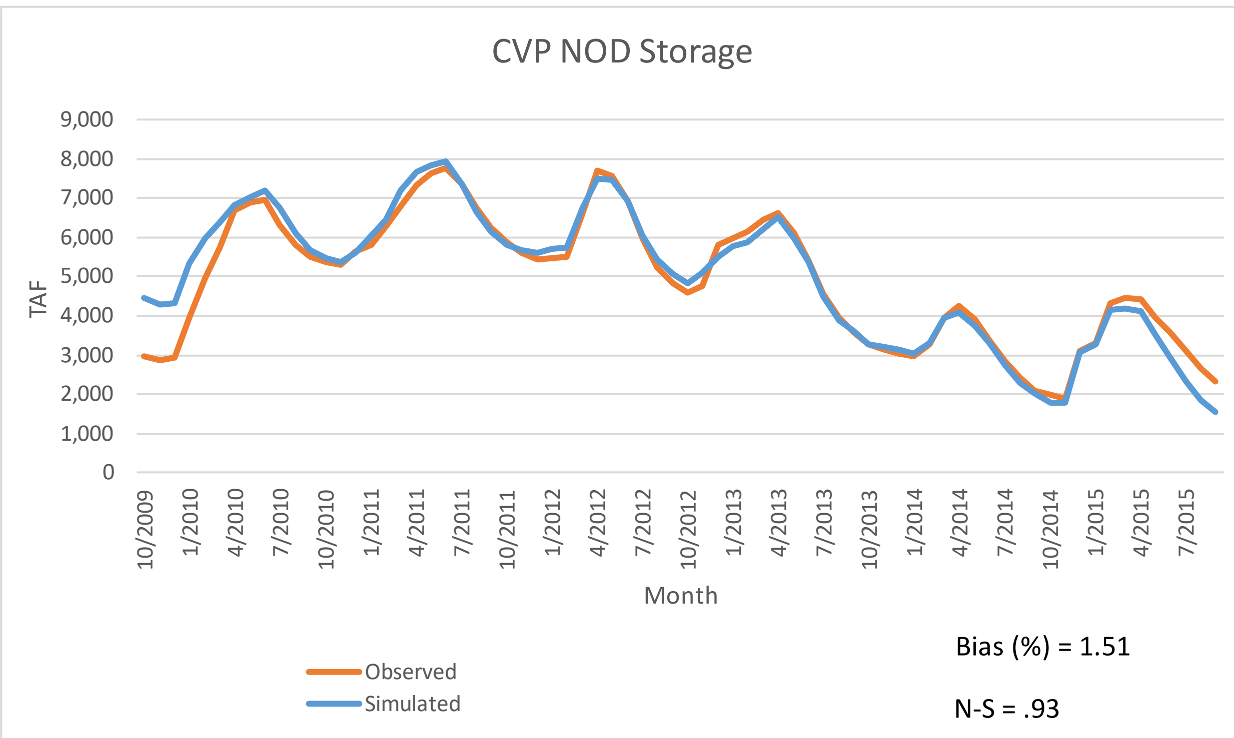


Figure A.7.1a. CVP NOD Storage, Monthly 2010 to 2015

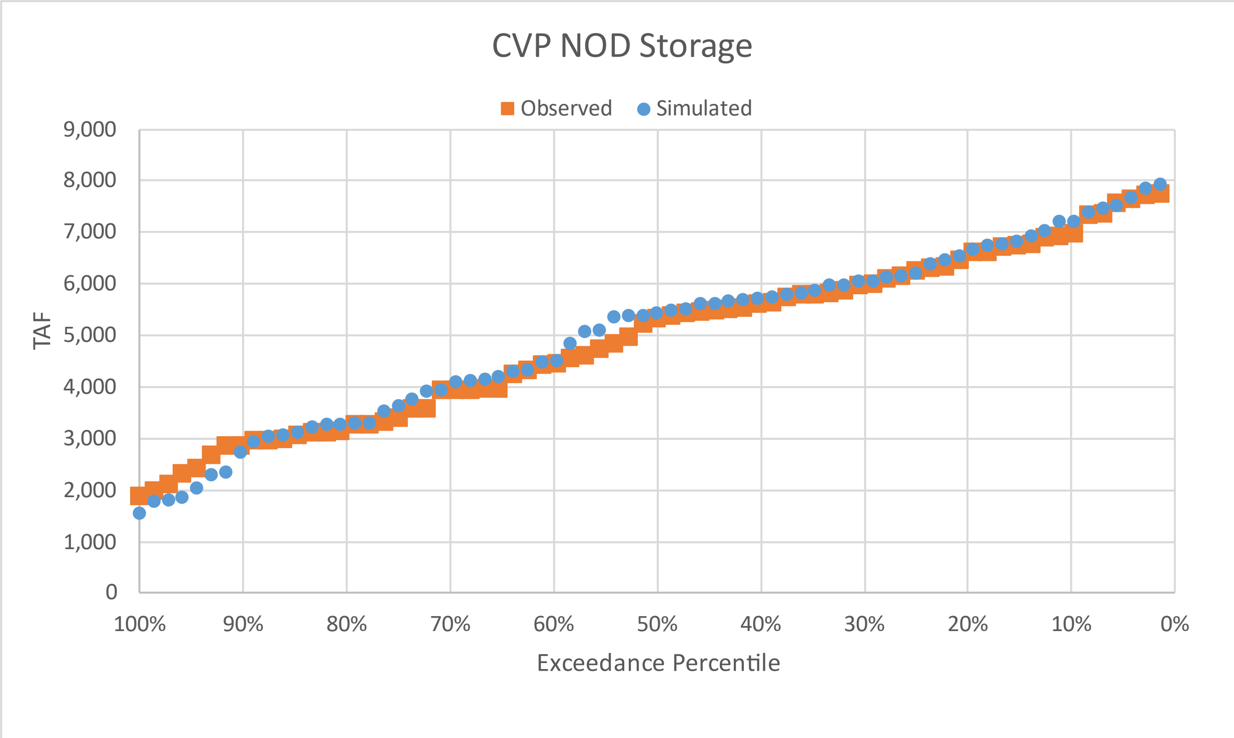


Figure A.7.1b. CVP NOD Storage, Exceedance

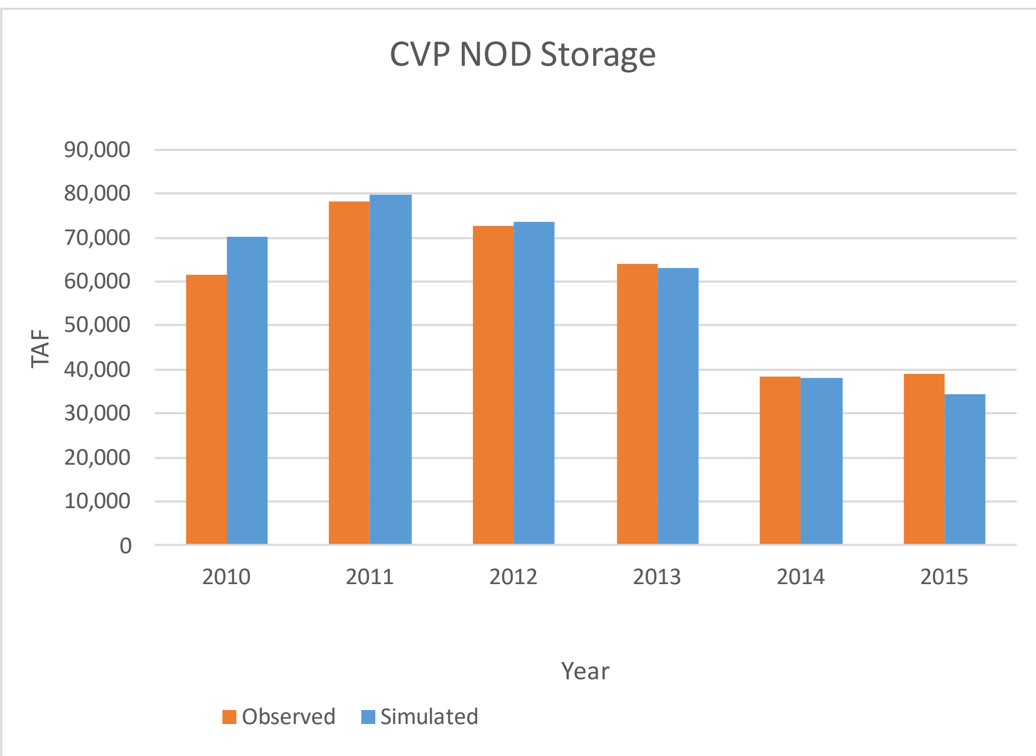


Figure A.7.1c. CVP NOD Storage, Annual 2010 to 2015

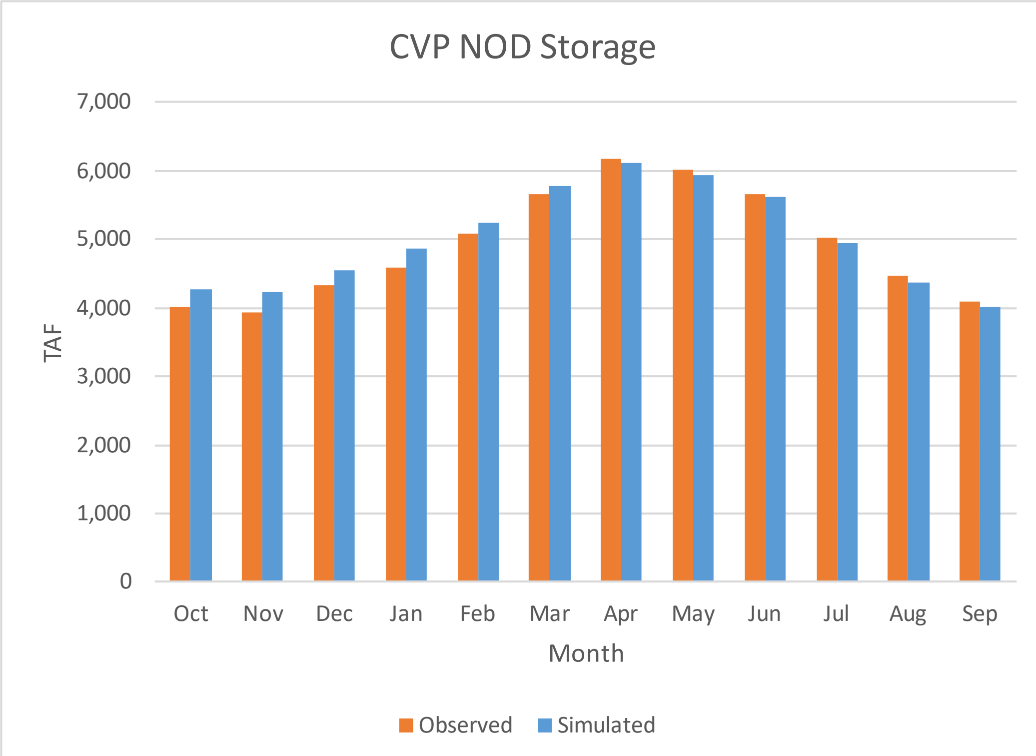


Figure A.7.1d. CVP NOD Storage, Average Monthly

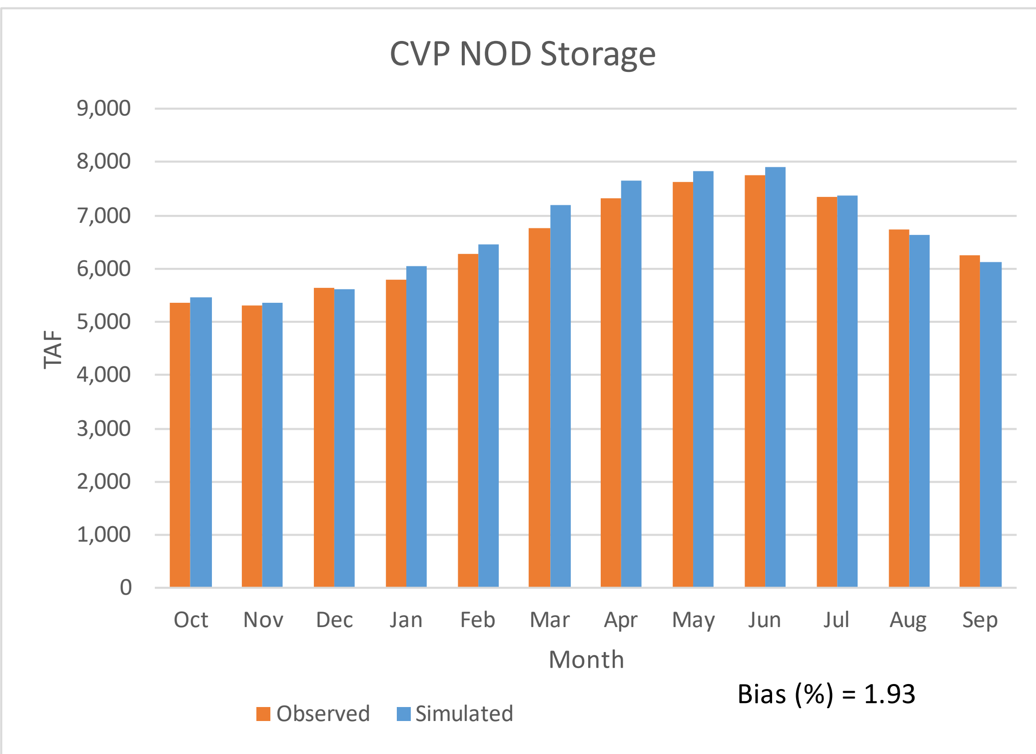


Figure A.7.1e. CVP NOD Storage, Average Monthly (Wet)

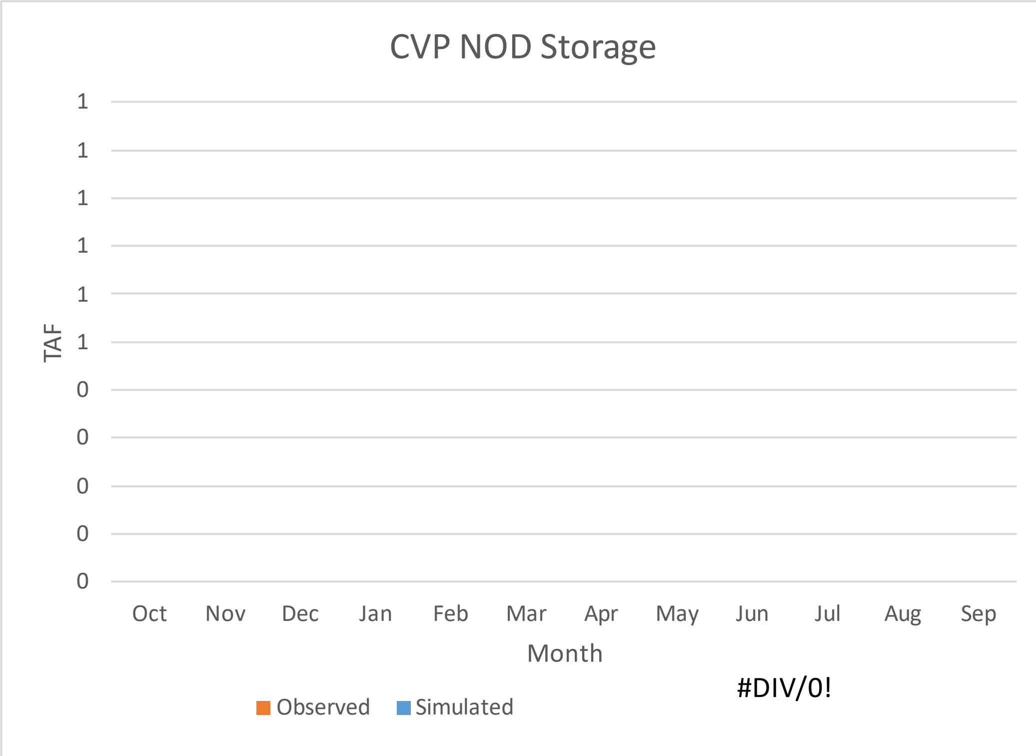


Figure A.7.1f. CVP NOD Storage, Average Monthly (Above Normal)

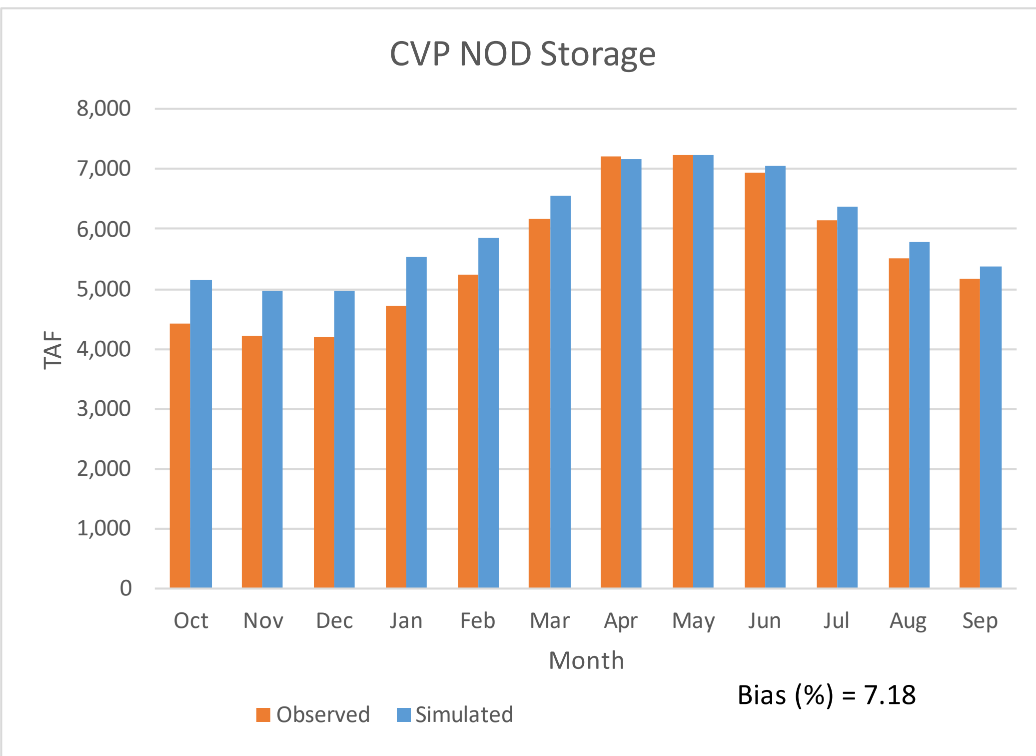


Figure A.7.1g. CVP NOD Storage, Average Monthly (Below Normal)

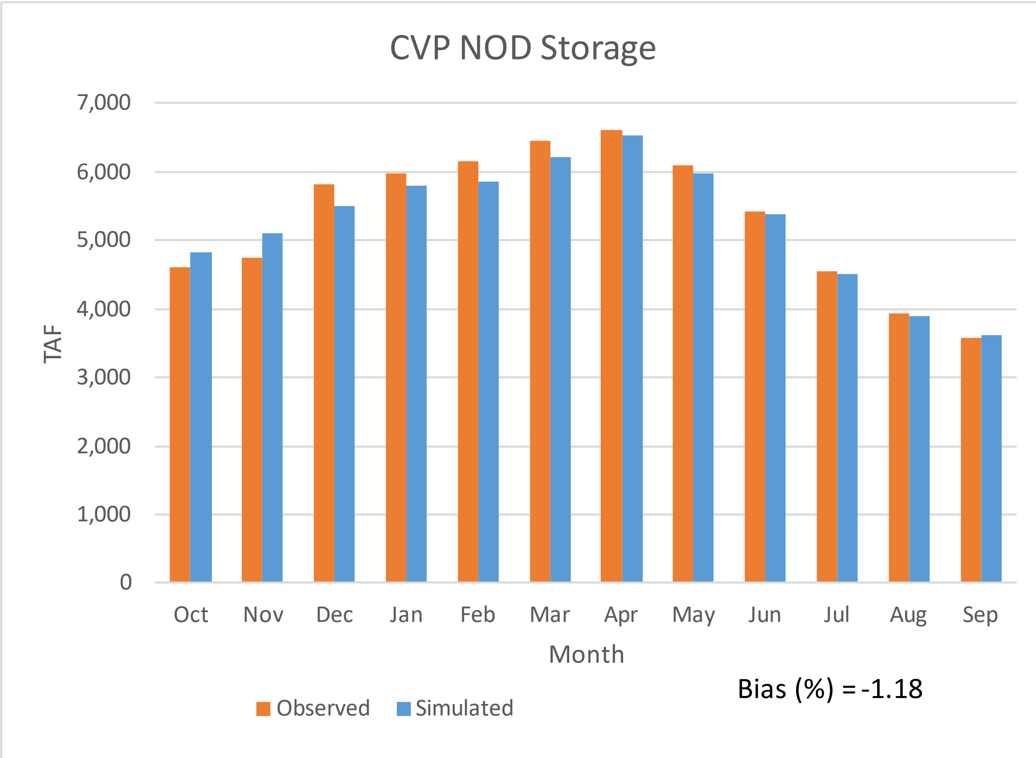


Figure A.7.1h. CVP NOD Storage, Average Monthly (Dry)

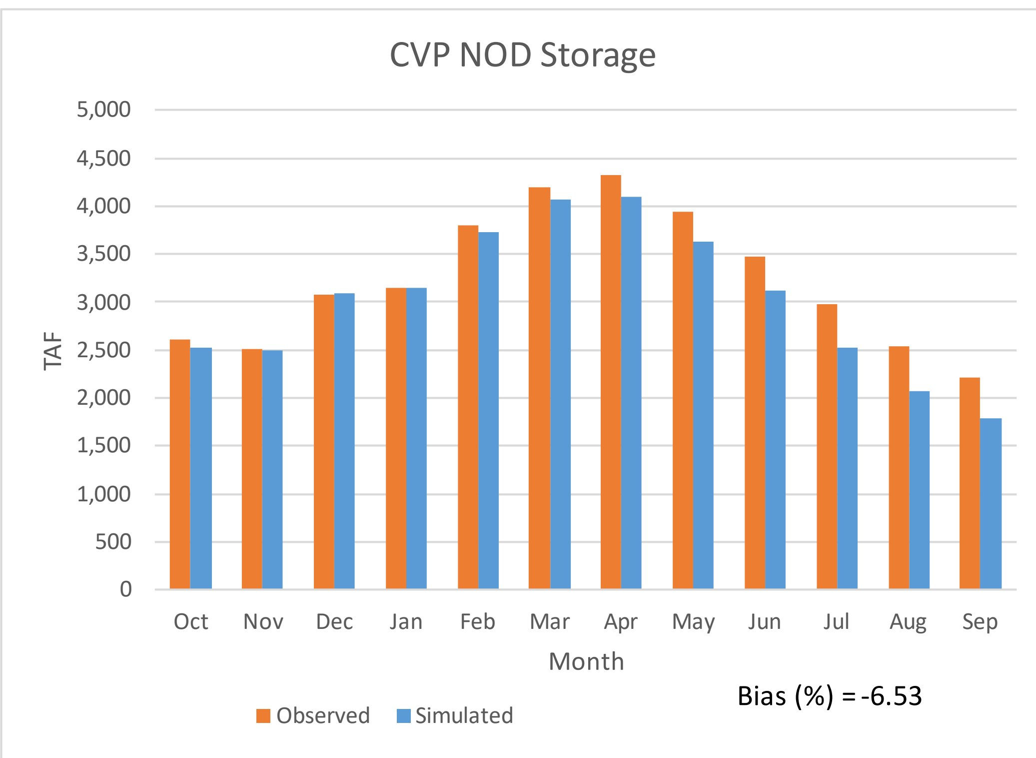


Figure A.7.1i. CVP NOD Storage, Average Monthly (Critical)

A.7.2 SWP NOD Storage

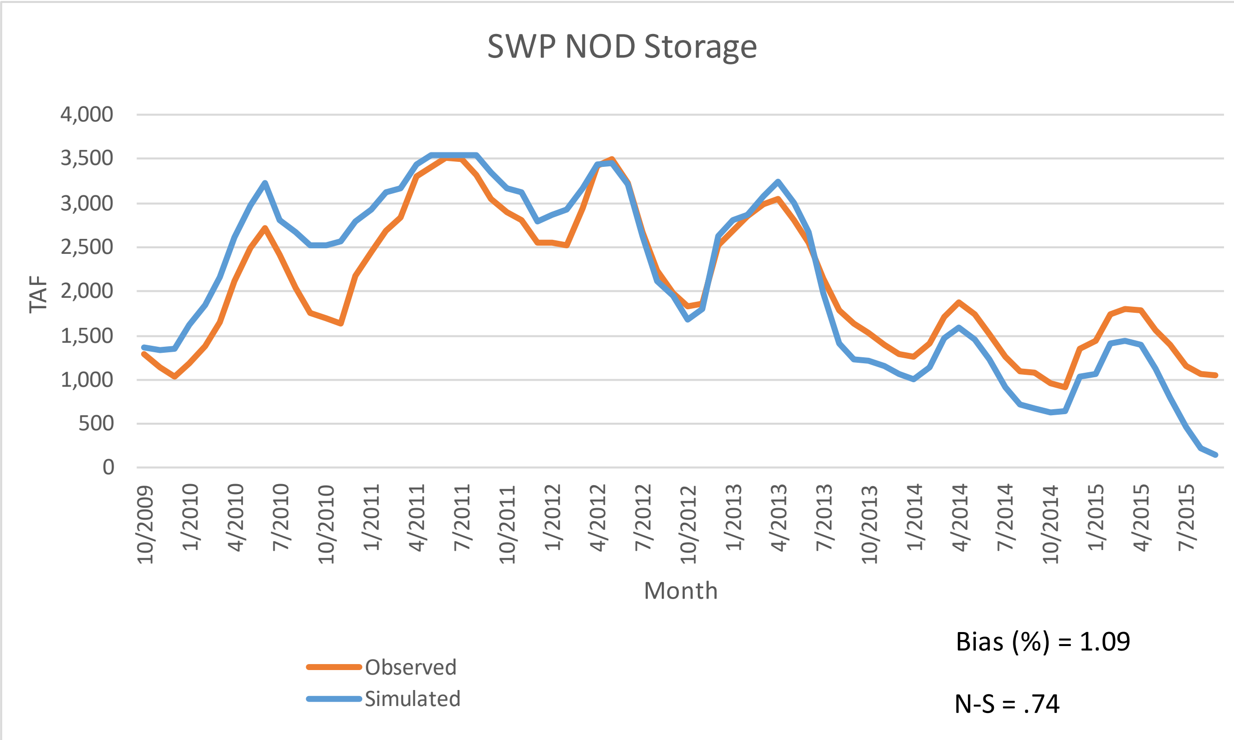


Figure A.7.2a. SWP NOD Storage, Monthly 2010 to 2015

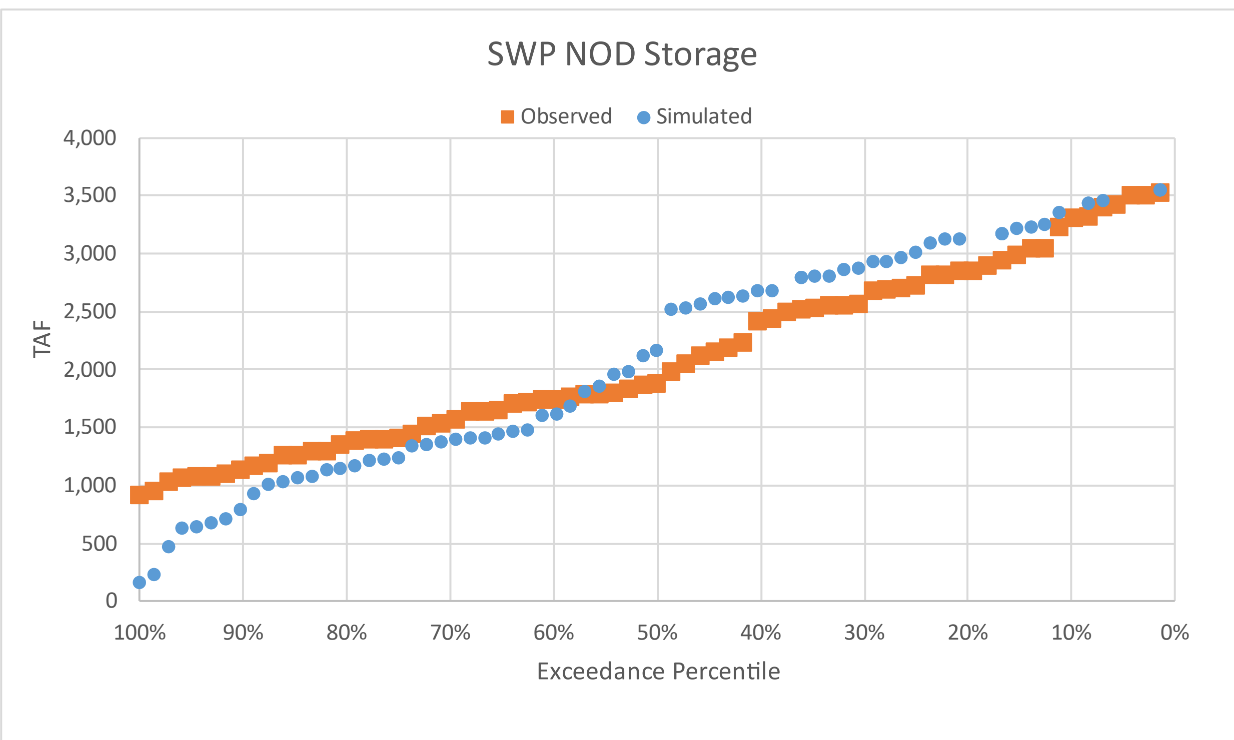


Figure A.7.2b. SWP NOD Storage, Exceedance

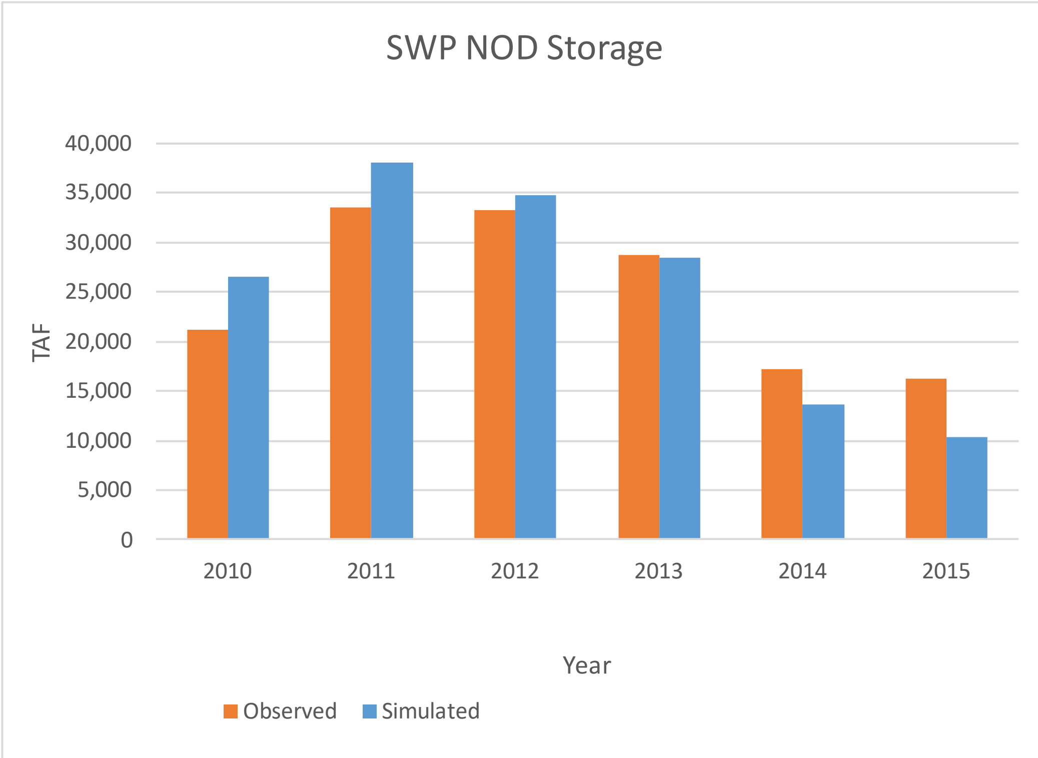


Figure A.7.2c. SWP NOD Storage, Annual 2010 to 2015

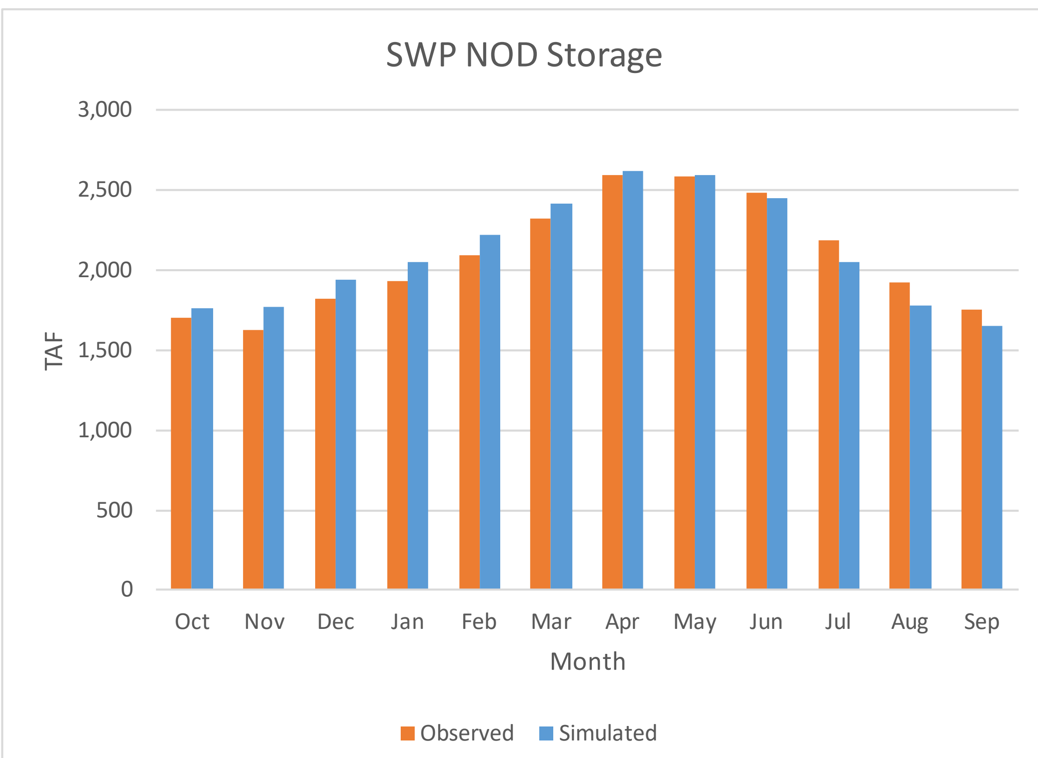


Figure A.7.2d. SWP NOD Storage, Average Monthly

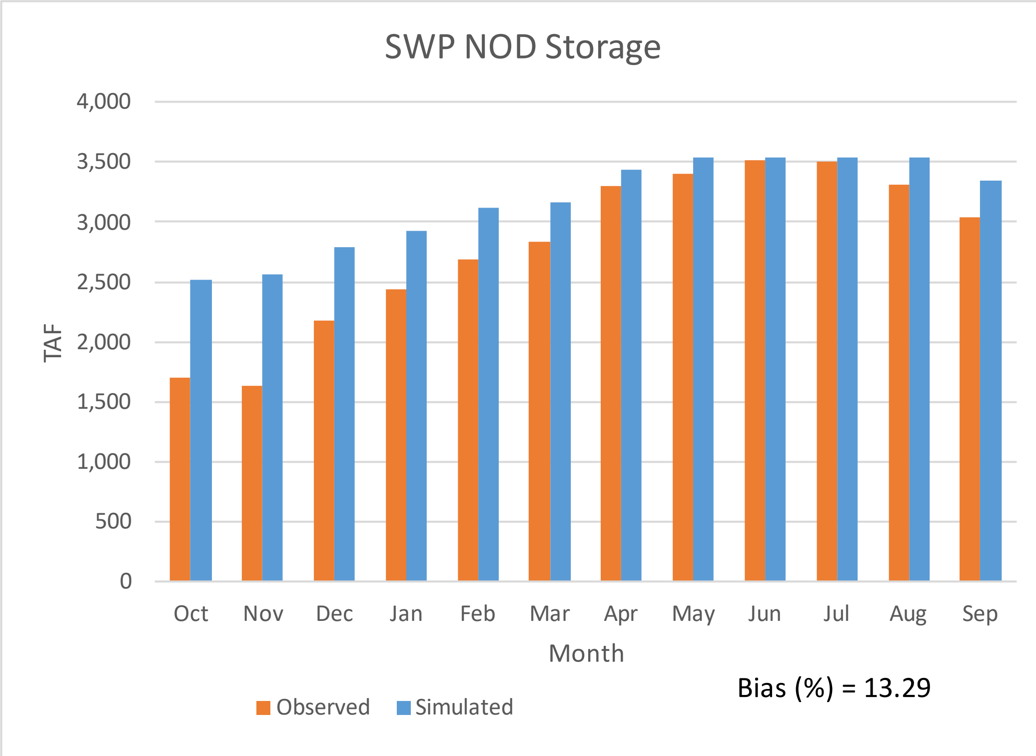


Figure A.7.2e. SWP NOD Storage, Average Monthly (Wet)

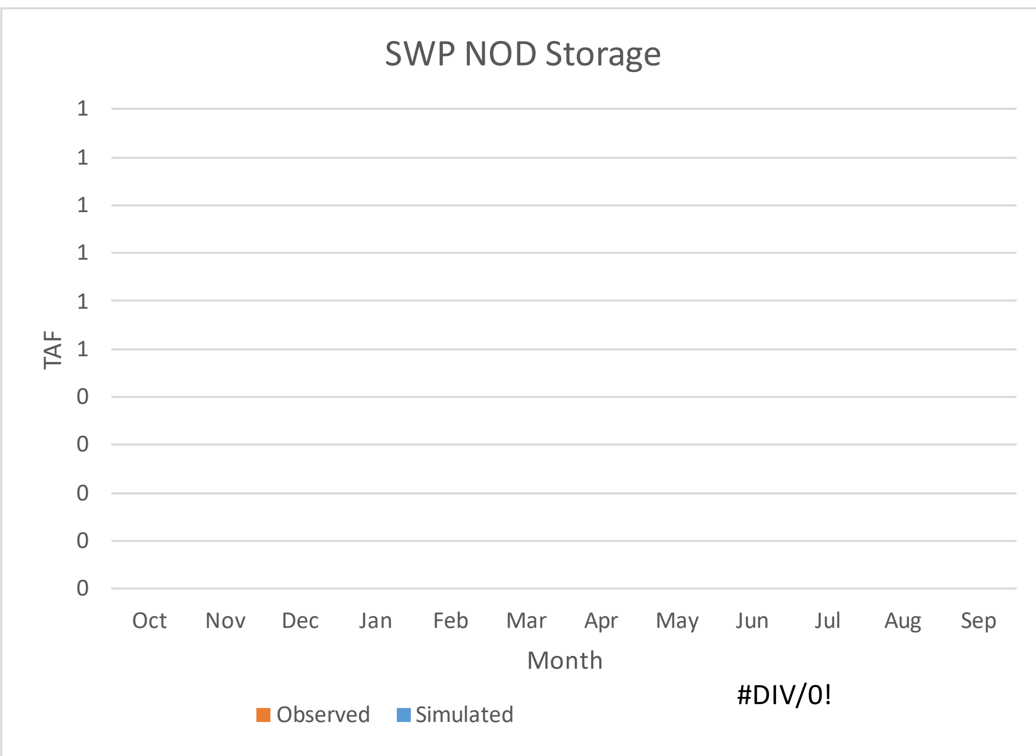


Figure A.7.2f. SWP NOD Storage, Average Monthly (Above Normal)

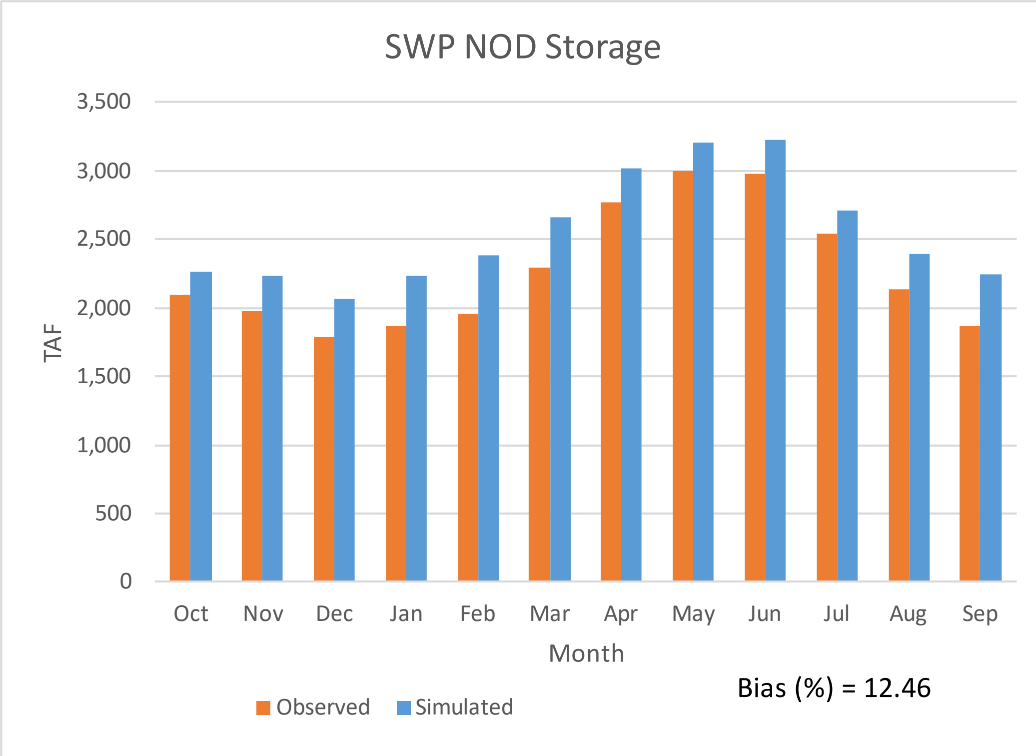


Figure A.7.2g. SWP NOD Storage, Average Monthly (Below Normal)

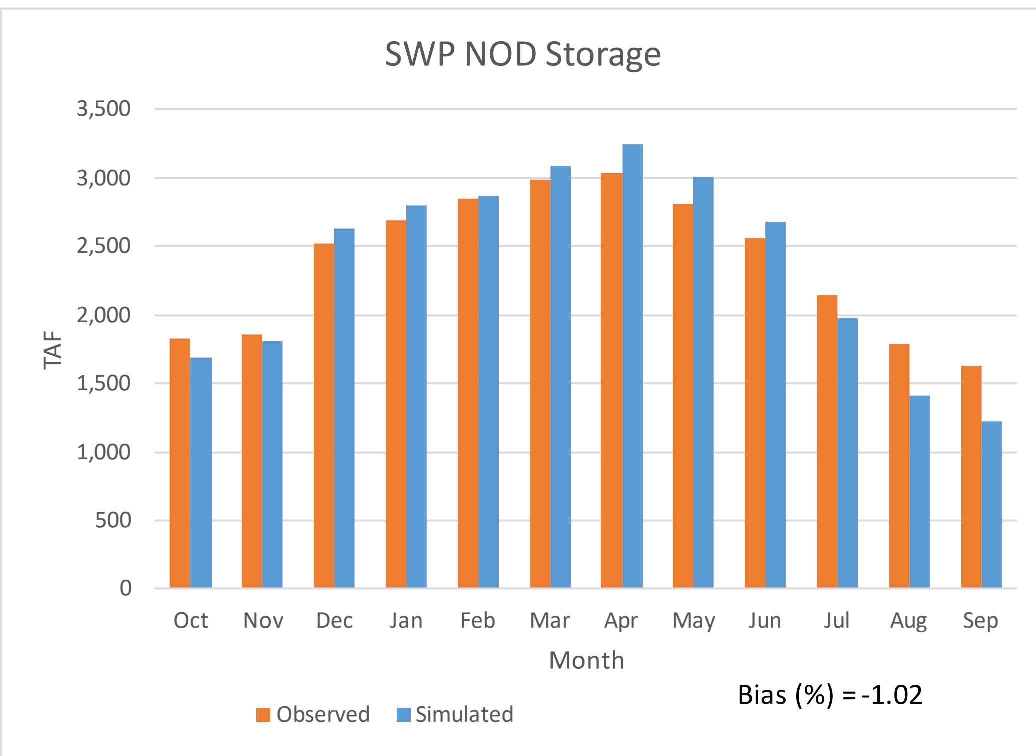


Figure A.7.2h. SWP NOD Storage, Average Monthly (Dry)

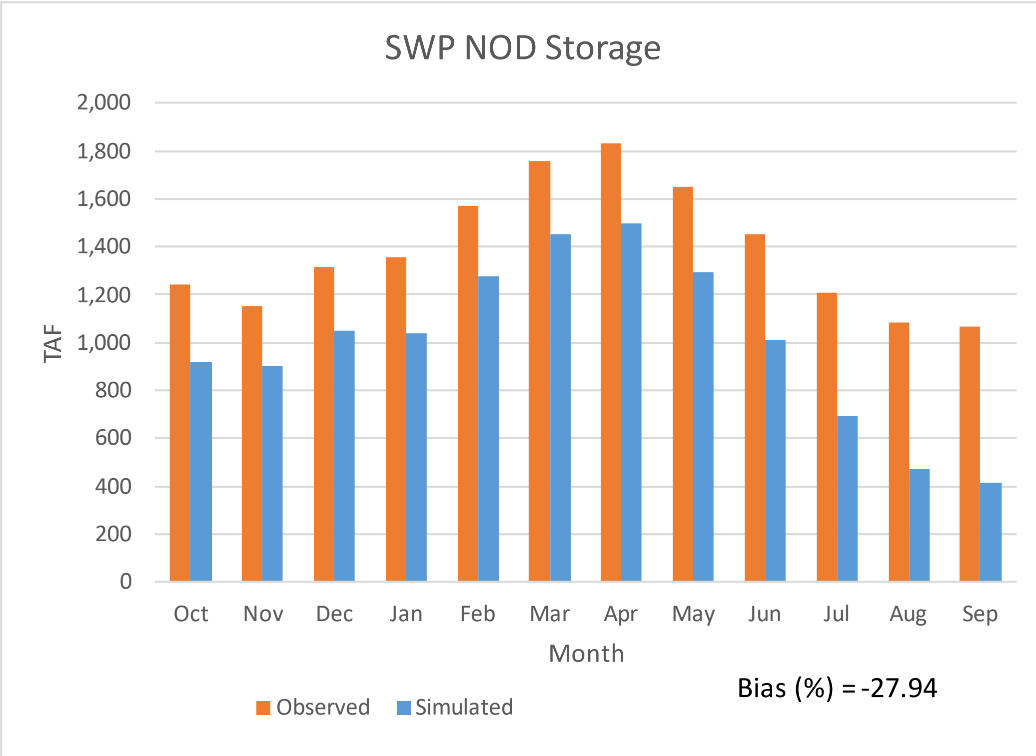


Figure A.7.2i. SWP NOD Storage, Average Monthly (Critical)

A.7.3 CVP San Luis Storage

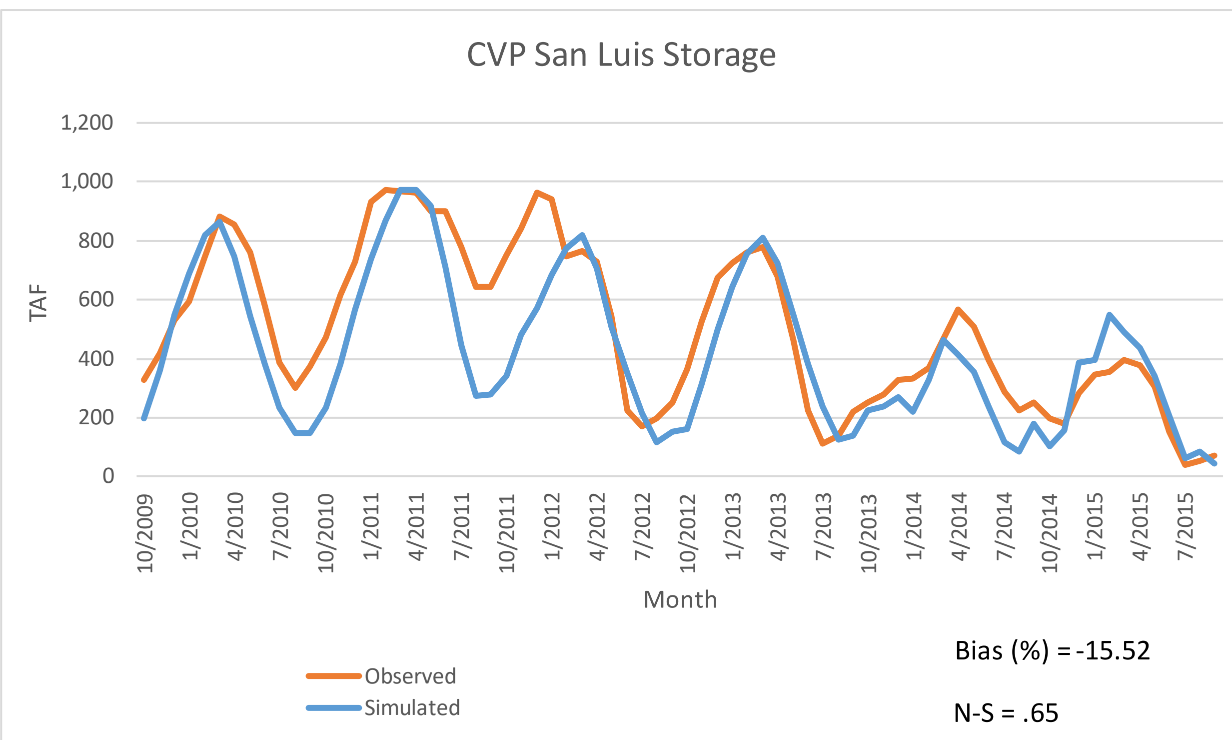


Figure A.7.3a. CVP San Luis Storage, Monthly 2010 to 2015

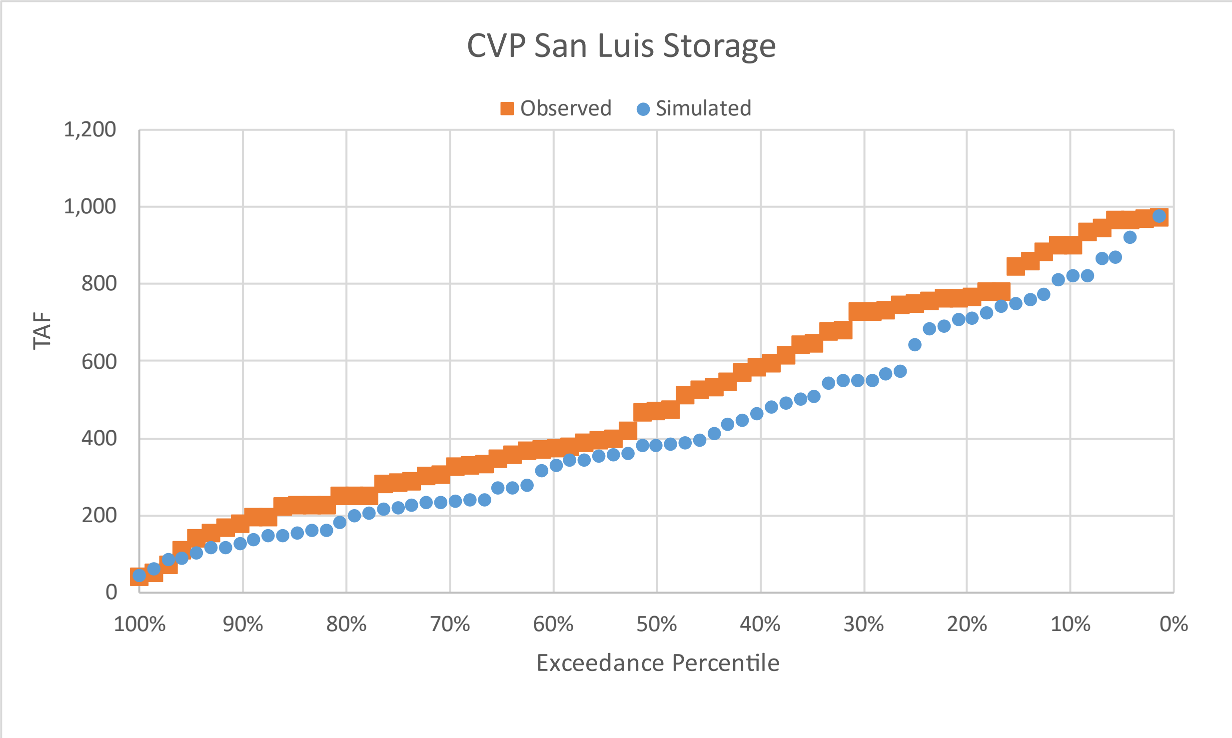


Figure A.7.3b. CVP San Luis Storage, Exceedance

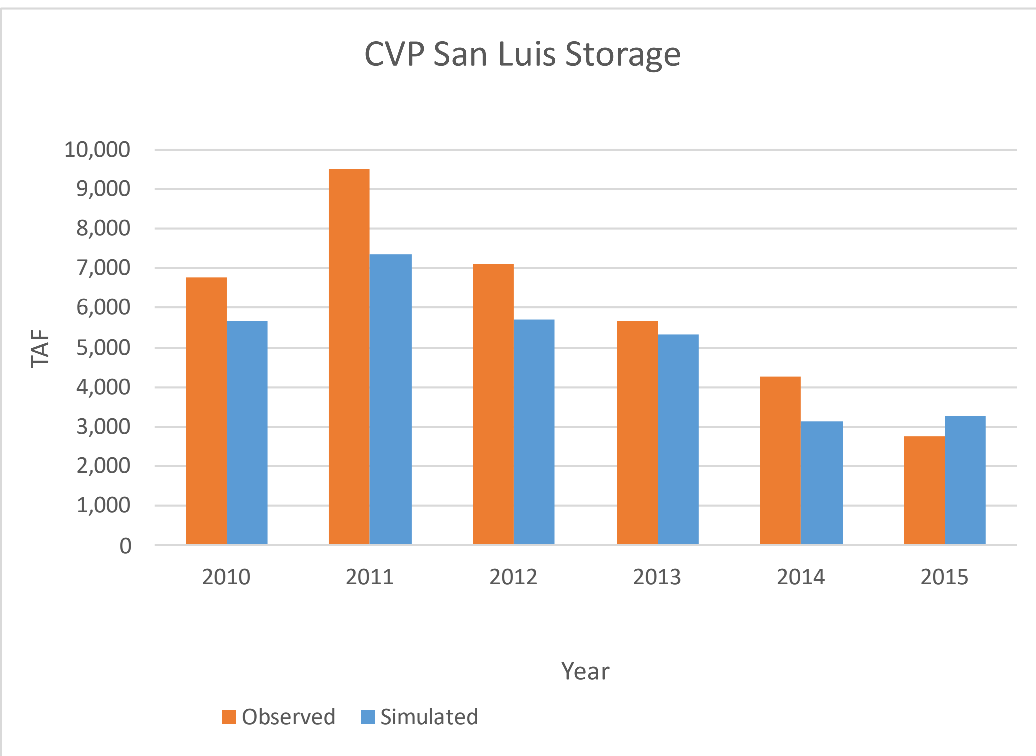


Figure A.7.3c. CVP San Luis Storage, Annual 2010 to 2015

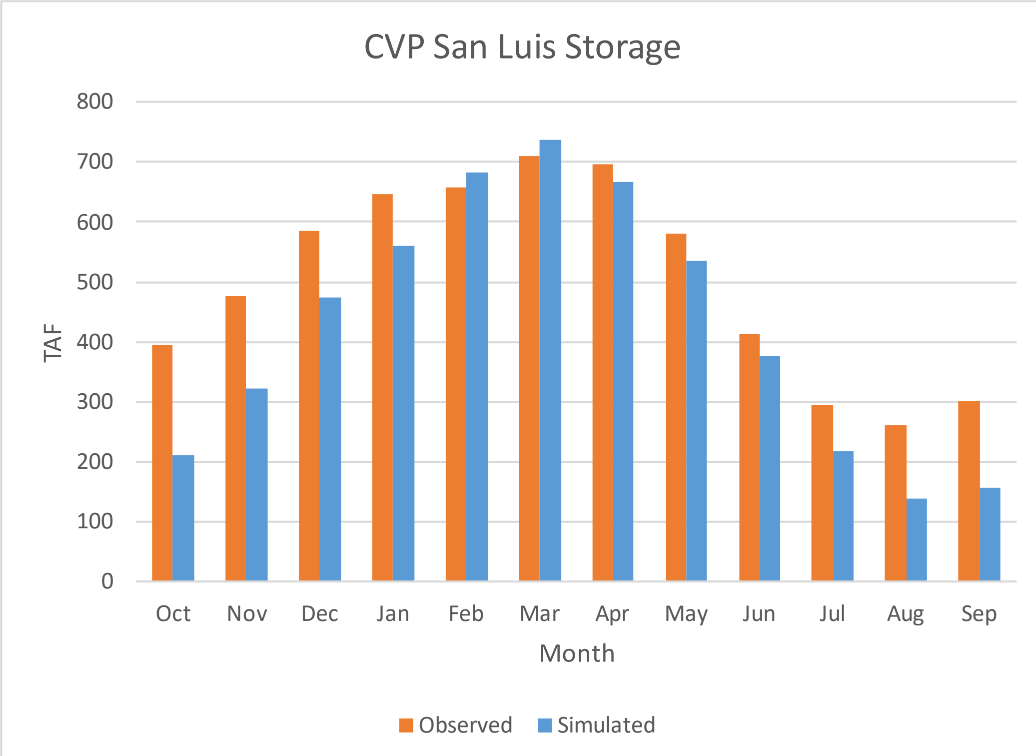


Figure A.7.3d. CVP San Luis Storage, Average Monthly

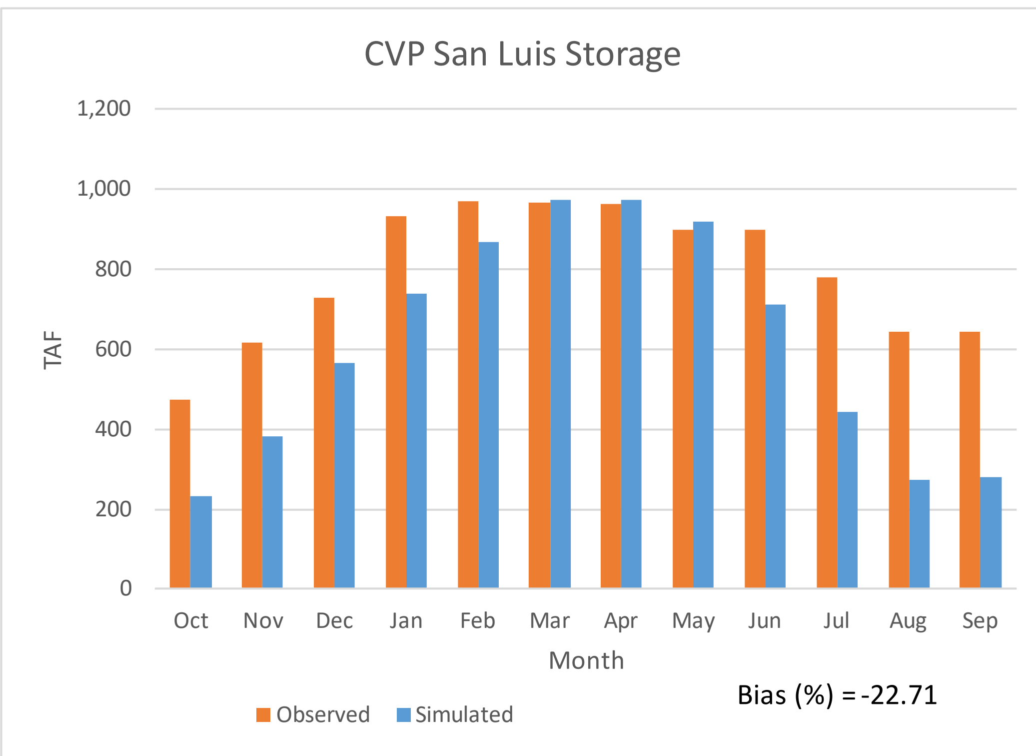


Figure A.7.3e. CVP San Luis Storage, Average Monthly (Wet)

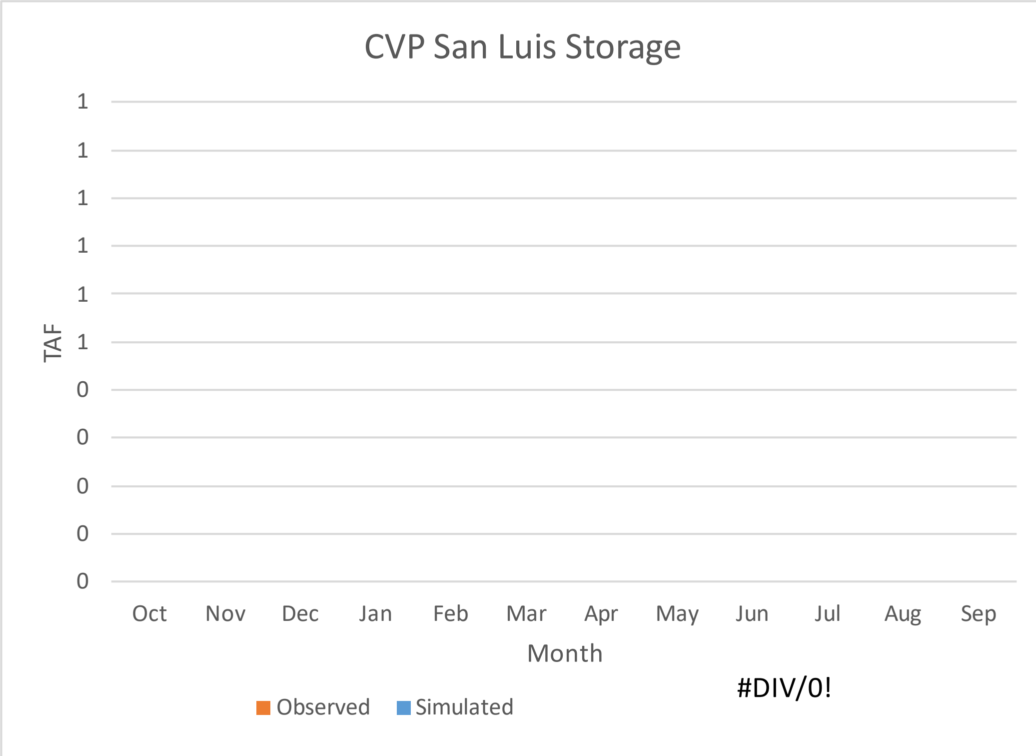


Figure A.7.3f. CVP San Luis Storage, Average Monthly (Above Normal)

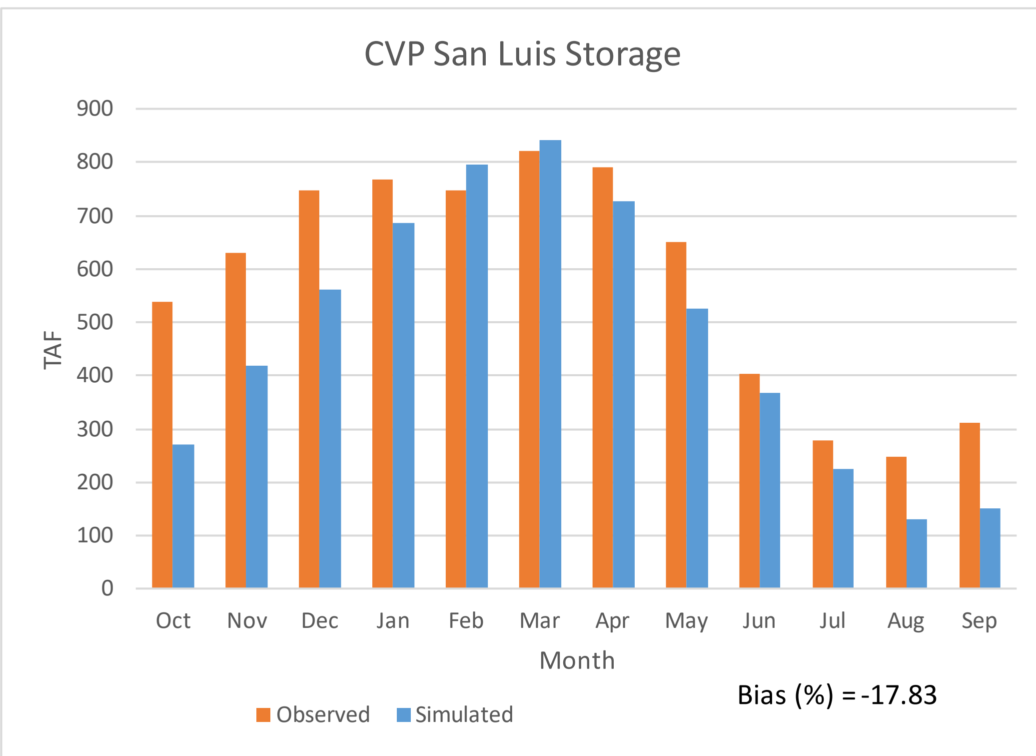


Figure A.7.3g. CVP San Luis Storage, Average Monthly (Below Normal)

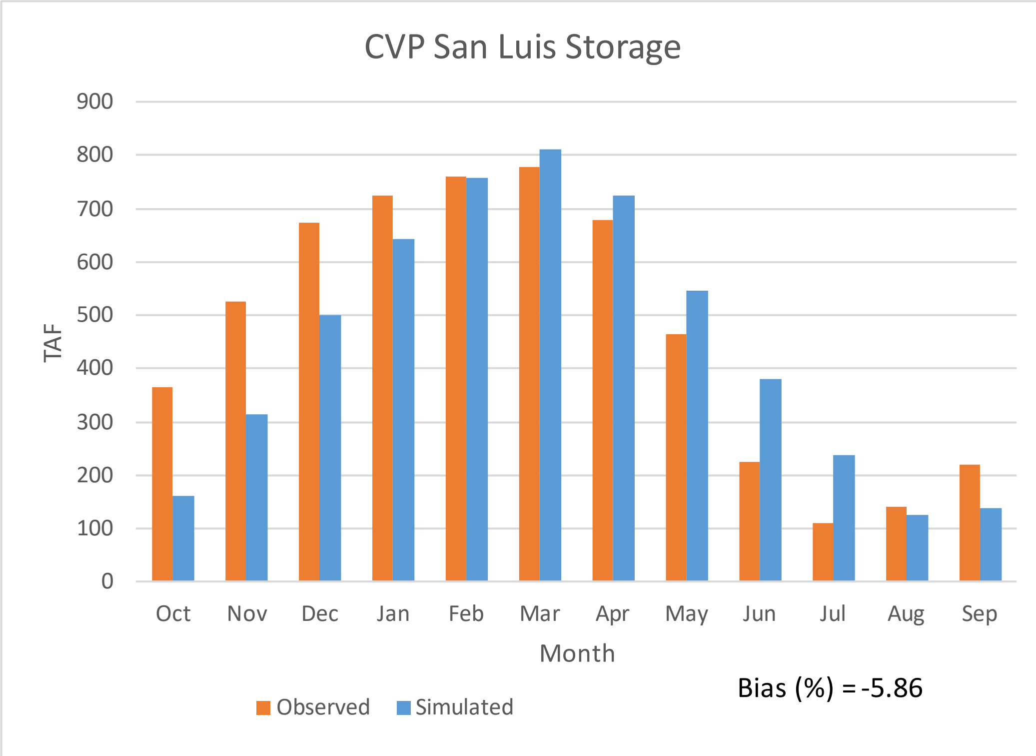


Figure A.7.3h. CVP San Luis Storage, Average Monthly (Dry)

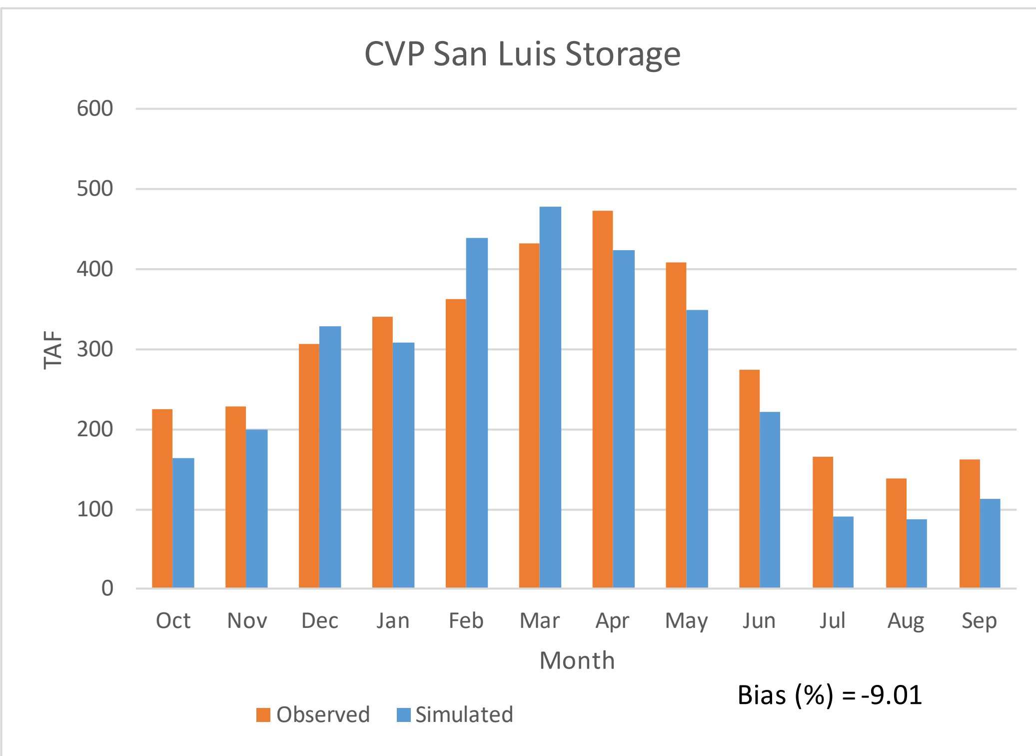


Figure A.7.3i. CVP San Luis Storage, Average Monthly (Critical)

A.7.4 SWP San Luis Storage

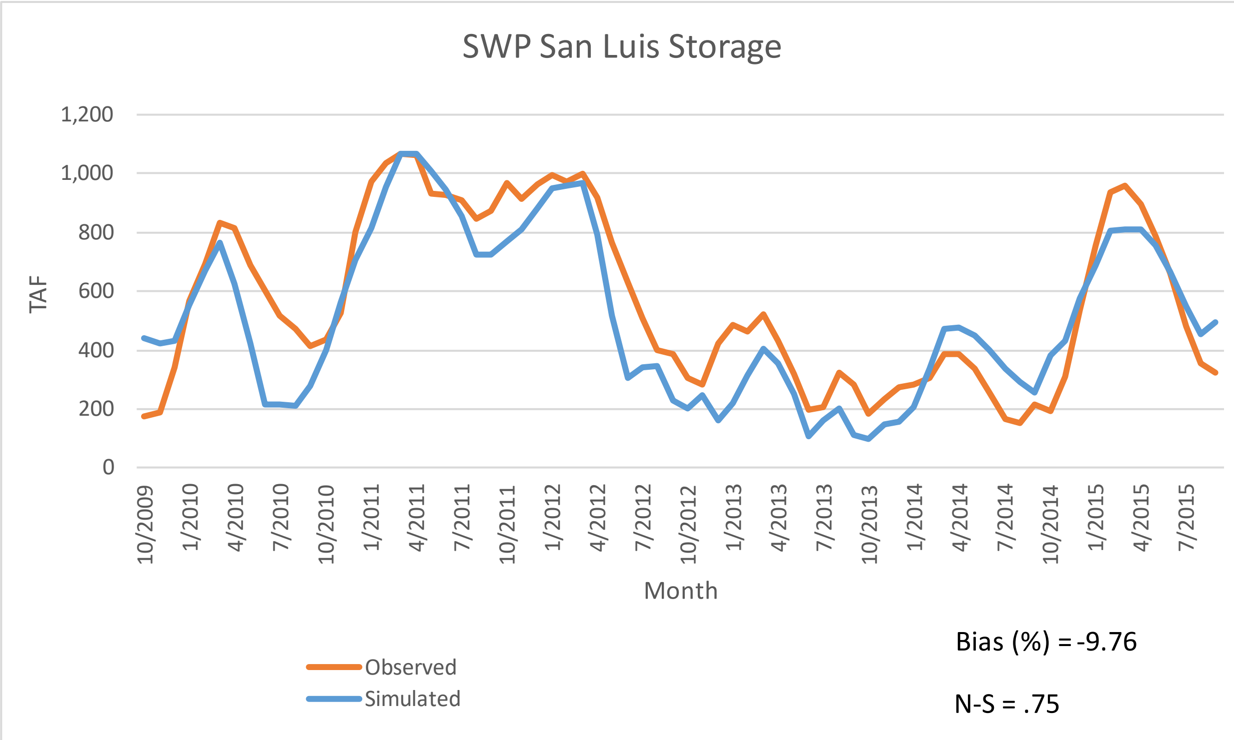


Figure A.7.4a. SWP San Luis Storage, Monthly 2010 to 2015

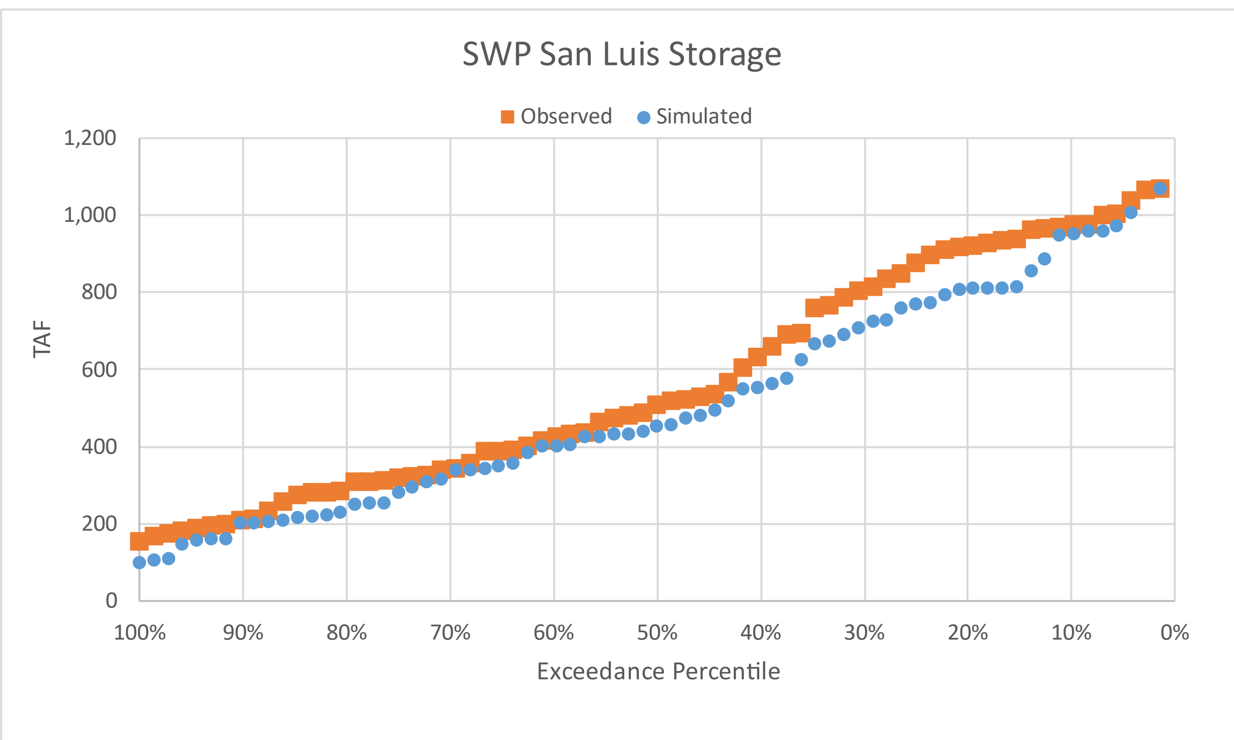


Figure A.7.4b. SWP San Luis Storage, Exceedance

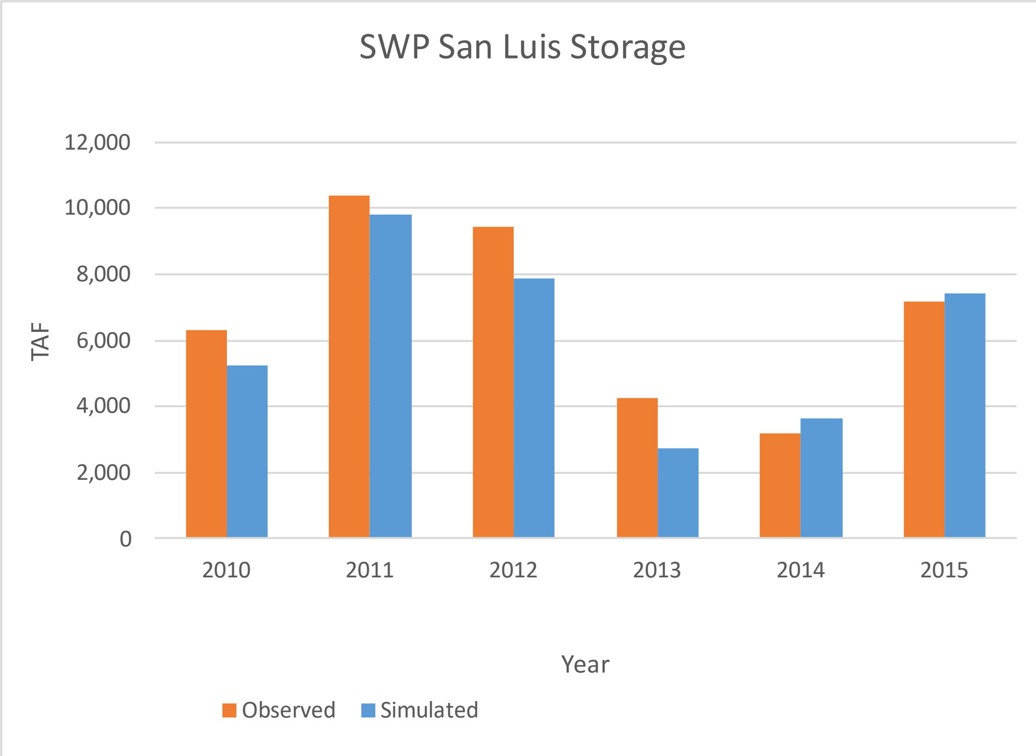


Figure A.7.4c. SWP San Luis Storage, Annual 2010 to 2015

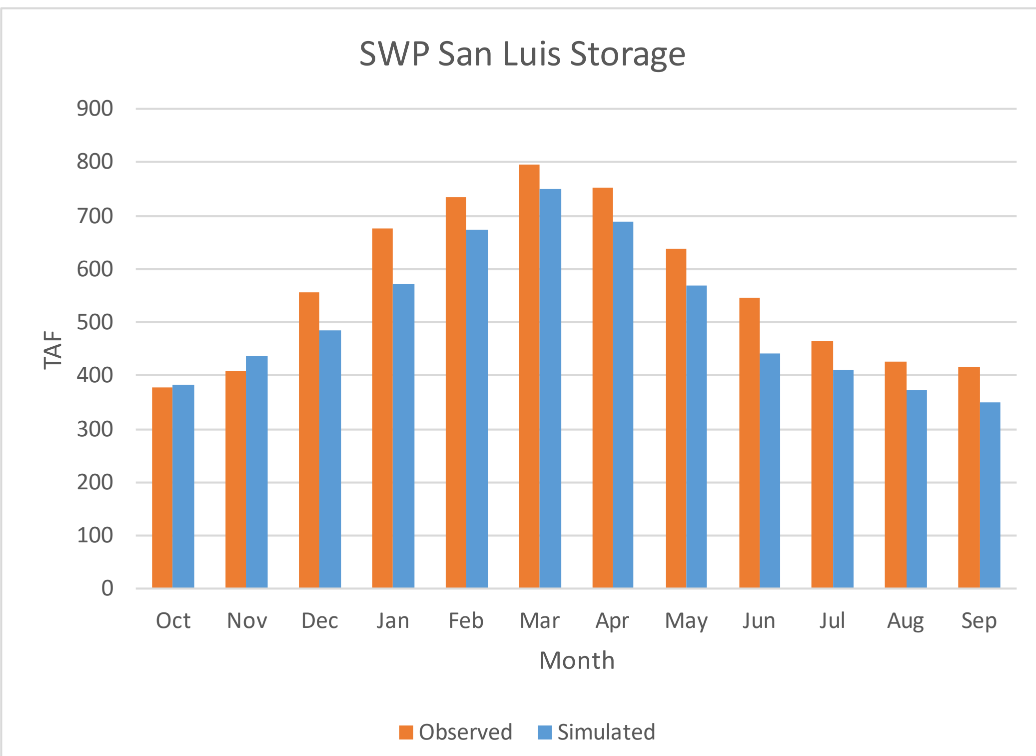


Figure A.7.4d. SWP San Luis Storage, Average Monthly

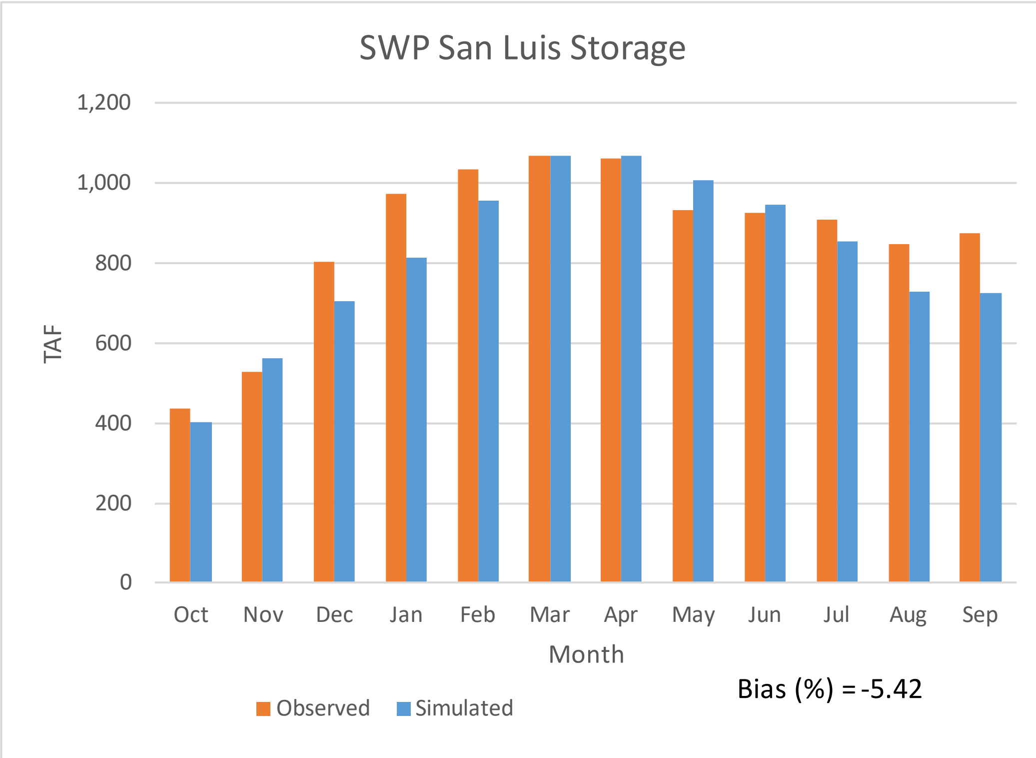


Figure A.7.4e. SWP San Luis Storage, Average Monthly (Wet)

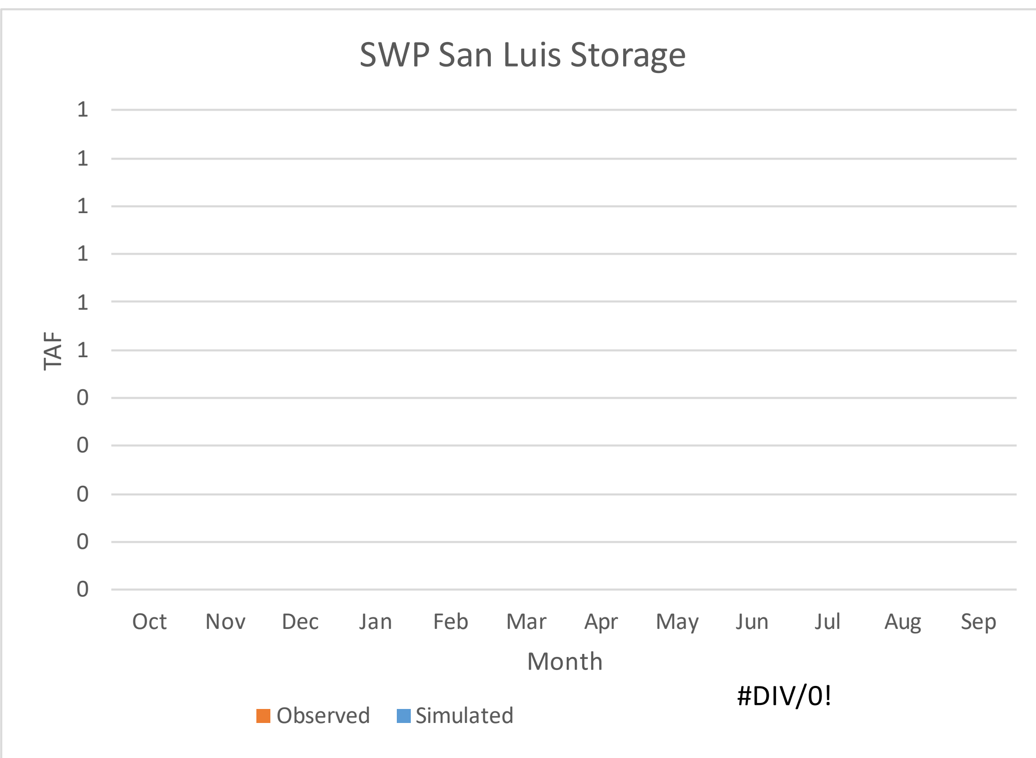


Figure A.7.4f. SWP San Luis Storage, Average Monthly (Above Normal)

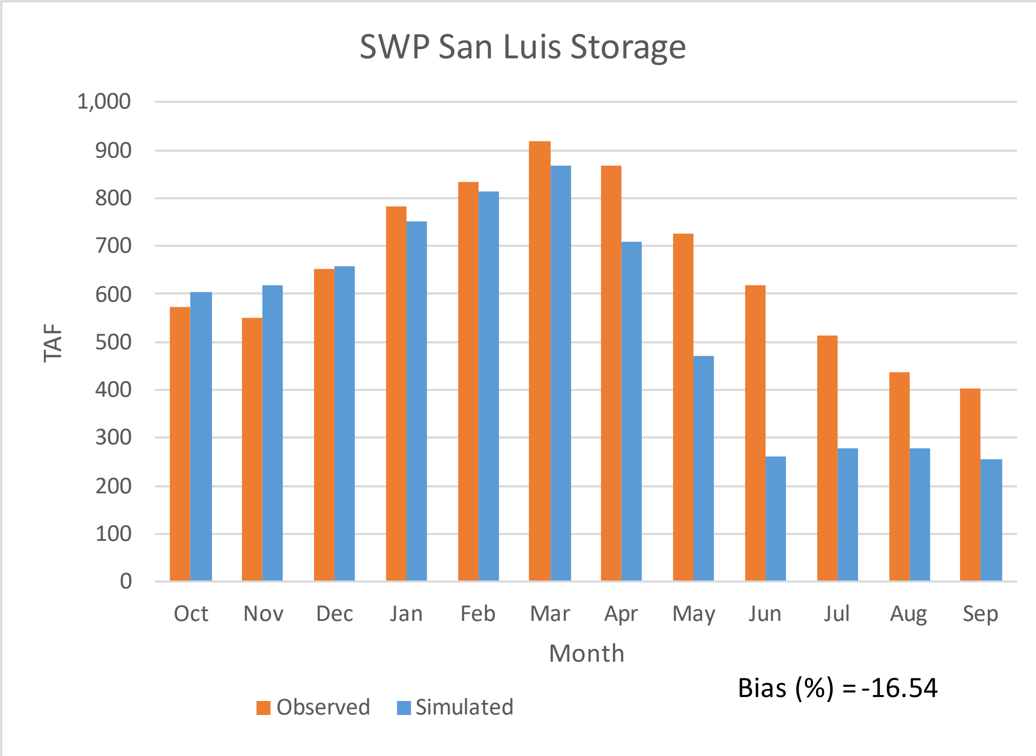


Figure A.7.4g. SWP San Luis Storage, Average Monthly (Below Normal)

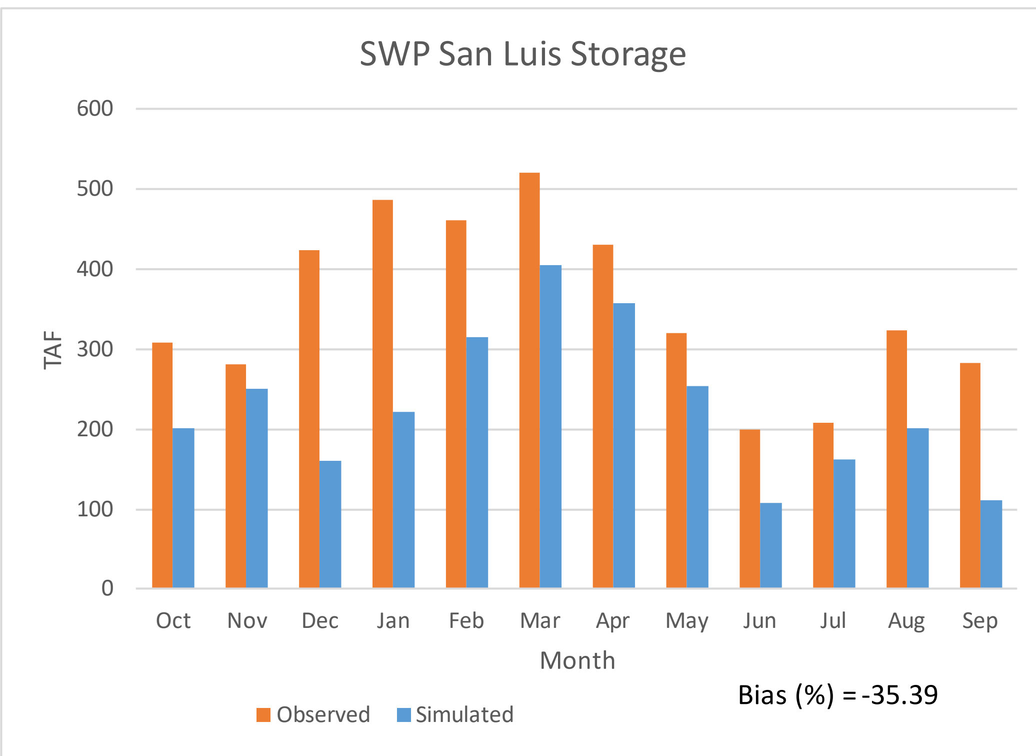


Figure A.7.4h. SWP San Luis Storage, Average Monthly (Dry)

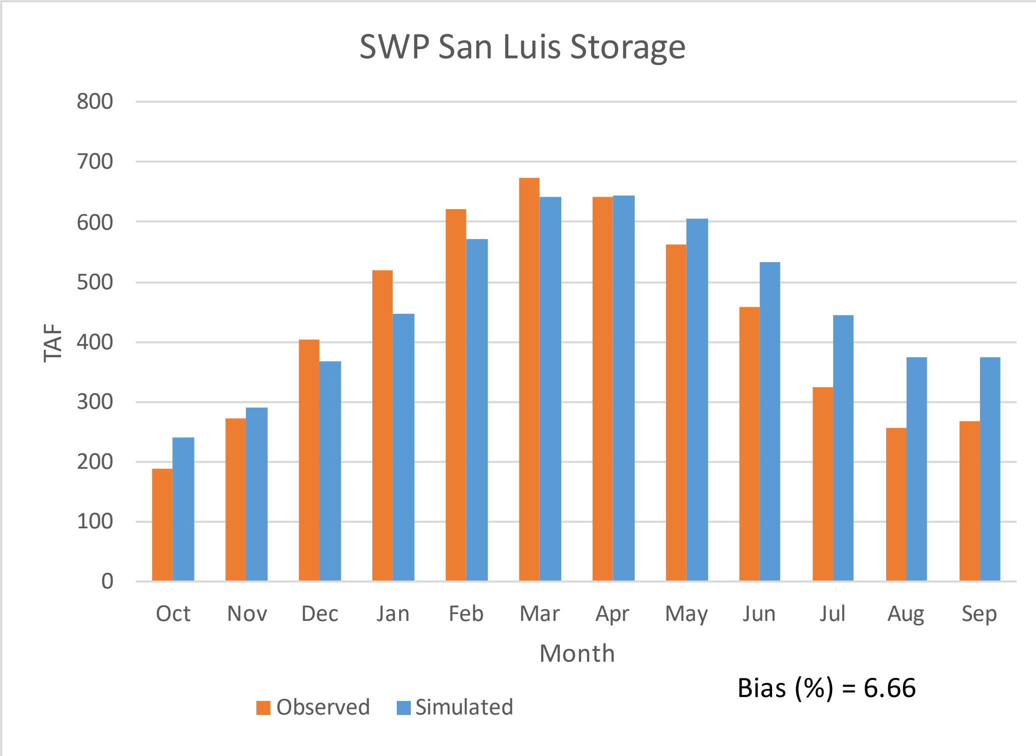


Figure A.7.4i. SWP San Luis Storage, Average Monthly (Critical)

A.7.5 Trinity River Imports

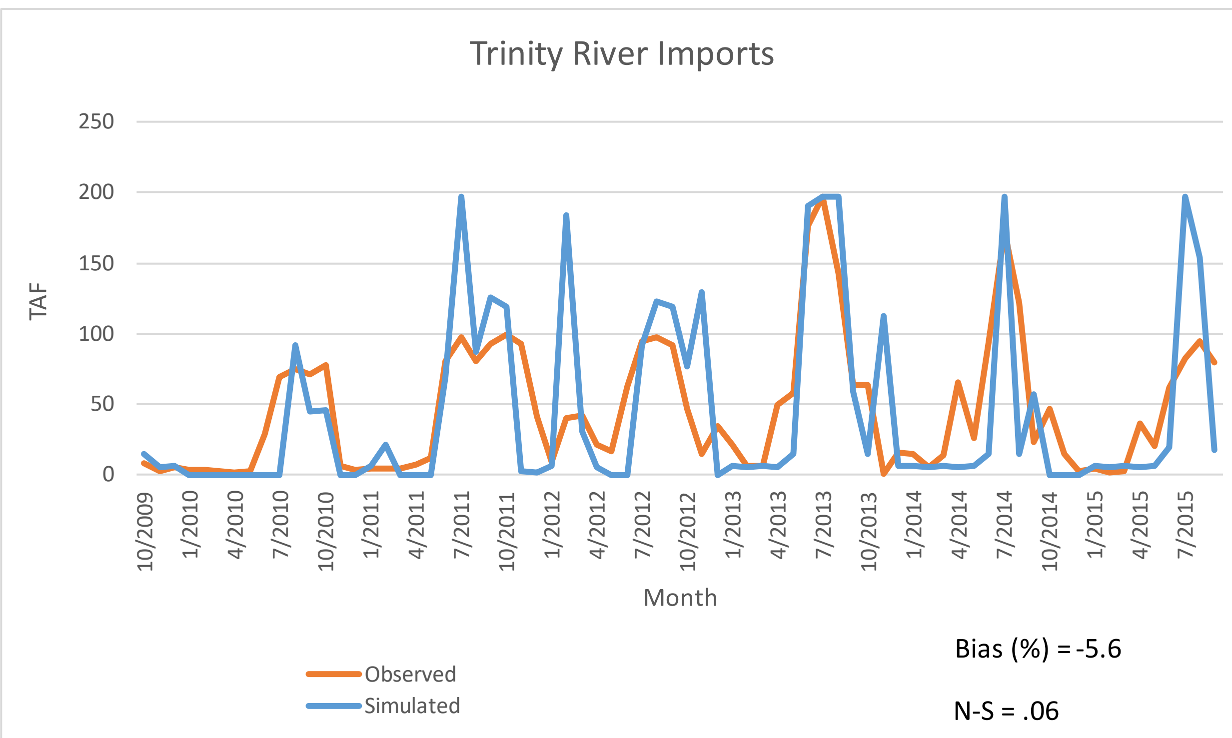


Figure A.7.5a. Trinity River Imports, Monthly 2010 to 2015

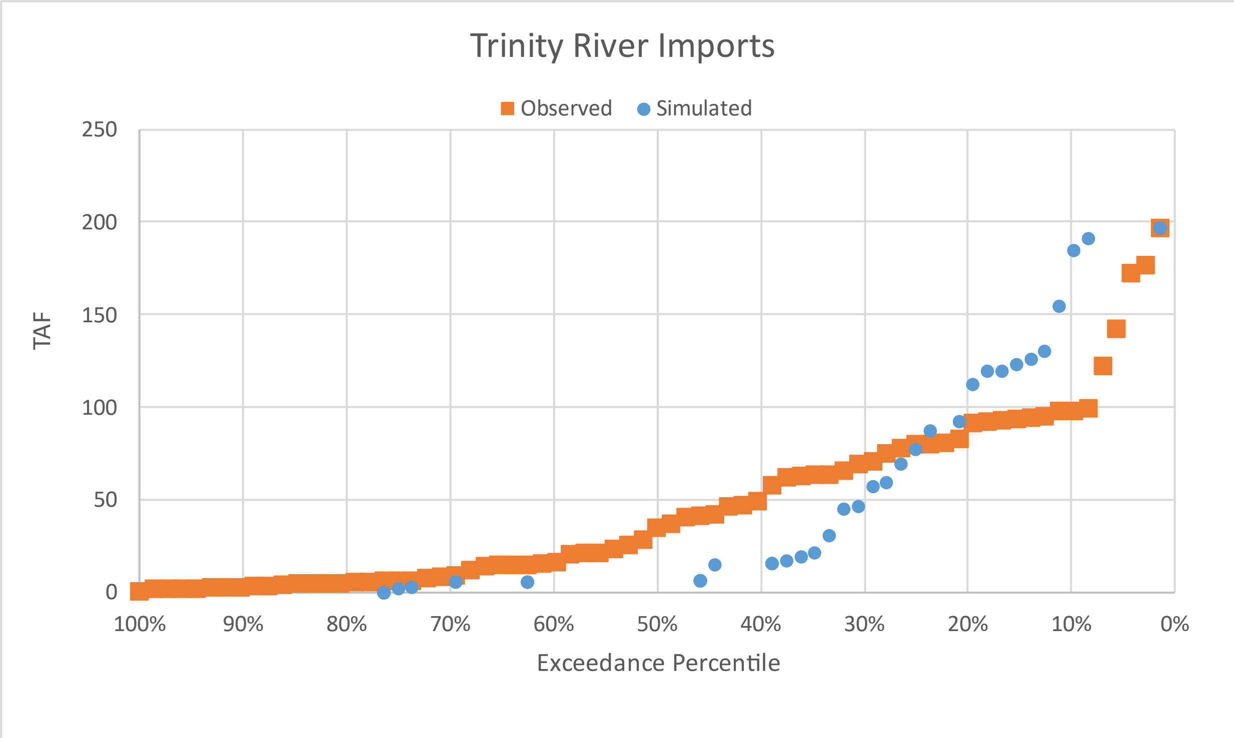


Figure A.7.5b. Trinity River Imports, Exceedance

Figure A.7.5c. Trinity River Imports, Annual 2010 to 2015

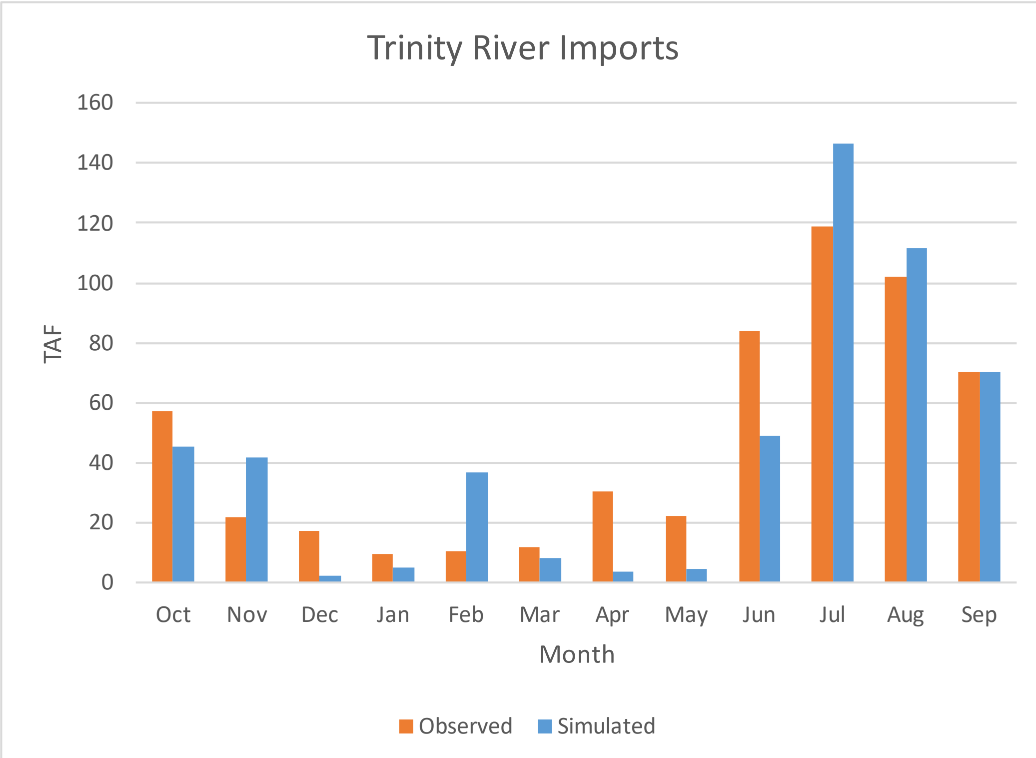


Figure A.7.5d. Trinity River Imports, Average Monthly

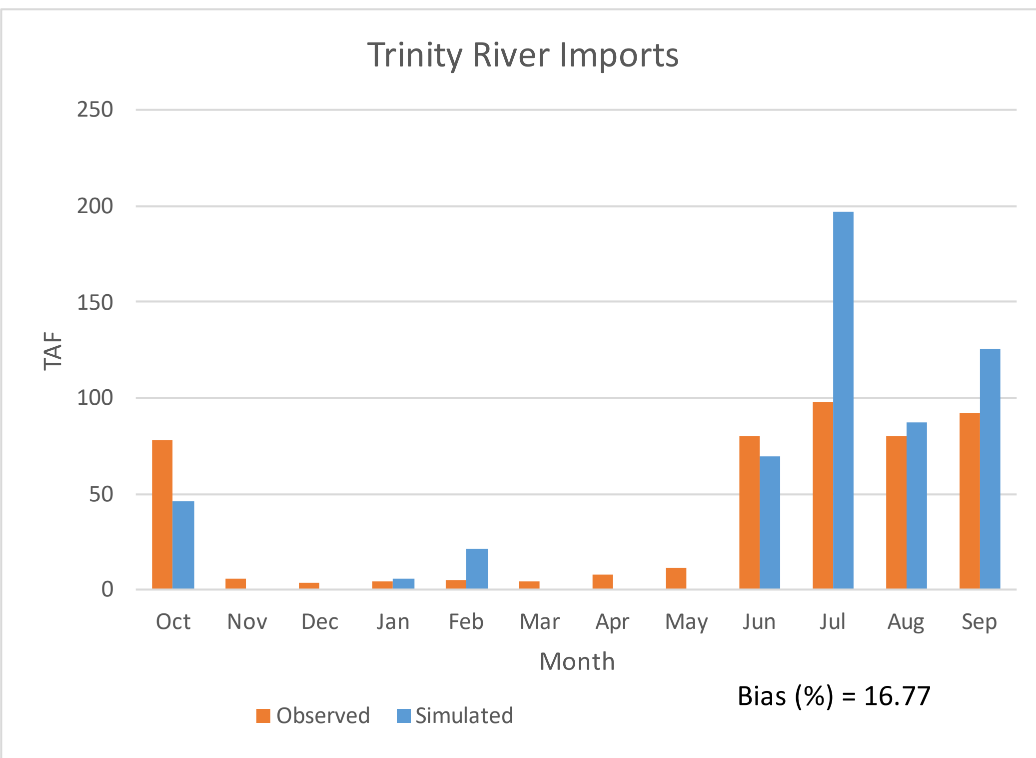


Figure A.7.5e. Trinity River Imports, Average Monthly (Wet)

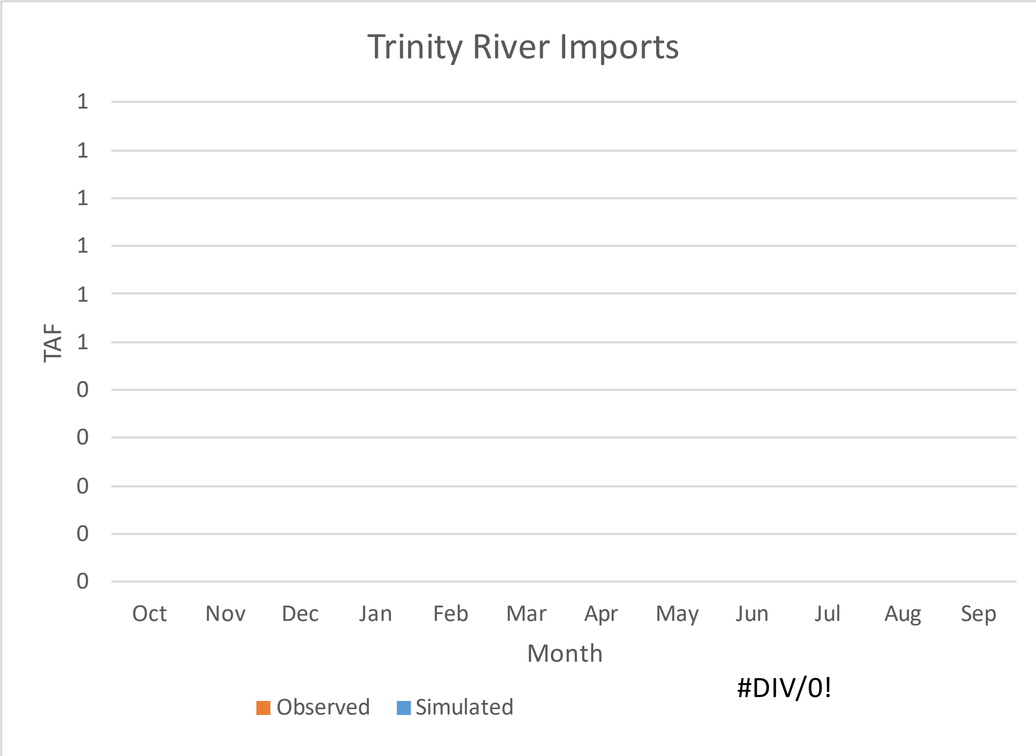


Figure A.7.5f. Trinity River Imports, Average Monthly (Above Normal)

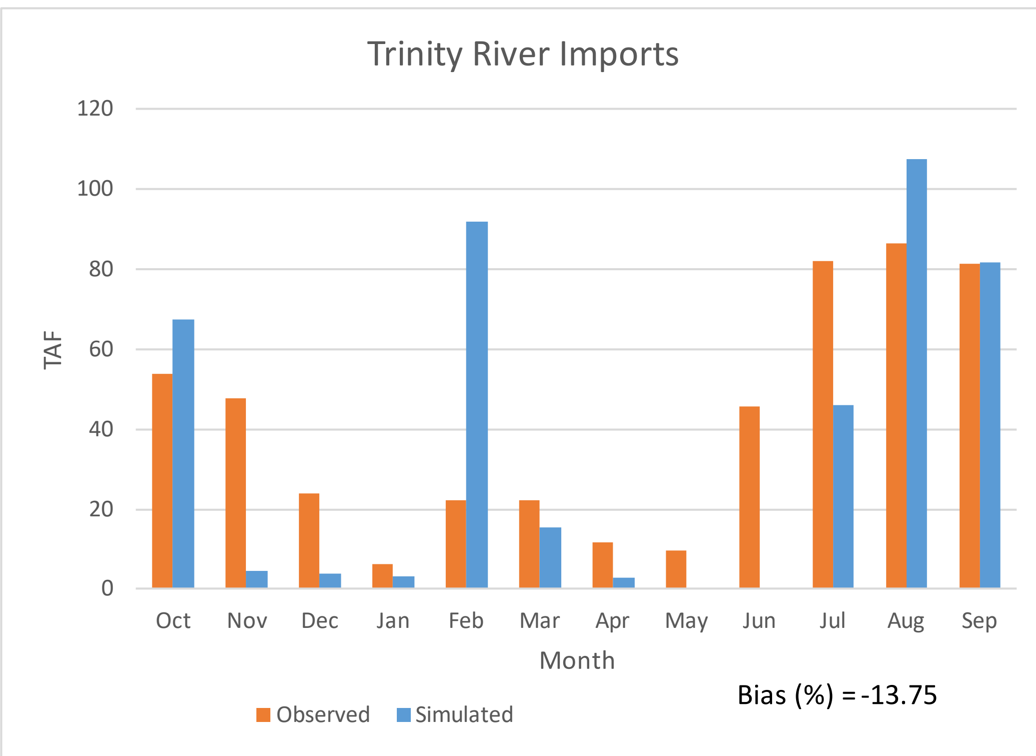


Figure A.7.5g. Trinity River Imports, Average Monthly (Below Normal)

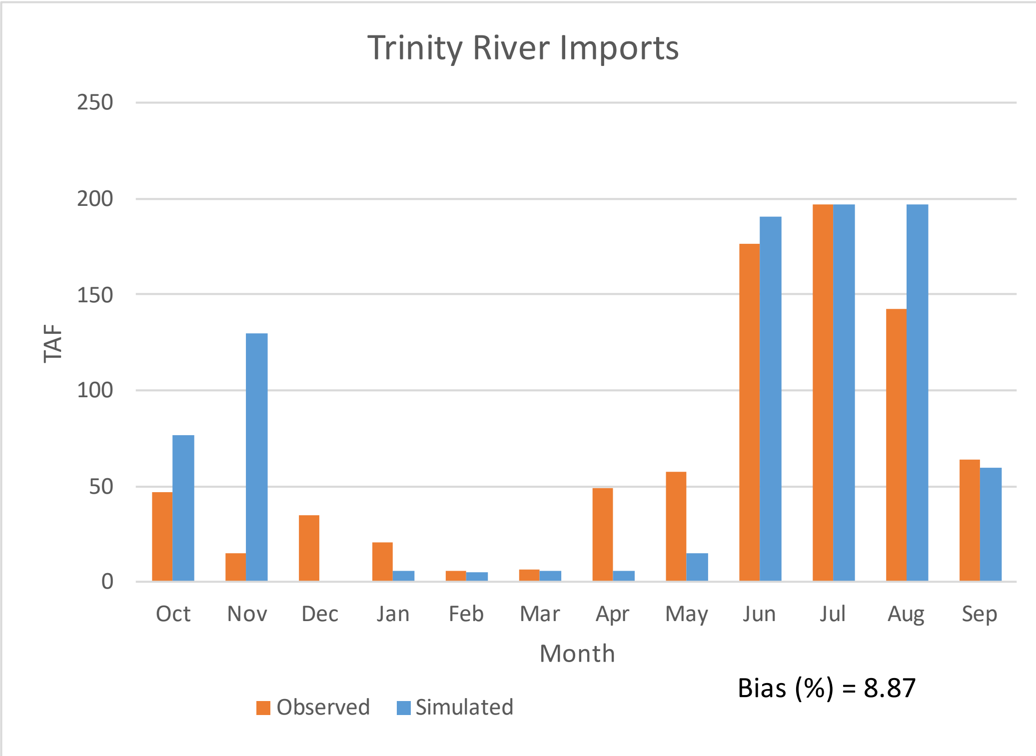


Figure A.7.5h. Trinity River Imports, Average Monthly (Dry)

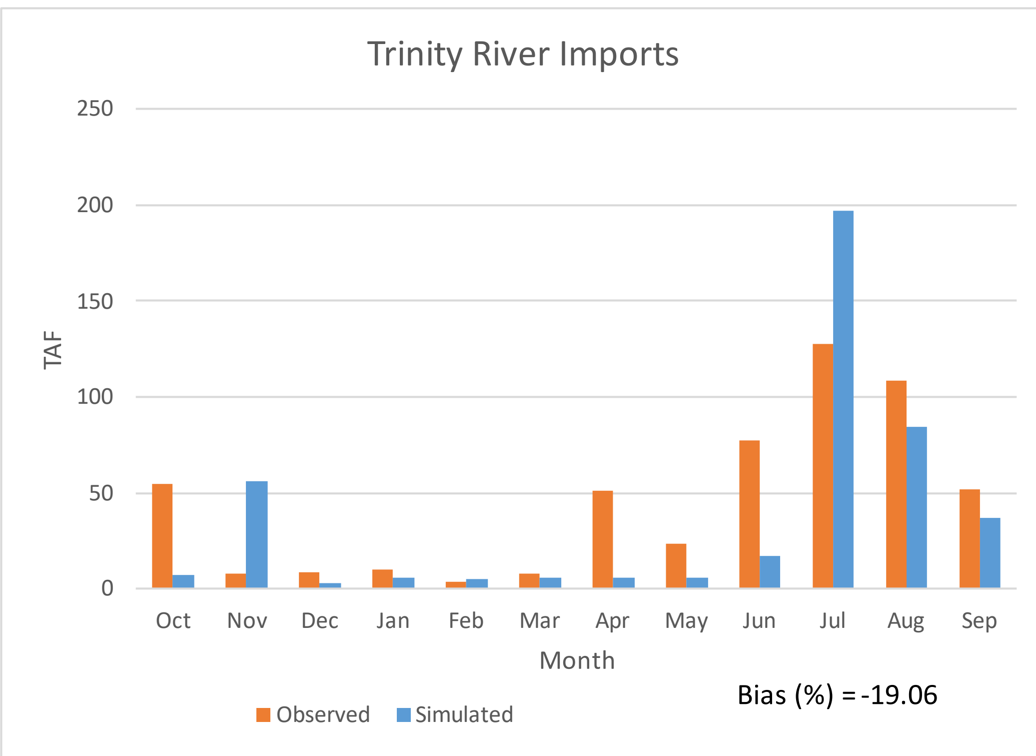


Figure A.7.5i. Trinity River Imports, Average Monthly (Critical)

A.7.6 American River at Fair Oaks

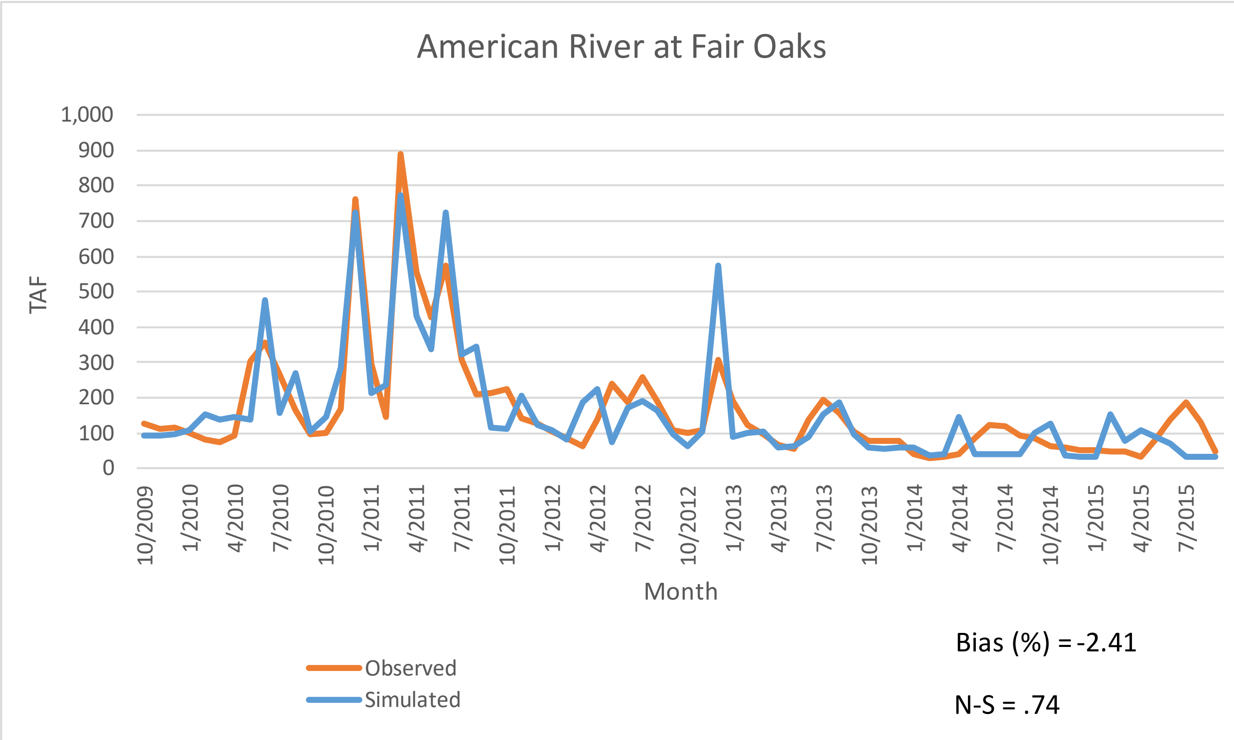


Figure A.7.6a. American River at Fair Oaks, Monthly 2010 to 2015

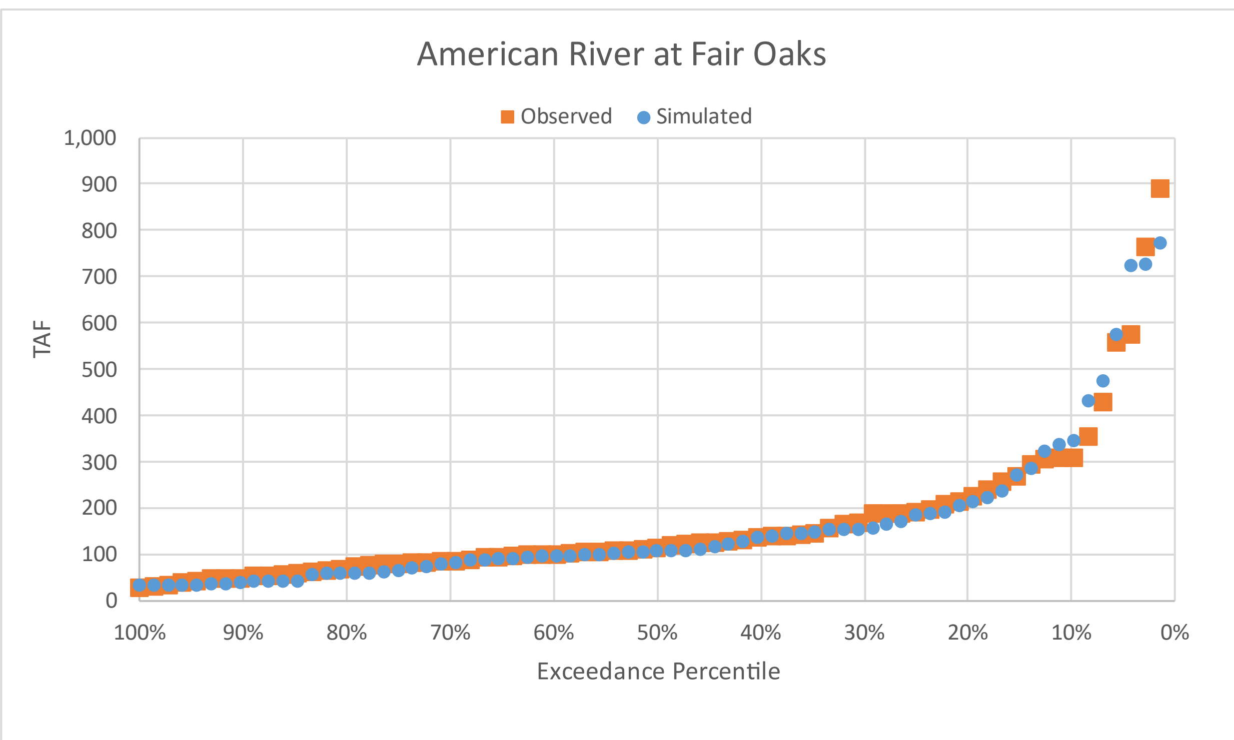


Figure A.7.6b. American River at Fair Oaks, Exceedance

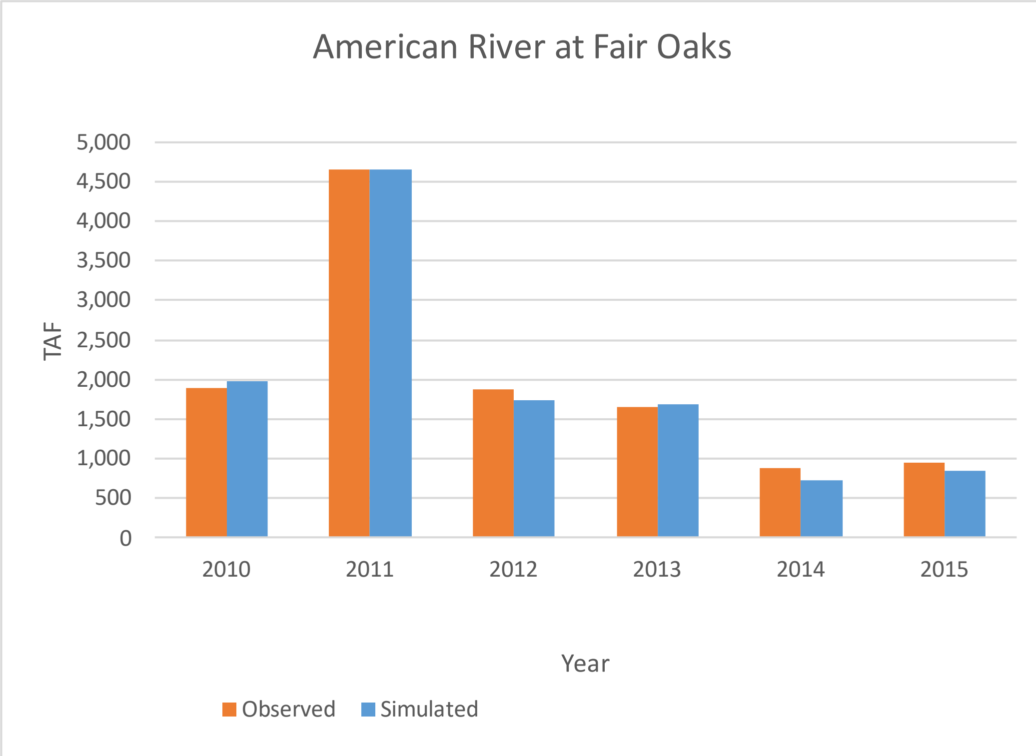


Figure A.7.6c. American River at Fair Oaks, Annual 2010 to 2015

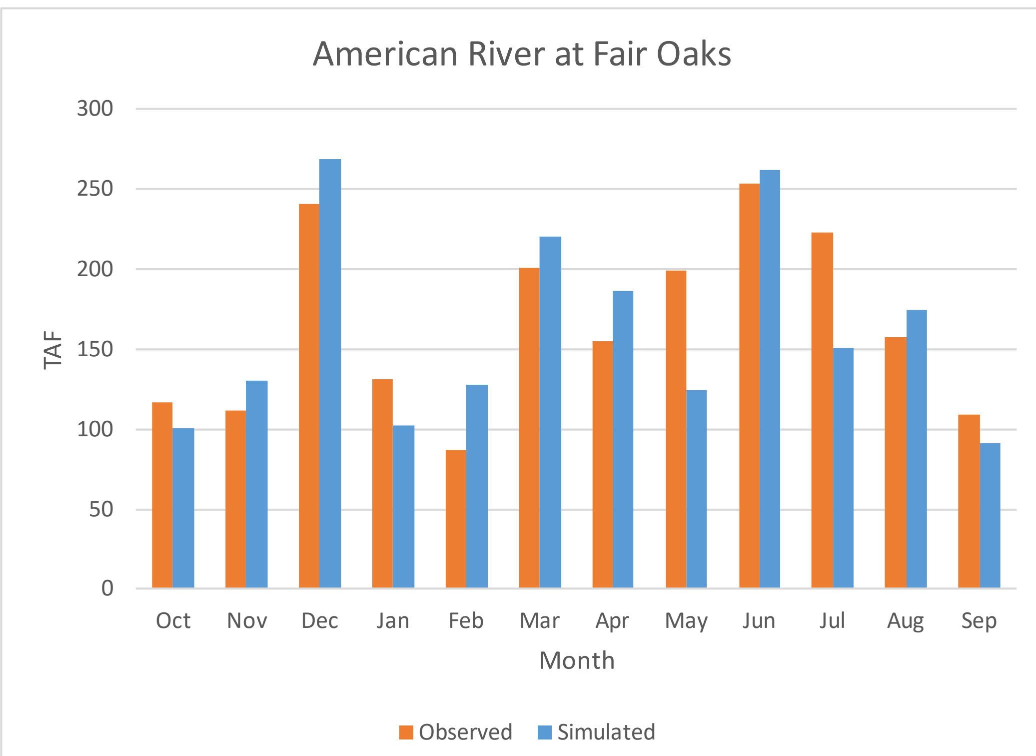


Figure A.7.6d. American River at Fair Oaks, Average Monthly

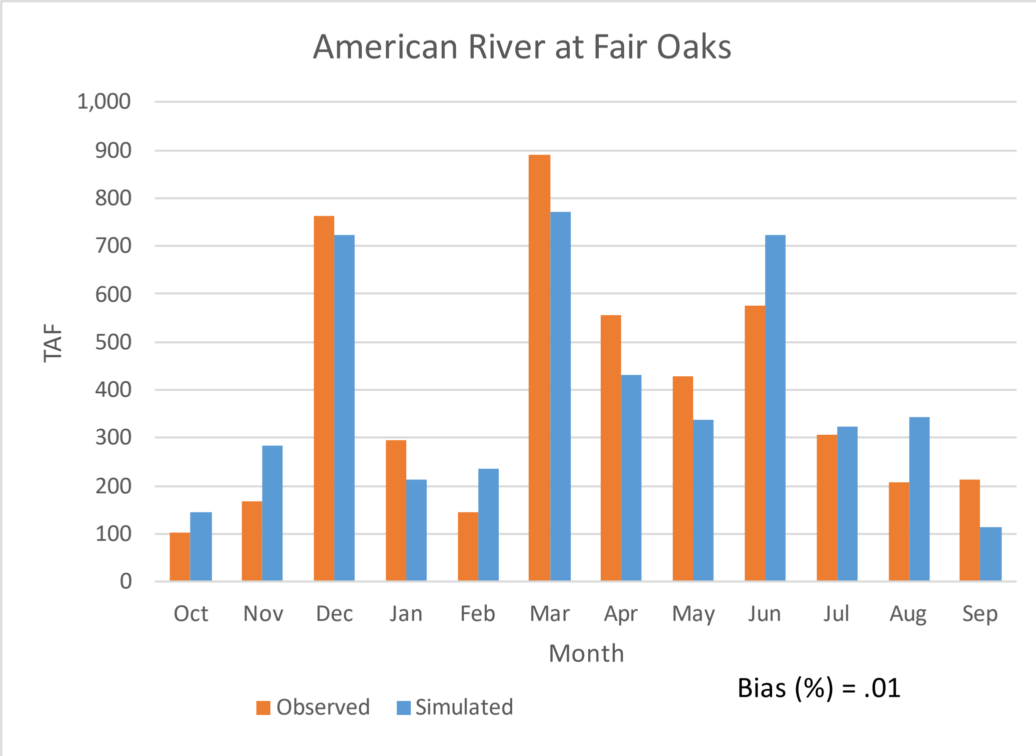


Figure A.7.6e. American River at Fair Oaks, Average Monthly (Wet)

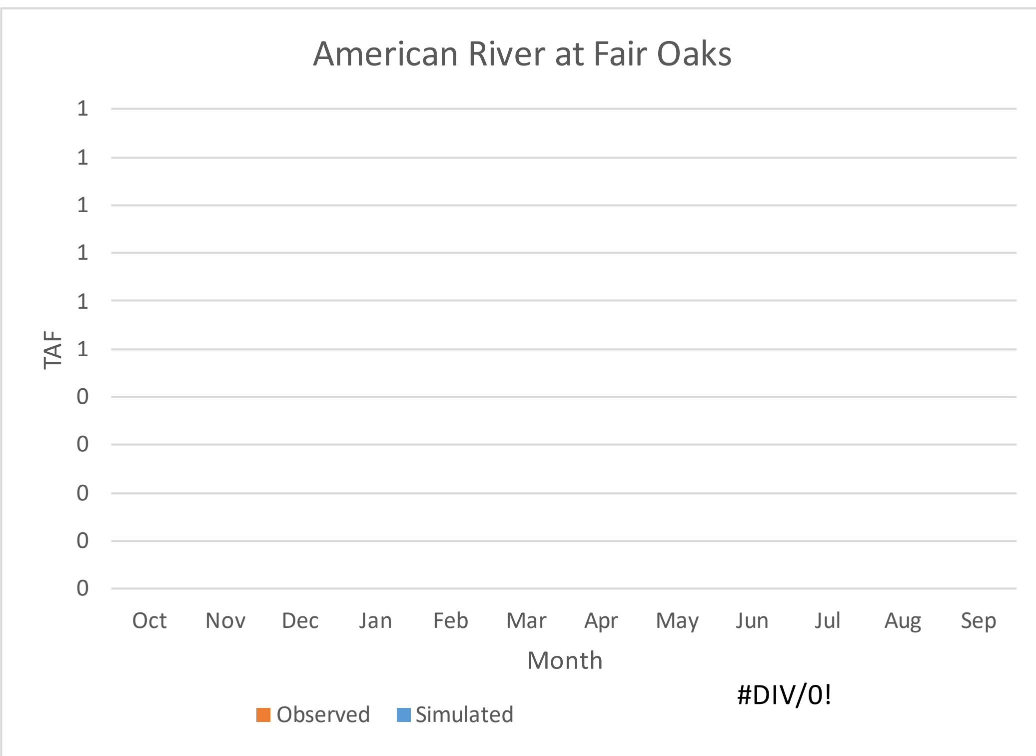


Figure A.7.6f. American River at Fair Oaks, Average Monthly (Above Normal)

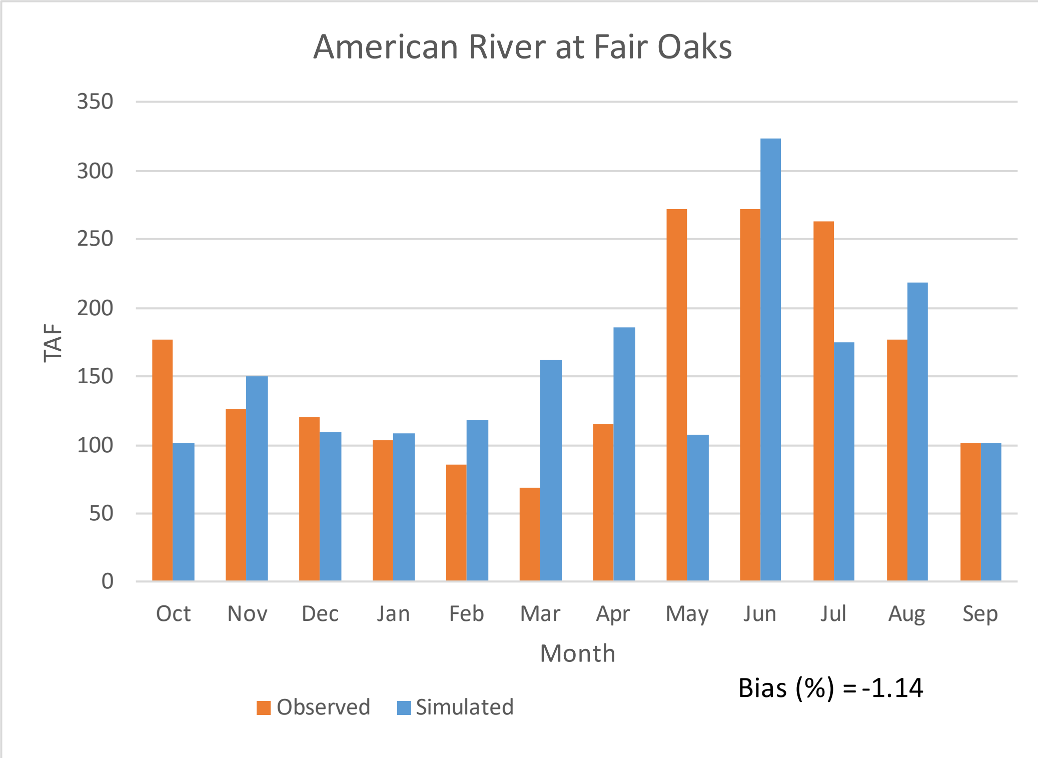


Figure A.7.6g. American River at Fair Oaks, Average Monthly (Below Normal)

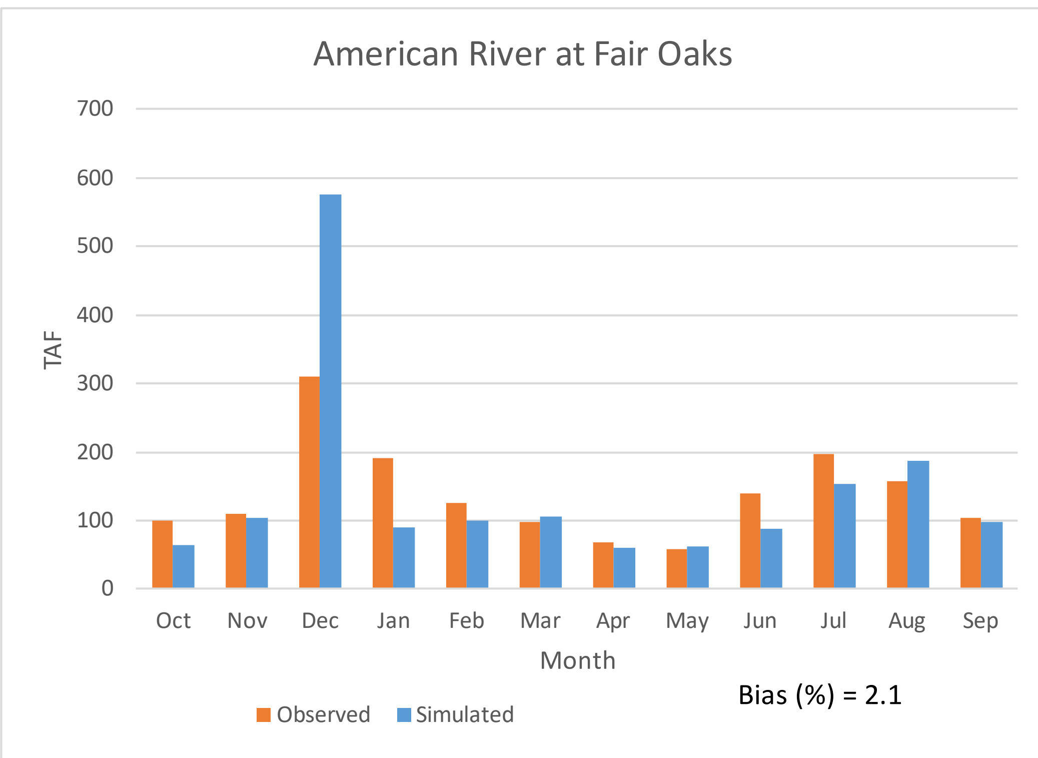


Figure A.7.6h. American River at Fair Oaks, Average Monthly (Dry)

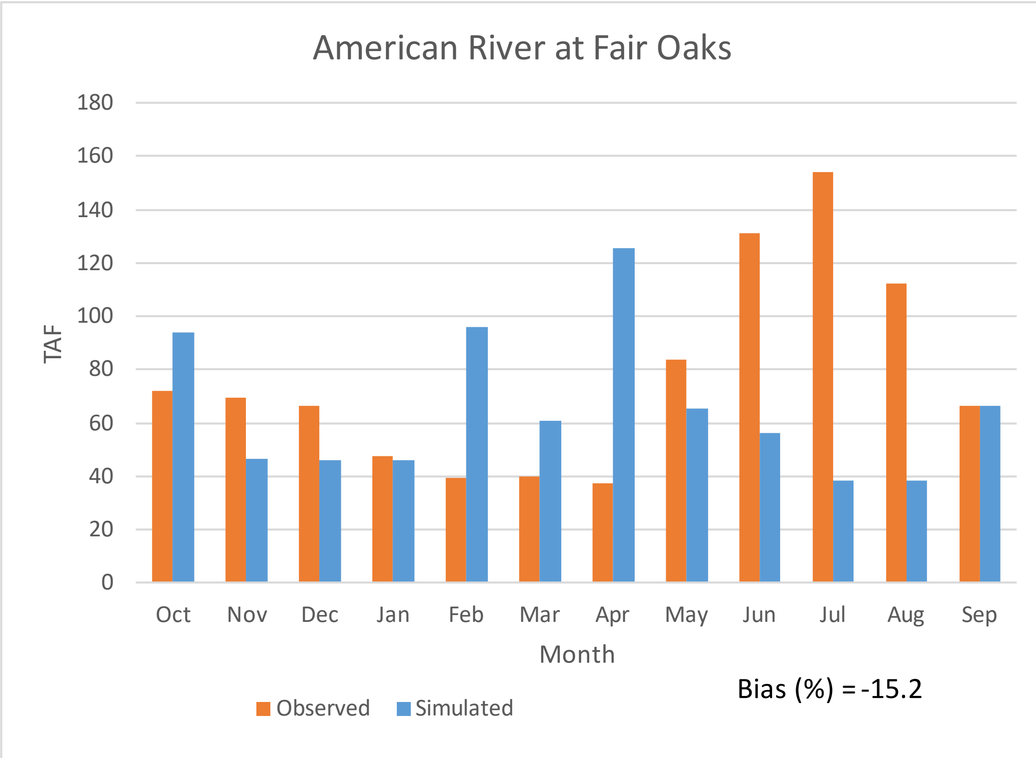


Figure A.7.6i. American River at Fair Oaks, Average Monthly (Critical)

A.7.7 Feather River at Gridley

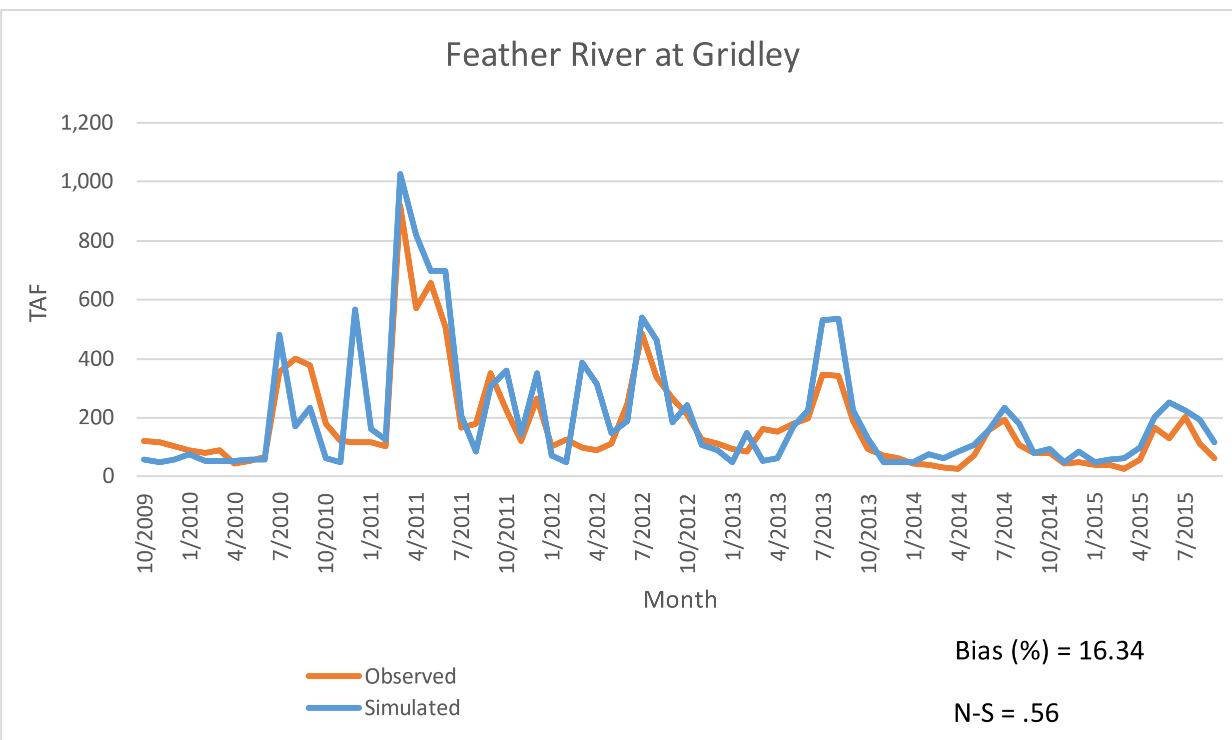


Figure A.7.7a. Feather River at Gridley, Monthly 2010 to 2015

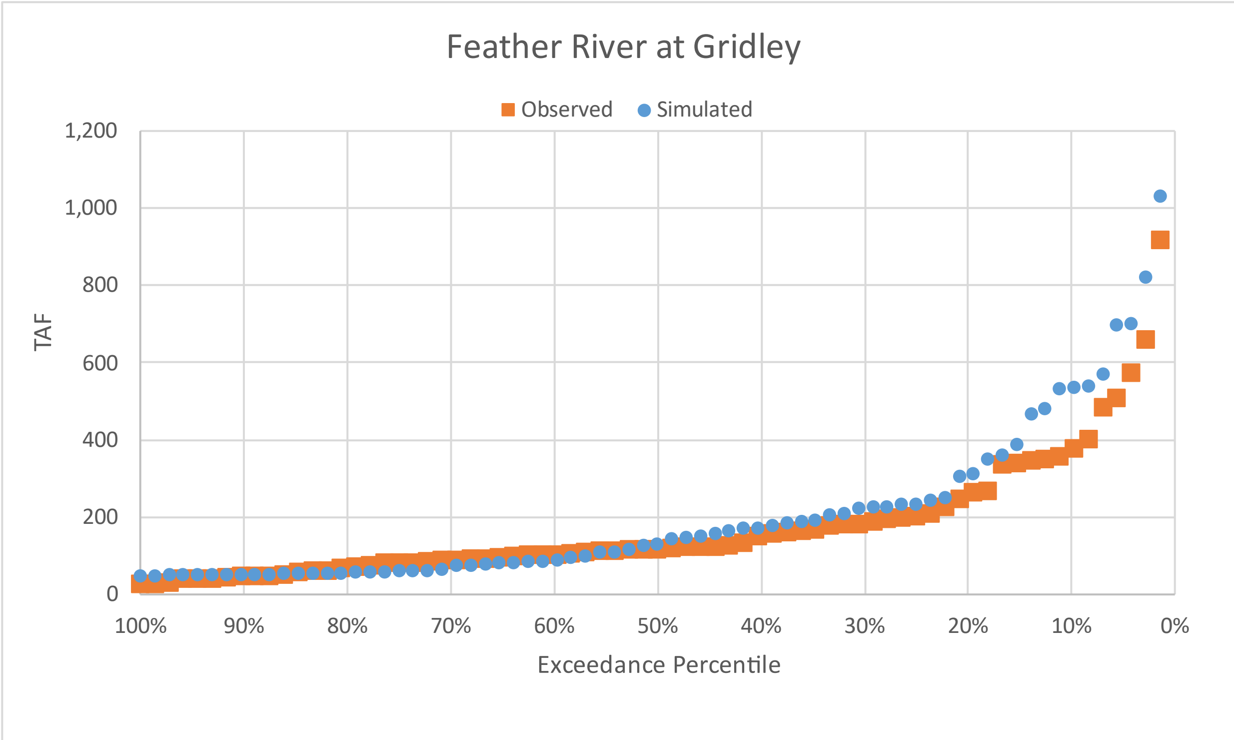


Figure A.7.7b. Feather River at Gridley, Exceedance

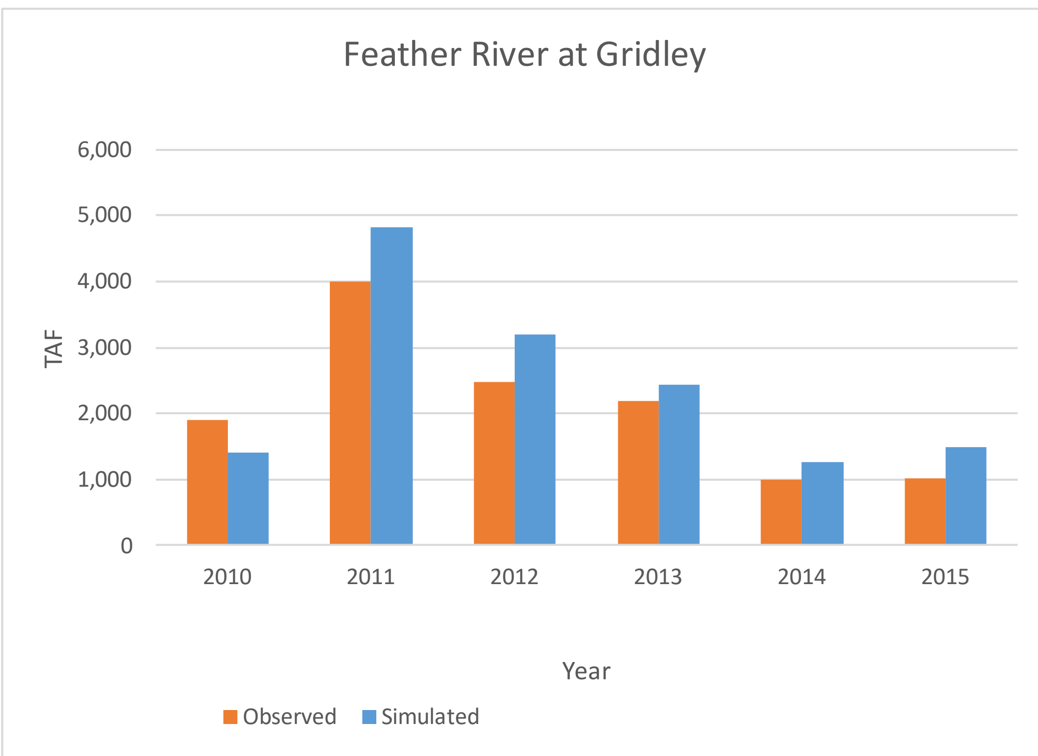


Figure A.7.7c. Feather River at Gridley, Annual 2010 to 2015

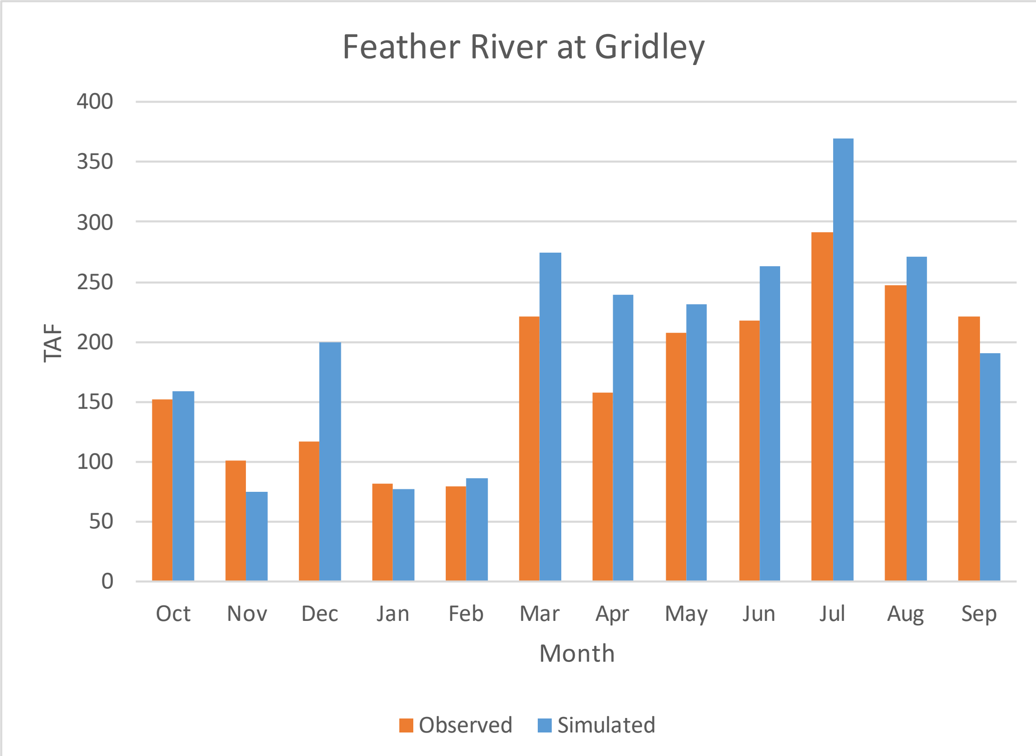


Figure A.7.7d. Feather River at Gridley, Average Monthly

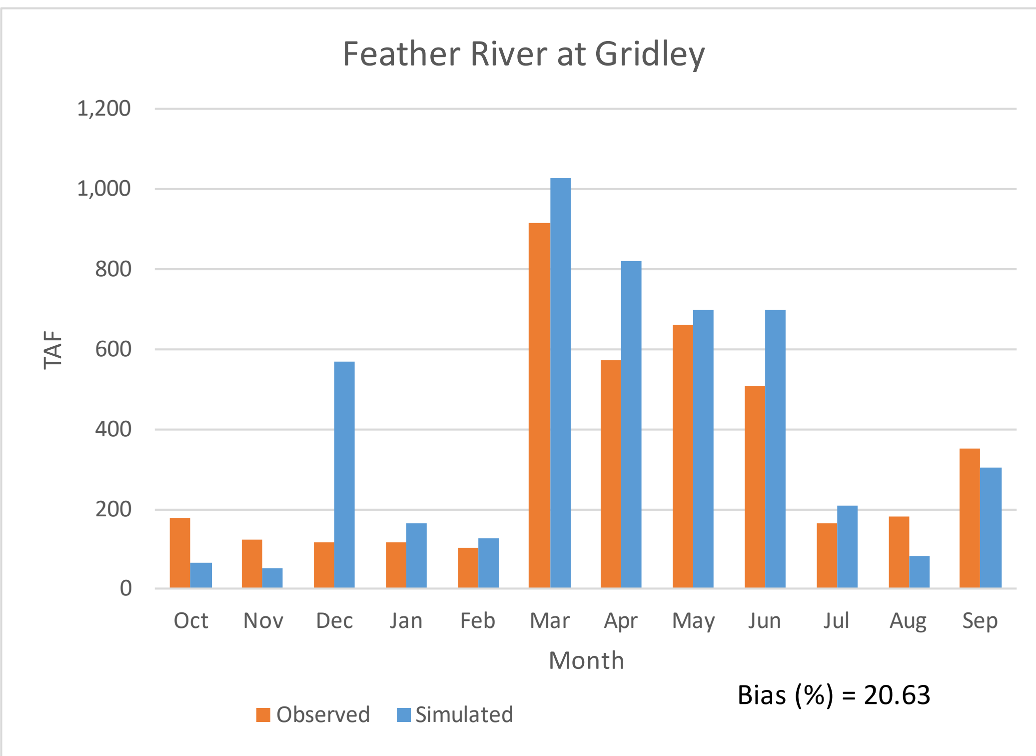


Figure A.7.7e. Feather River at Gridley, Average Monthly (Wet)

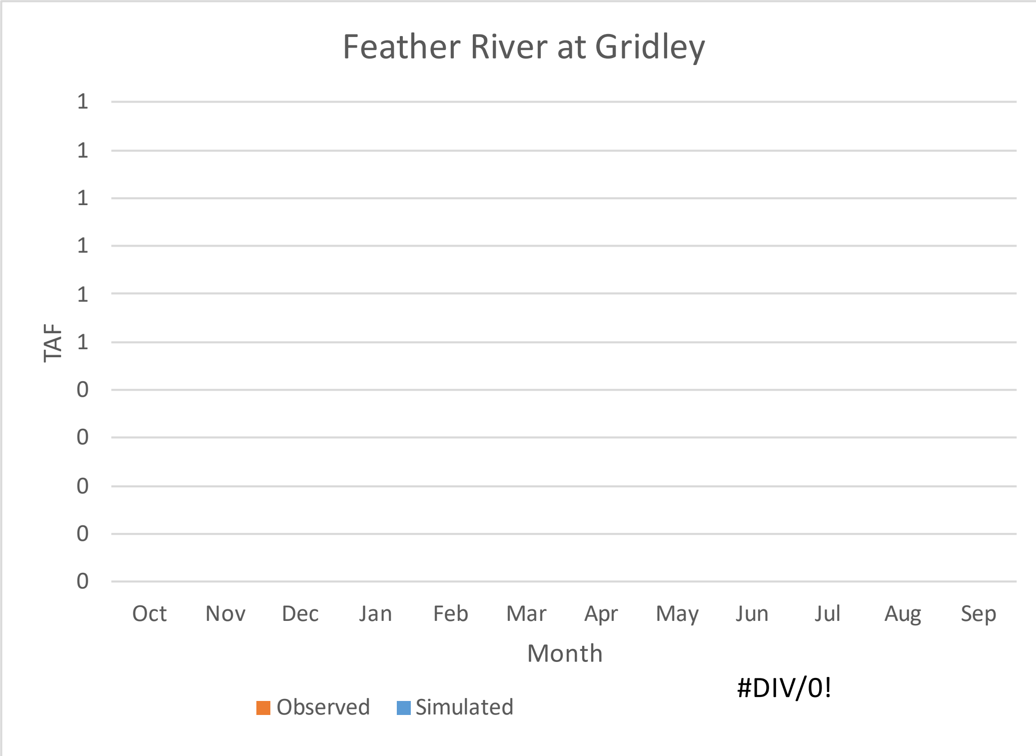


Figure A.7.7f. Feather River at Gridley, Average Monthly (Above Normal)

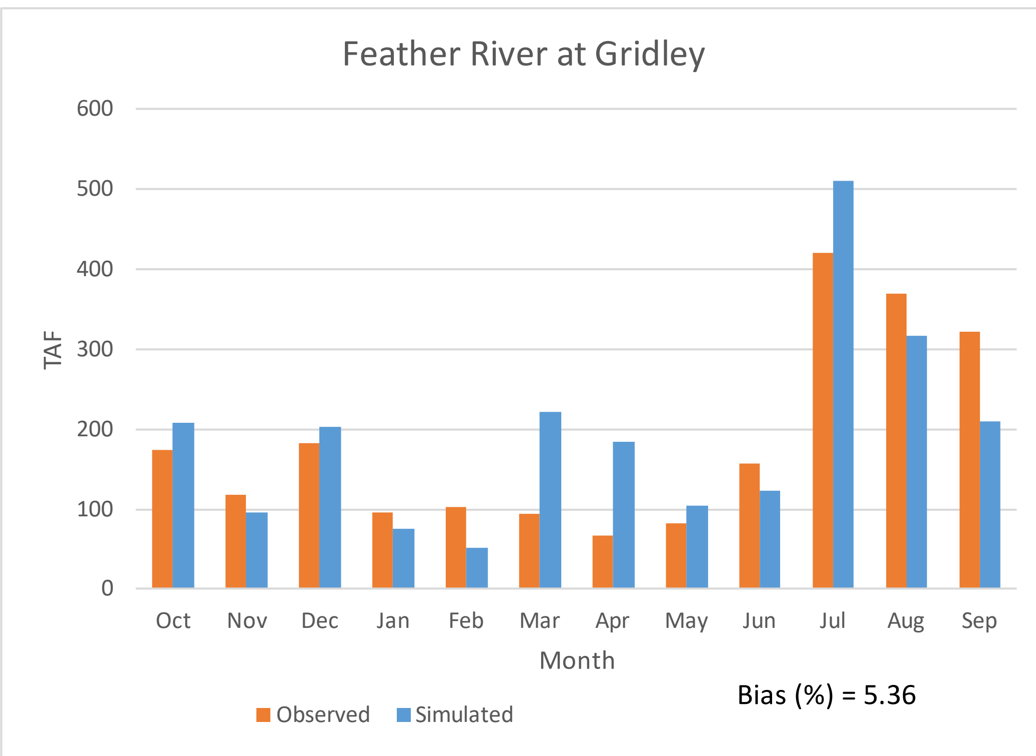


Figure A.7.7g. Feather River at Gridley, Average Monthly (Below Normal)

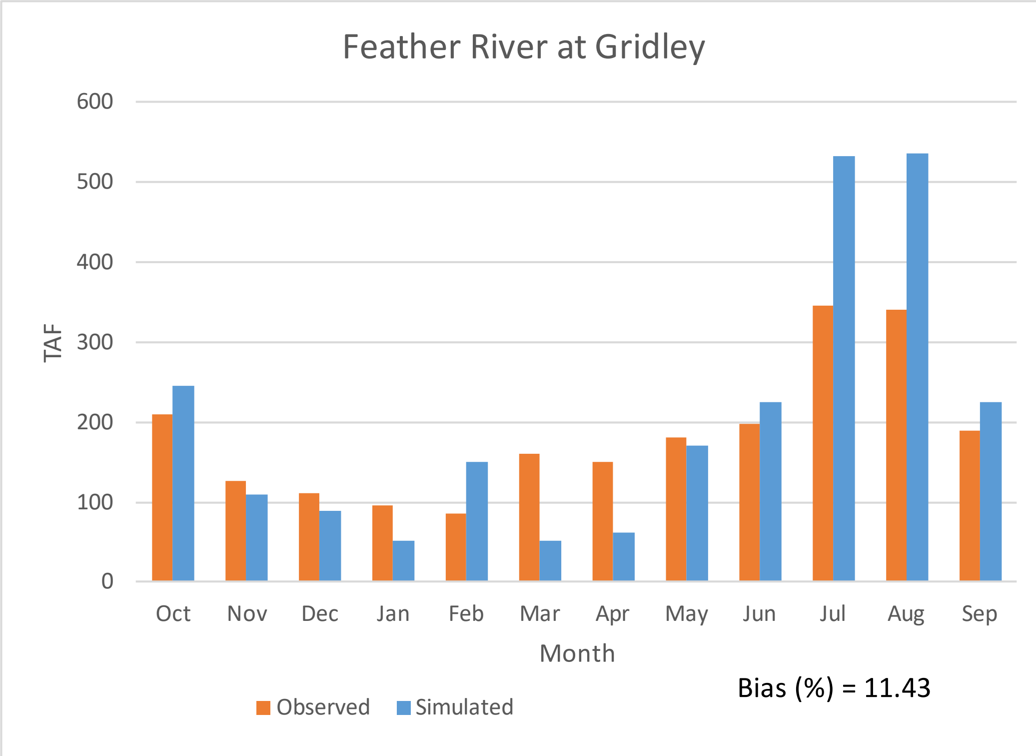


Figure A.7.7h. Feather River at Gridley, Average Monthly (Dry)

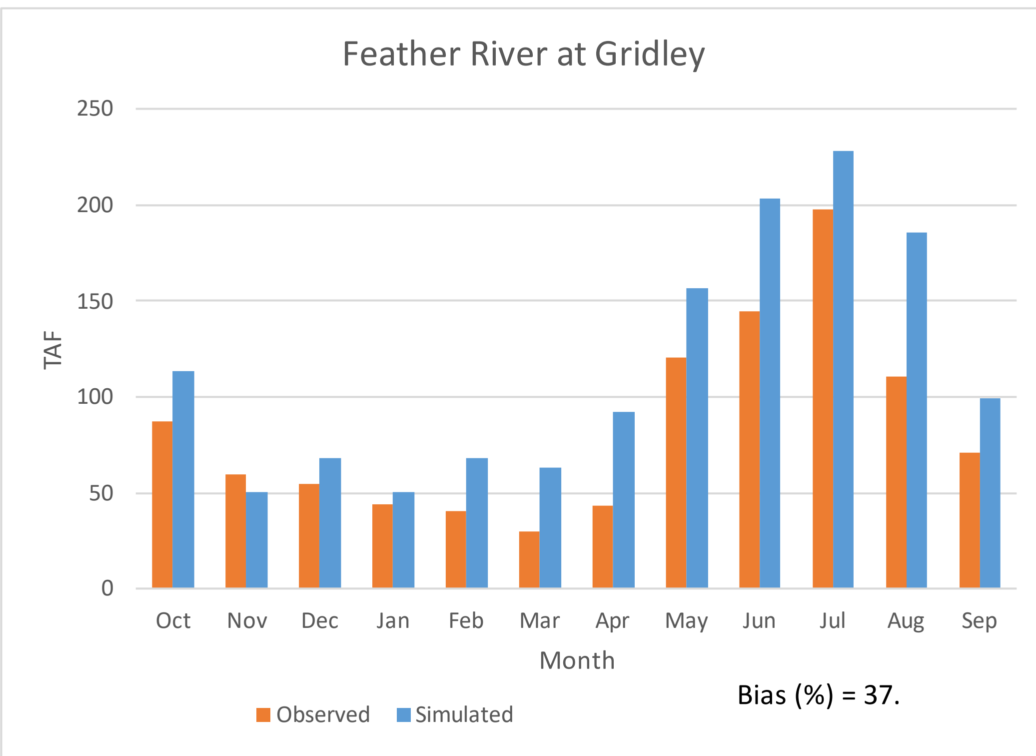


Figure A.7.7i. Feather River at Gridley, Average Monthly (Critical)

A.7.8 Sacramento River at Freeport

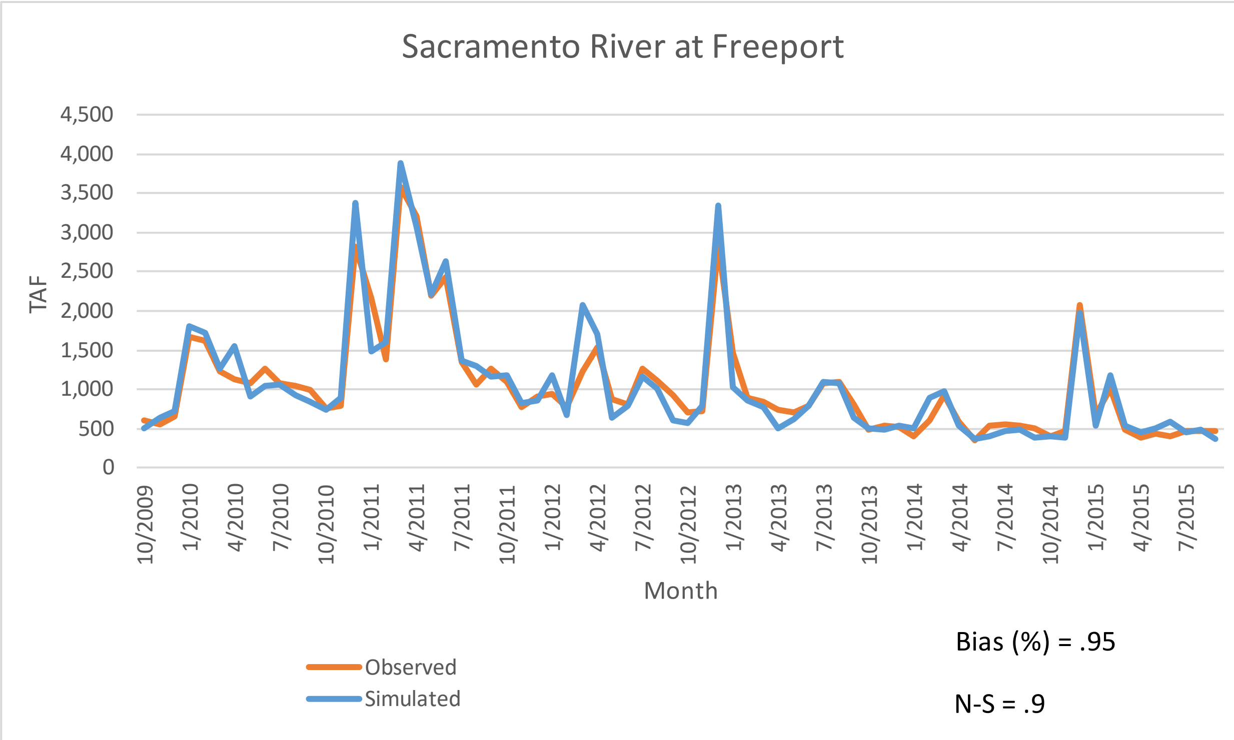


Figure A.7.8a. Sacramento River at Freeport, Monthly 2010 to 2015

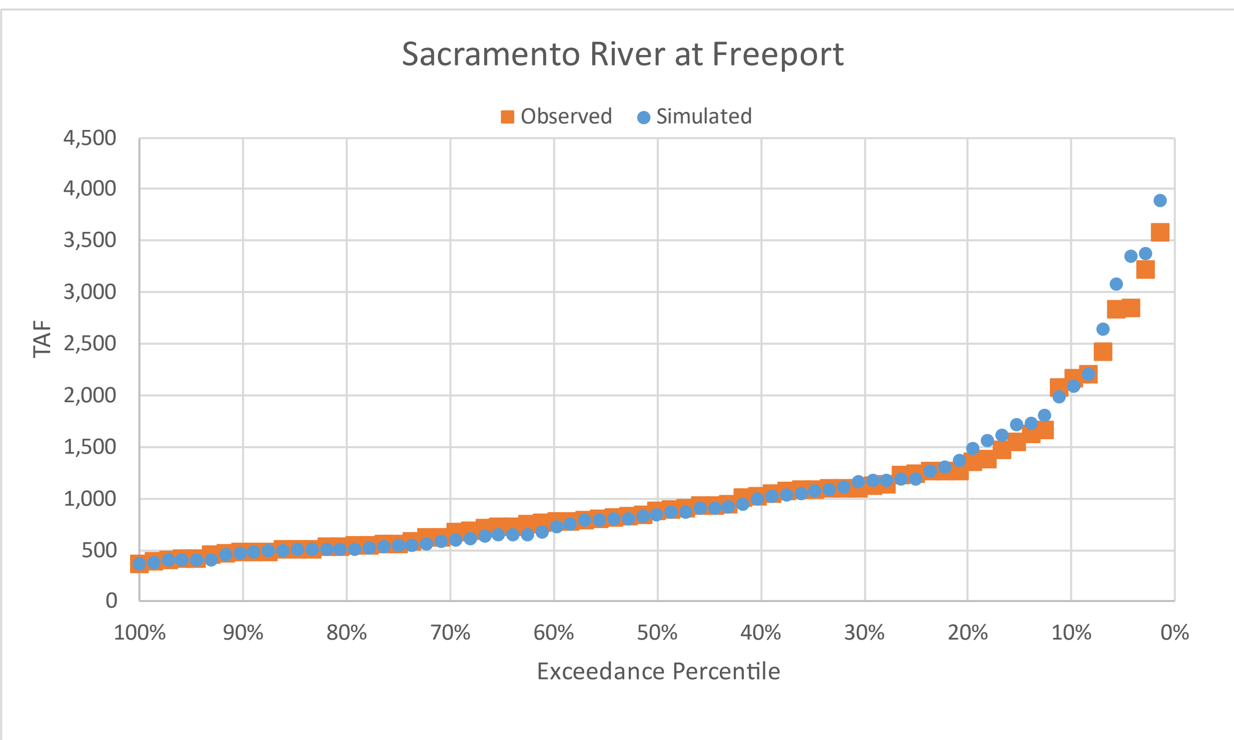


Figure A.7.8b. Sacramento River at Freeport, Exceedance

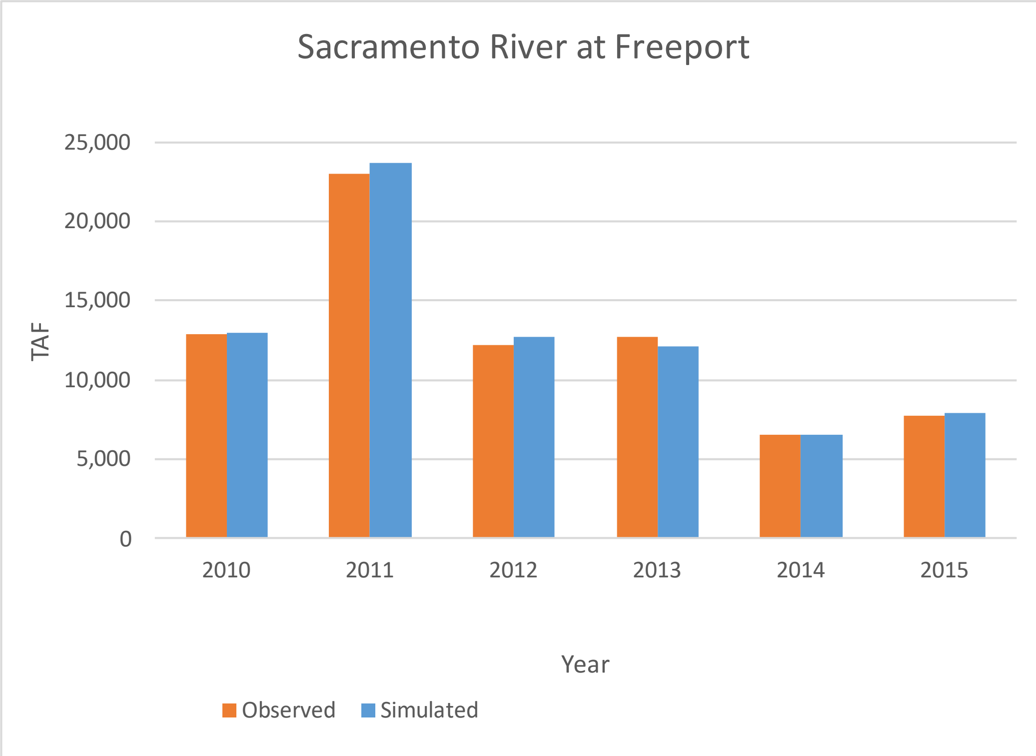


Figure A.7.8c. Sacramento River at Freeport, Annual 2010 to 2015

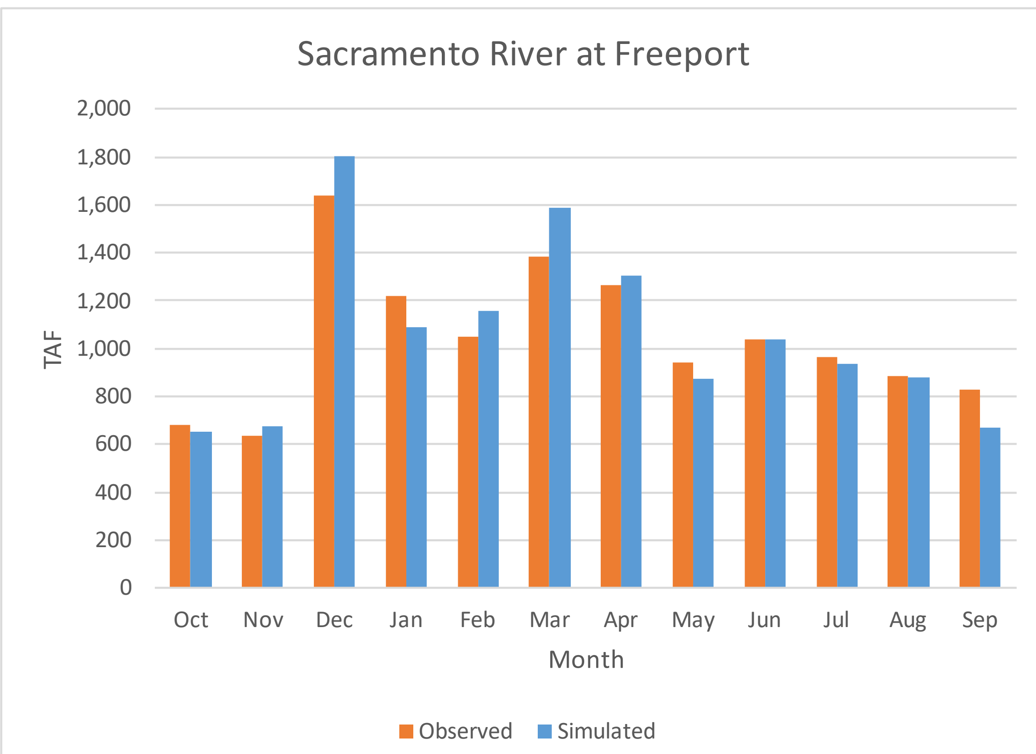


Figure A.7.8d. Sacramento River at Freeport, Average Monthly

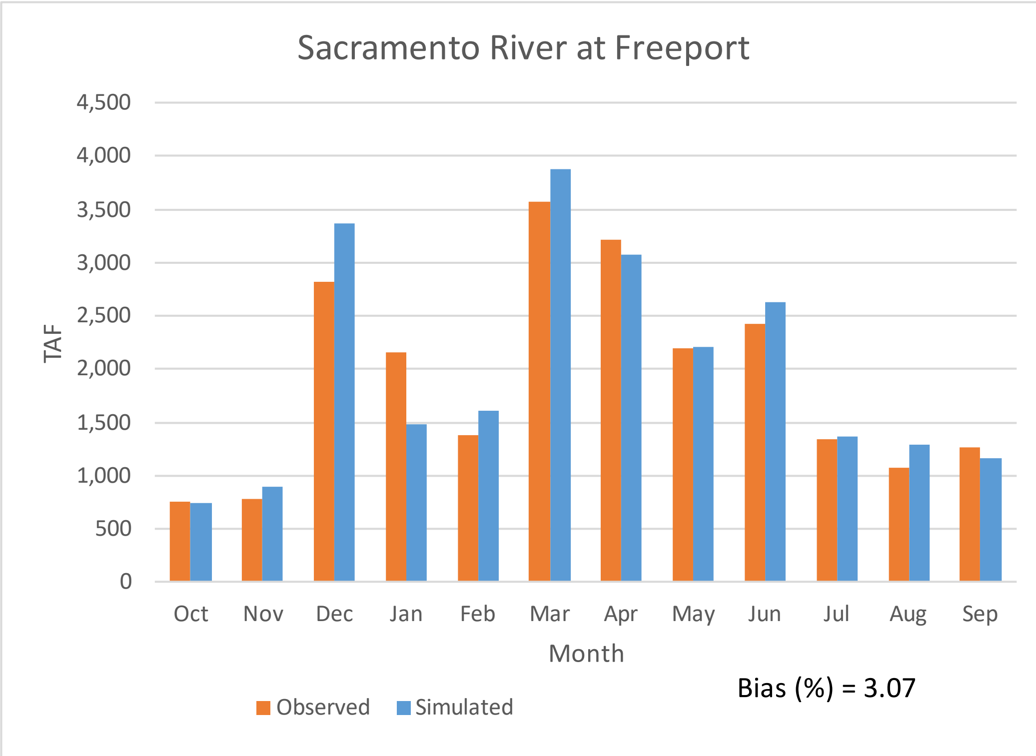


Figure A.7.8e. Sacramento River at Freeport, Average Monthly (Wet)

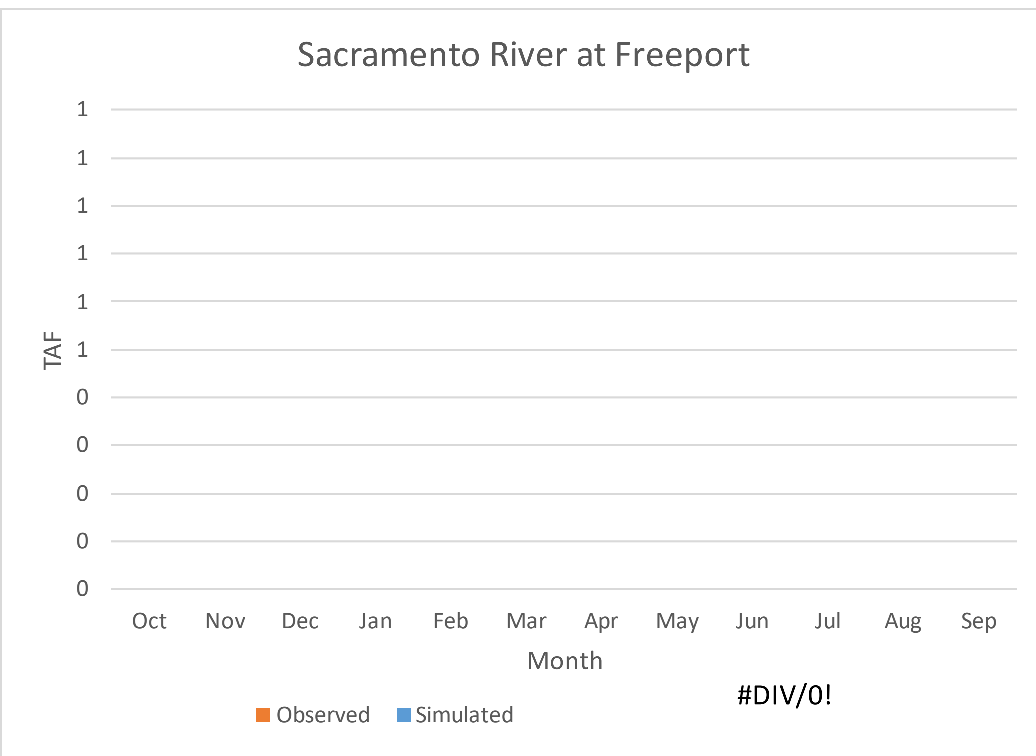


Figure A.7.8f. Sacramento River at Freeport, Average Monthly (Above Normal)

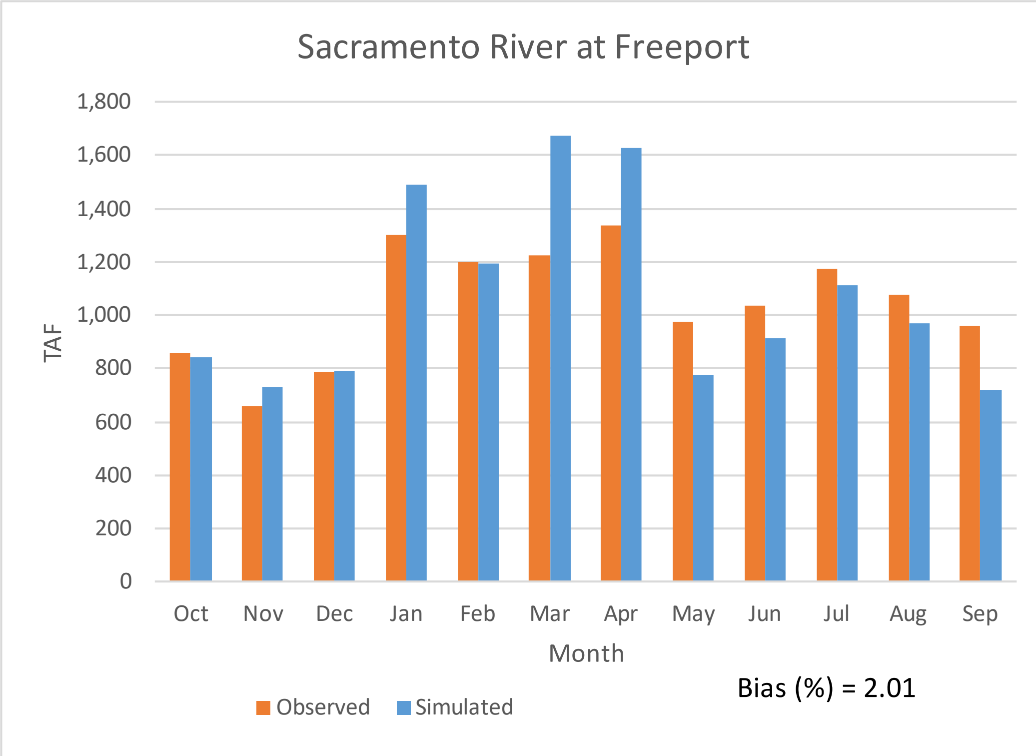


Figure A.7.8g. Sacramento River at Freeport, Average Monthly (Below Normal)

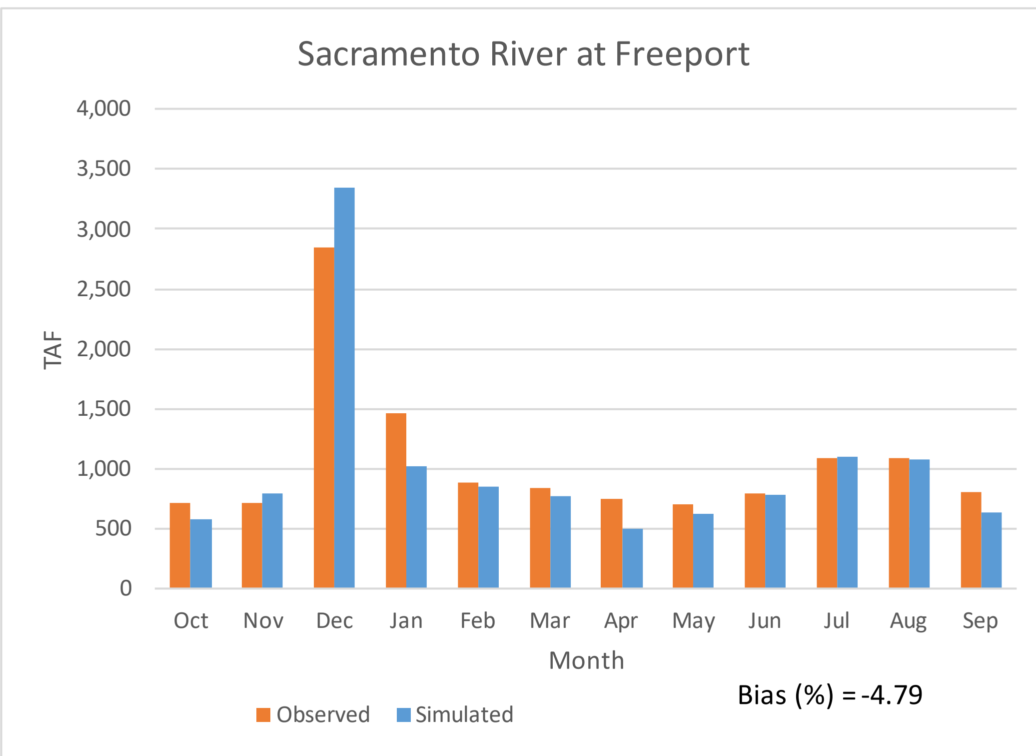


Figure A.7.8h. Sacramento River at Freeport, Average Monthly (Dry)

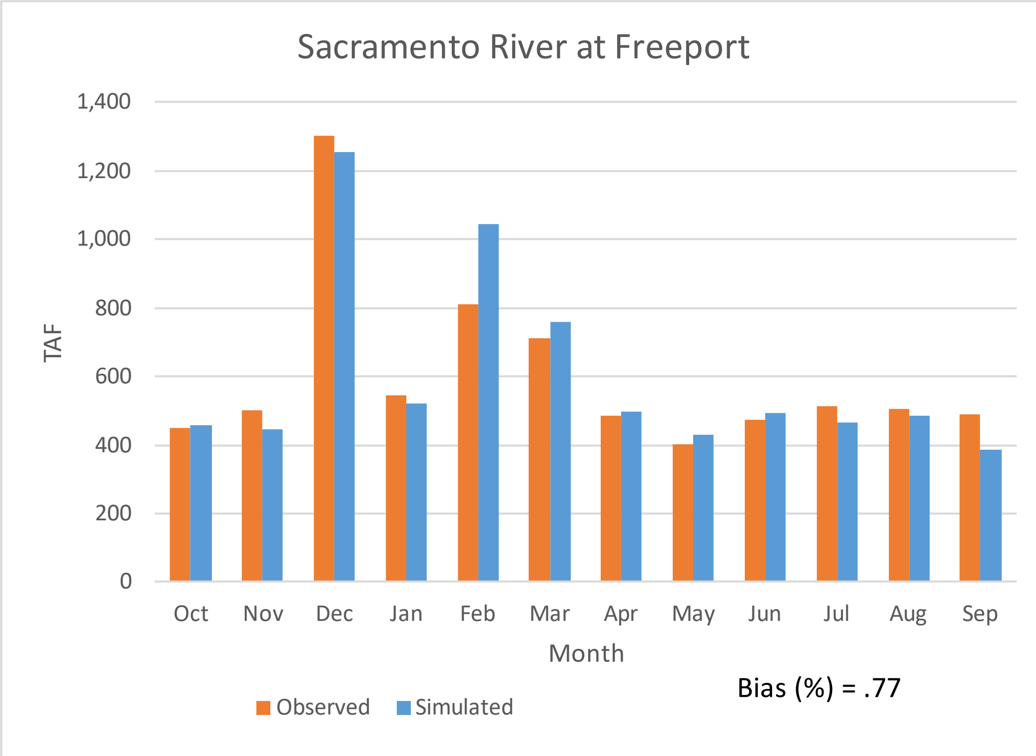


Figure A.7.8i. Sacramento River at Freeport, Average Monthly (Critical)

A.7.9 Delta Inflow

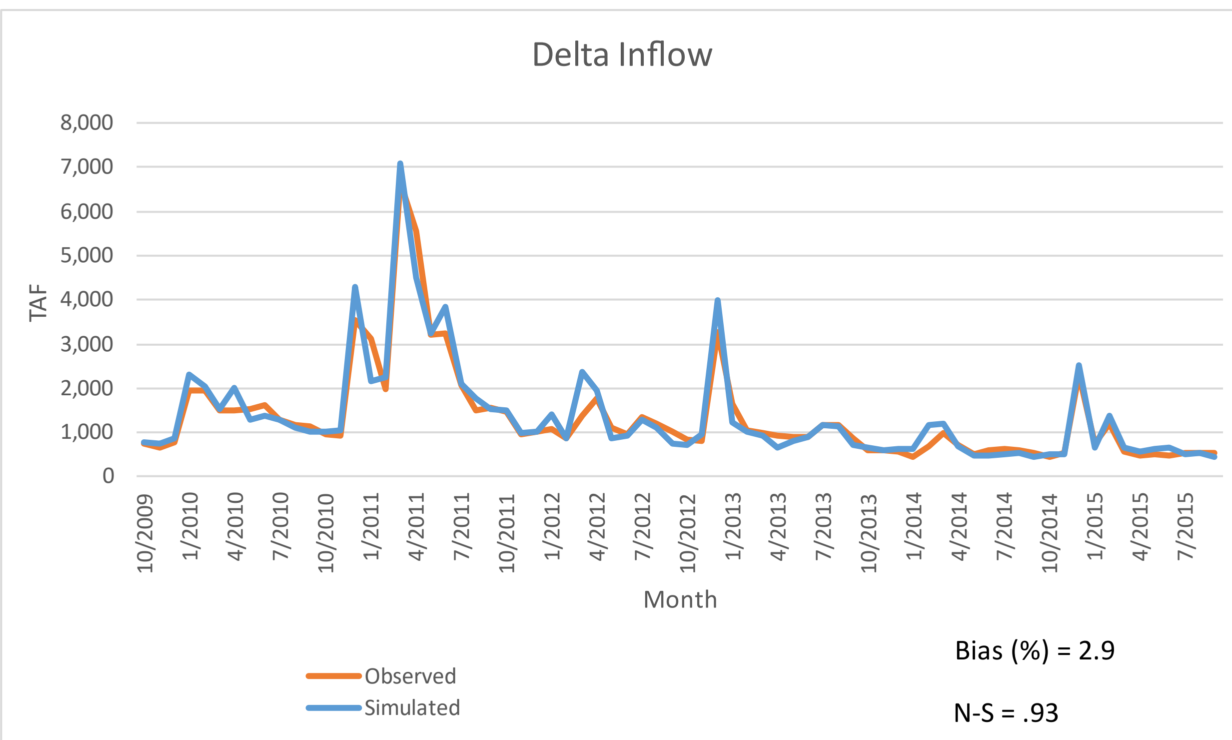


Figure A.7.9a. Delta Inflow, Monthly 2010 to 2015

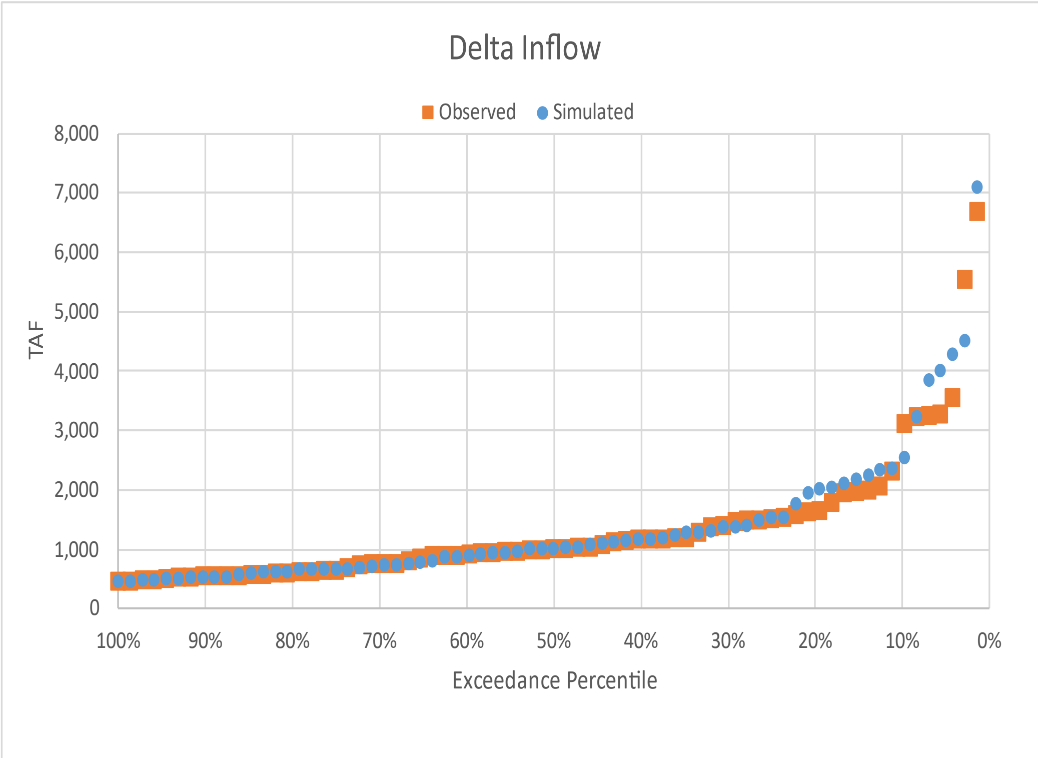


Figure A.7.9b. Delta Inflow, Exceedance

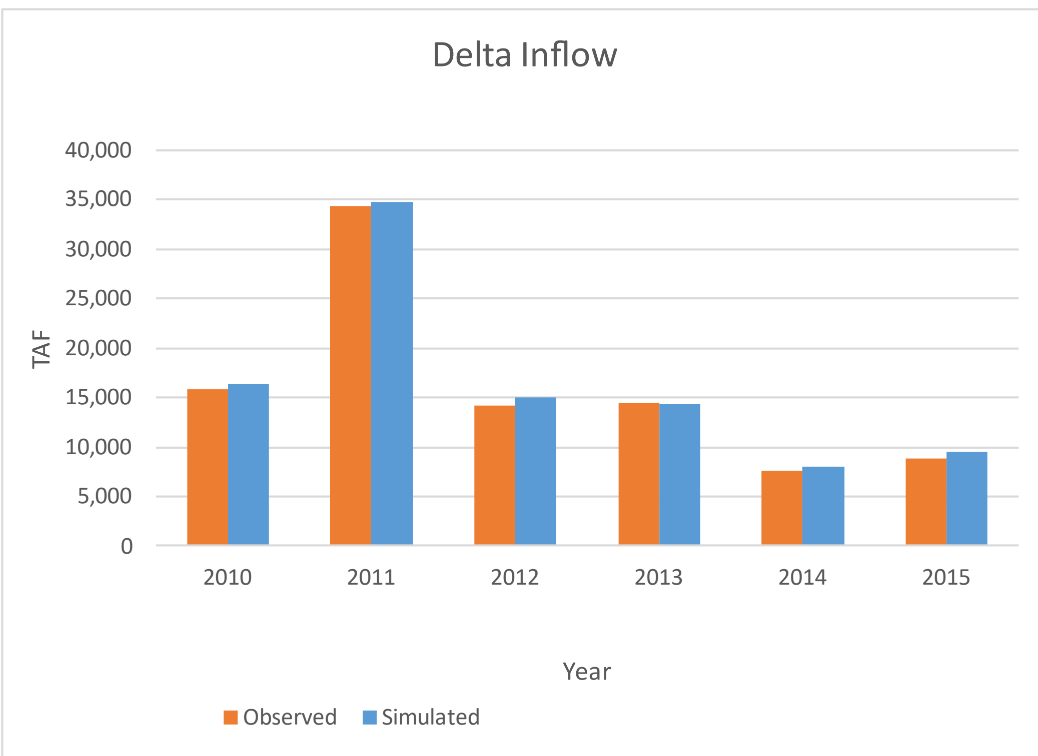


Figure A.7.9c. Delta Inflow, Annual 2010 to 2015

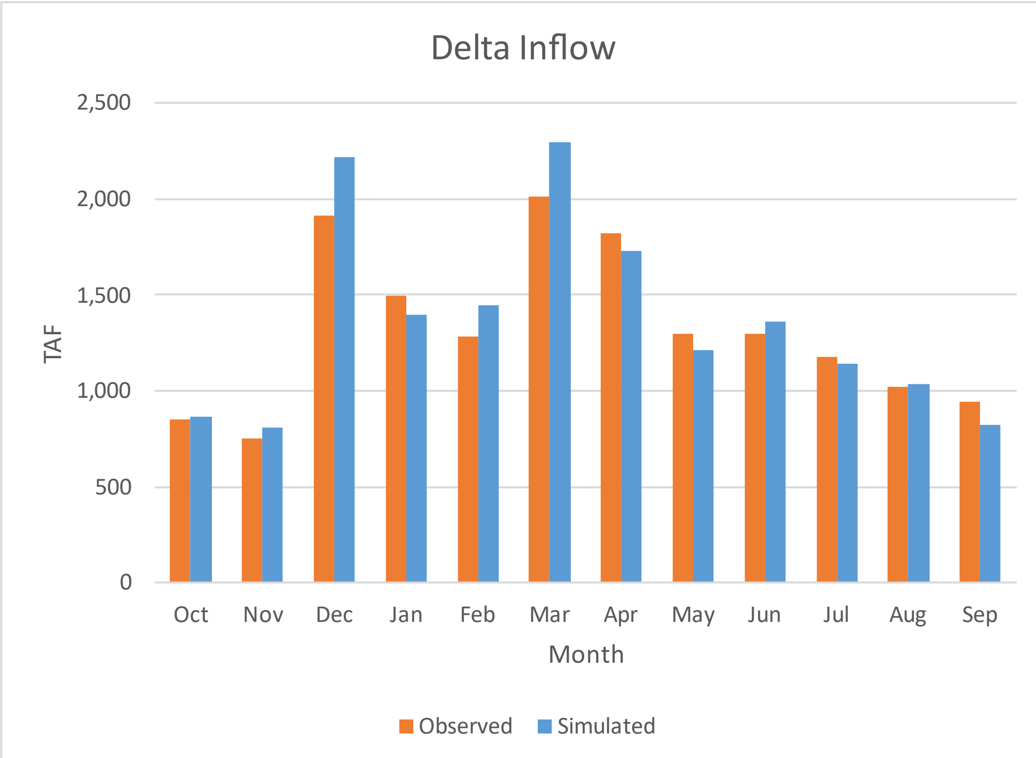


Figure A.7.9d. Delta Inflow, Average Monthly

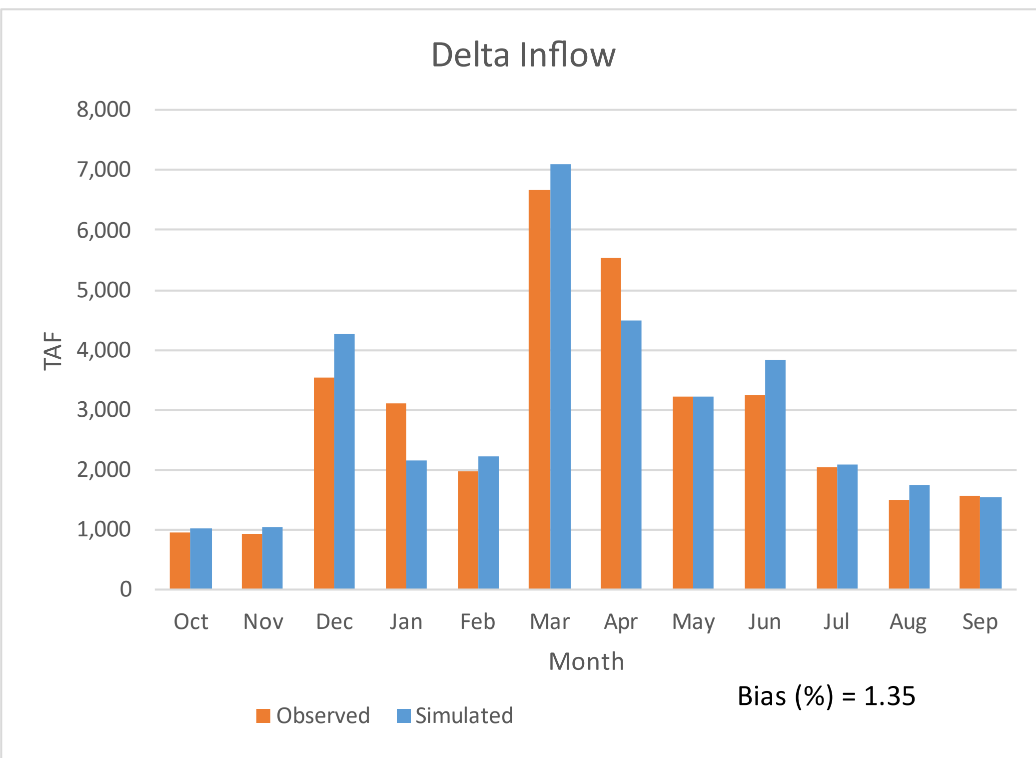


Figure A.7.9e. Delta Inflow, Average Monthly (Wet)

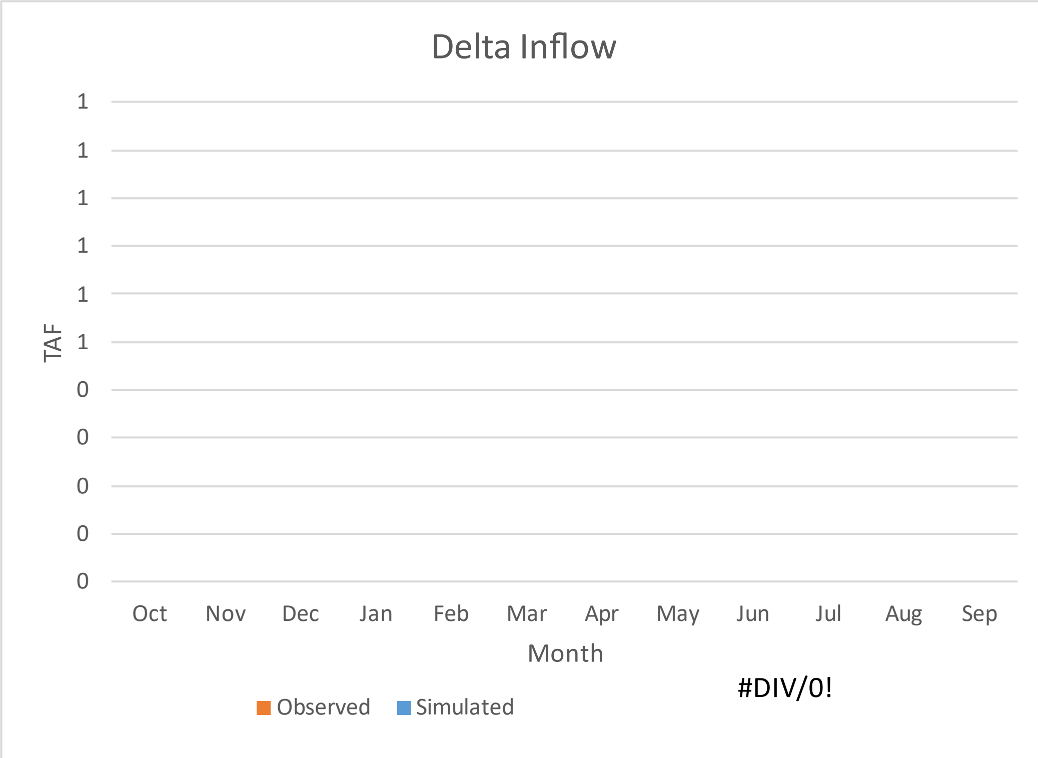


Figure A.7.9f. Delta Inflow, Average Monthly (Above Normal)

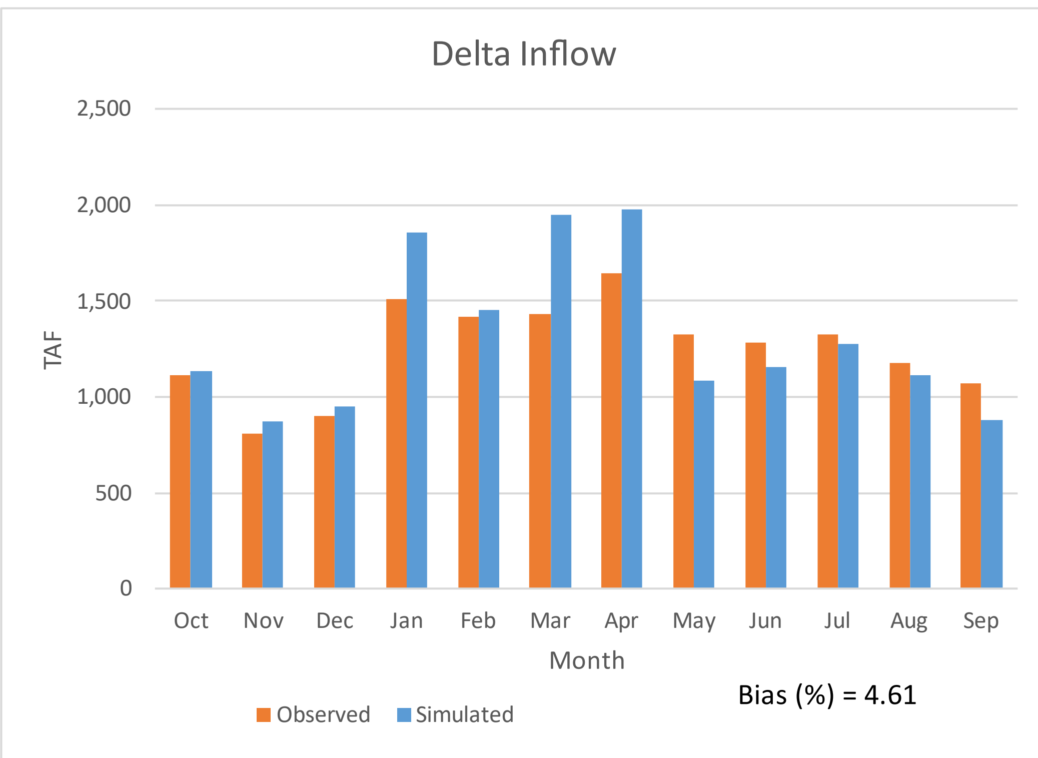


Figure A.7.9g. Delta Inflow, Average Monthly (Below Normal)

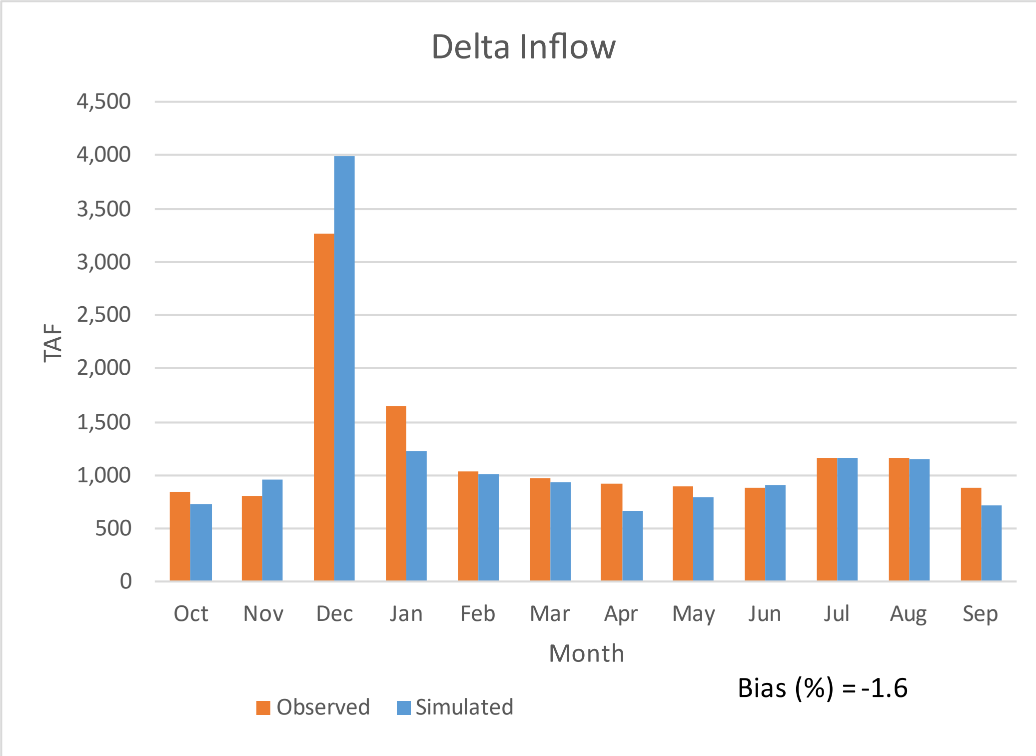


Figure A.7.9h. Delta Inflow, Average Monthly (Dry)

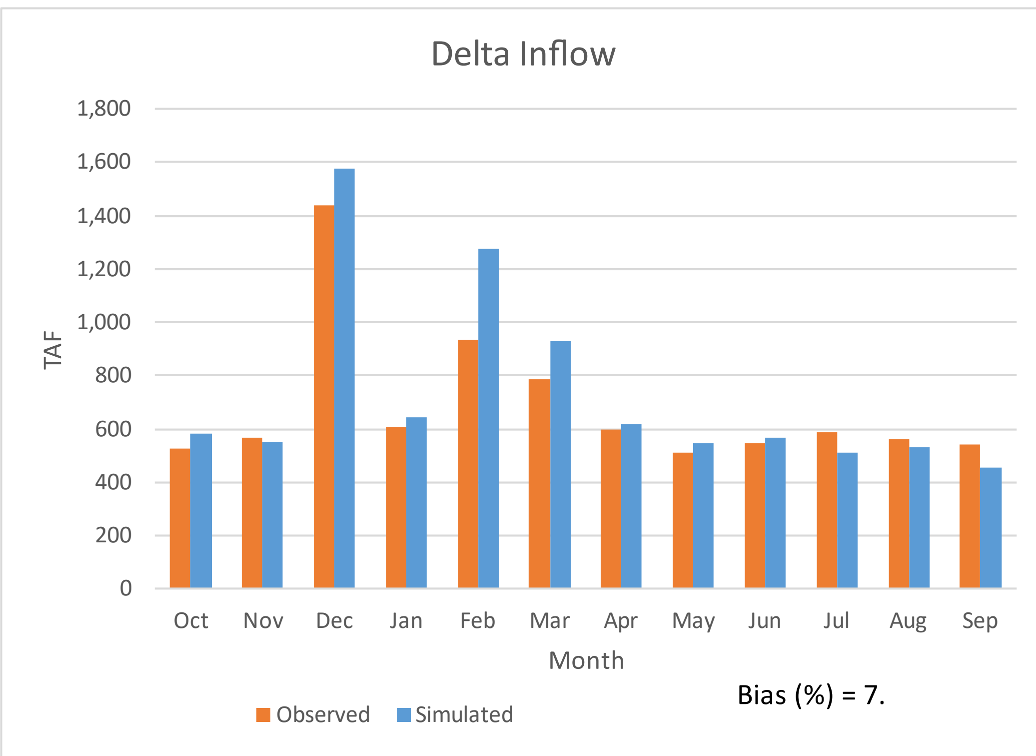


Figure A.7.9i. Delta Inflow, Average Monthly (Critical)

A.7.10 CVP Delta Exports

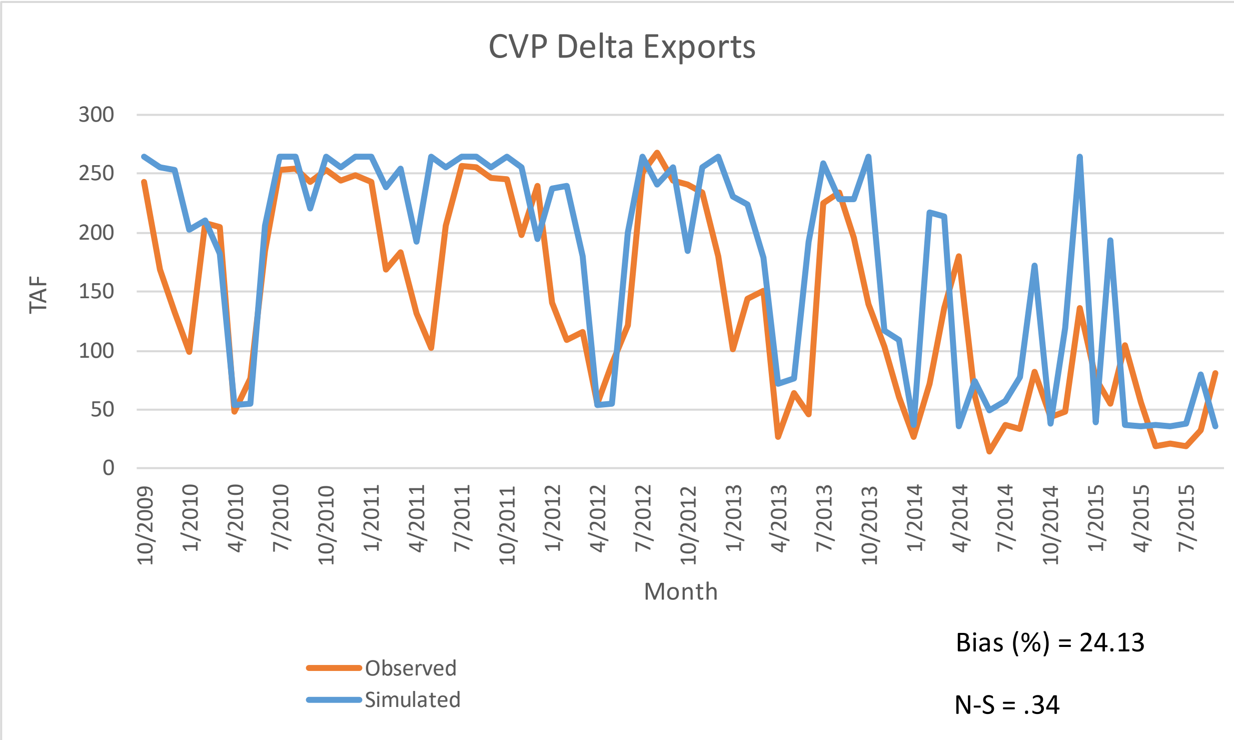


Figure A.7.10a. CVP Delta Exports, Monthly 2010 to 2015

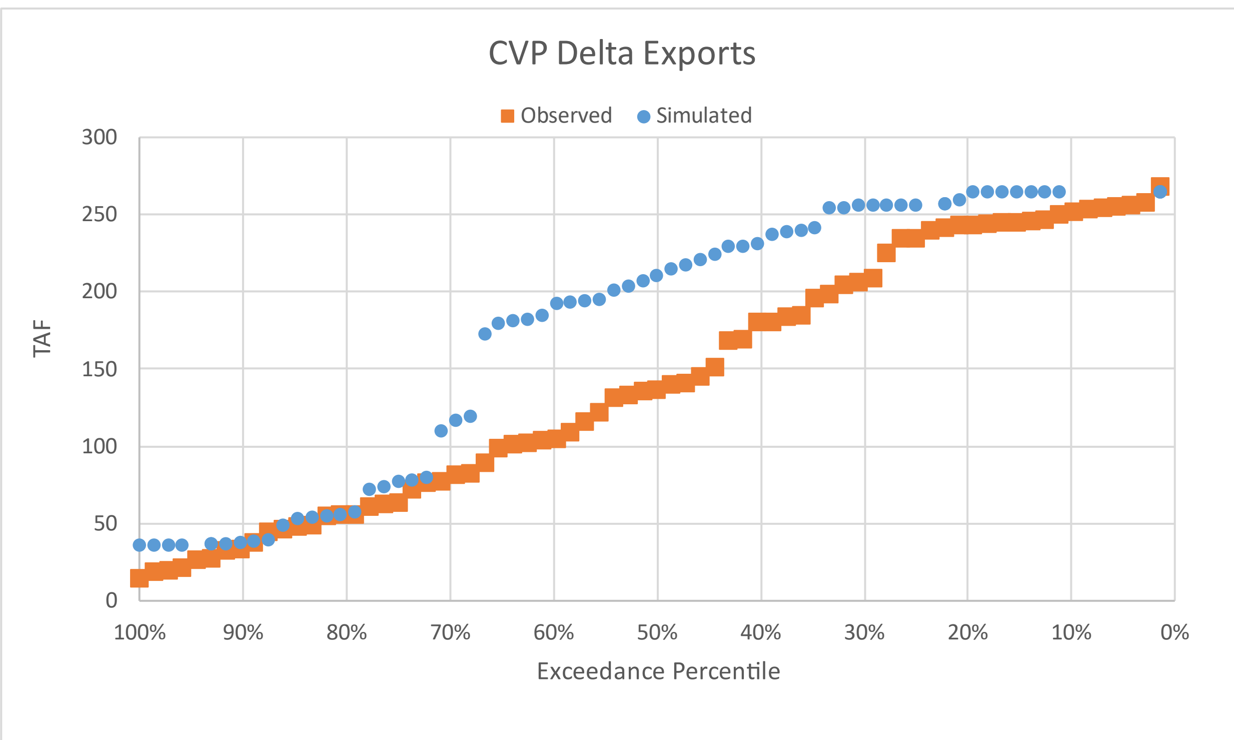


Figure A.7.10b. CVP Delta Exports, Exceedance

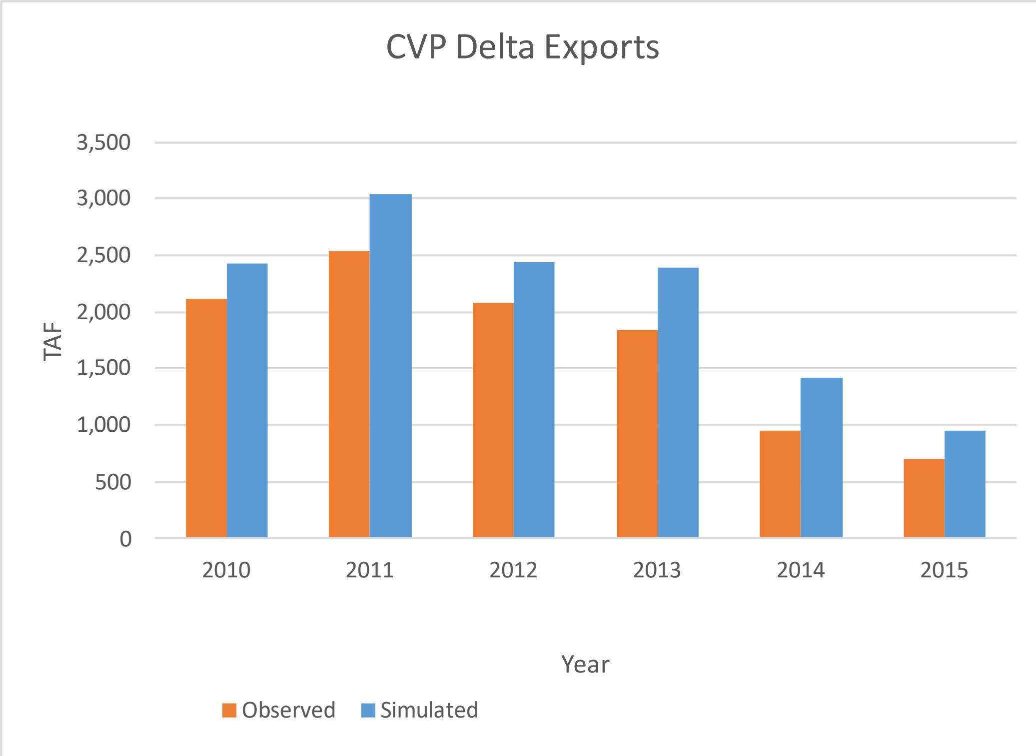


Figure A.7.10c. CVP Delta Exports, Annual 2010 to 2015

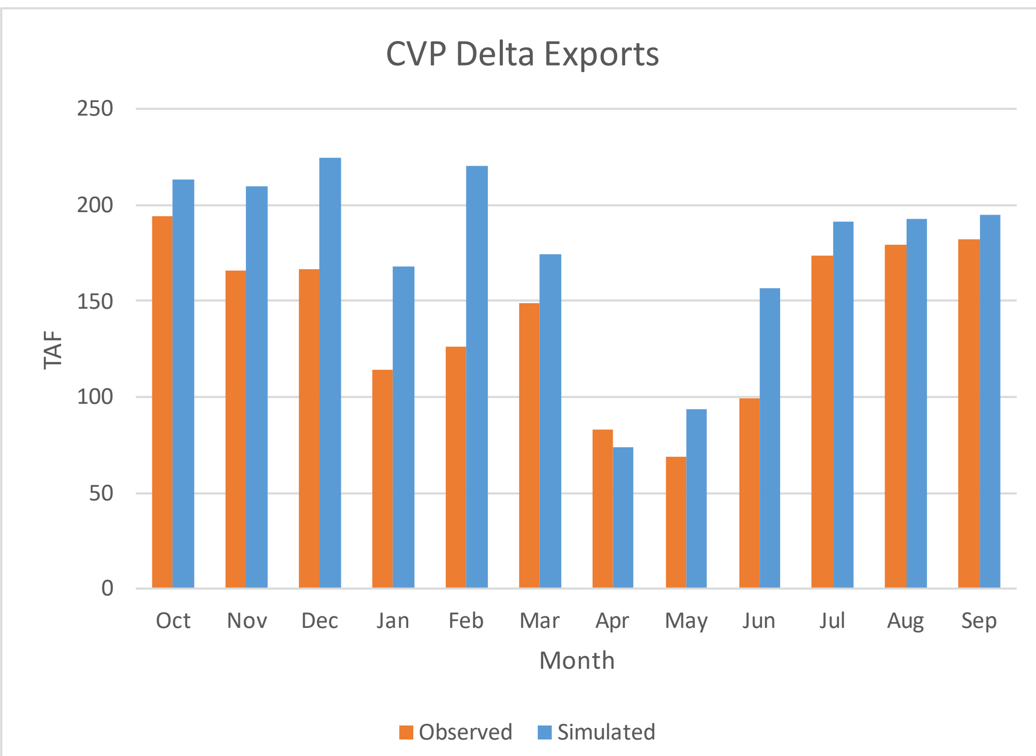


Figure A.7.10d. CVP Delta Exports, Average Monthly

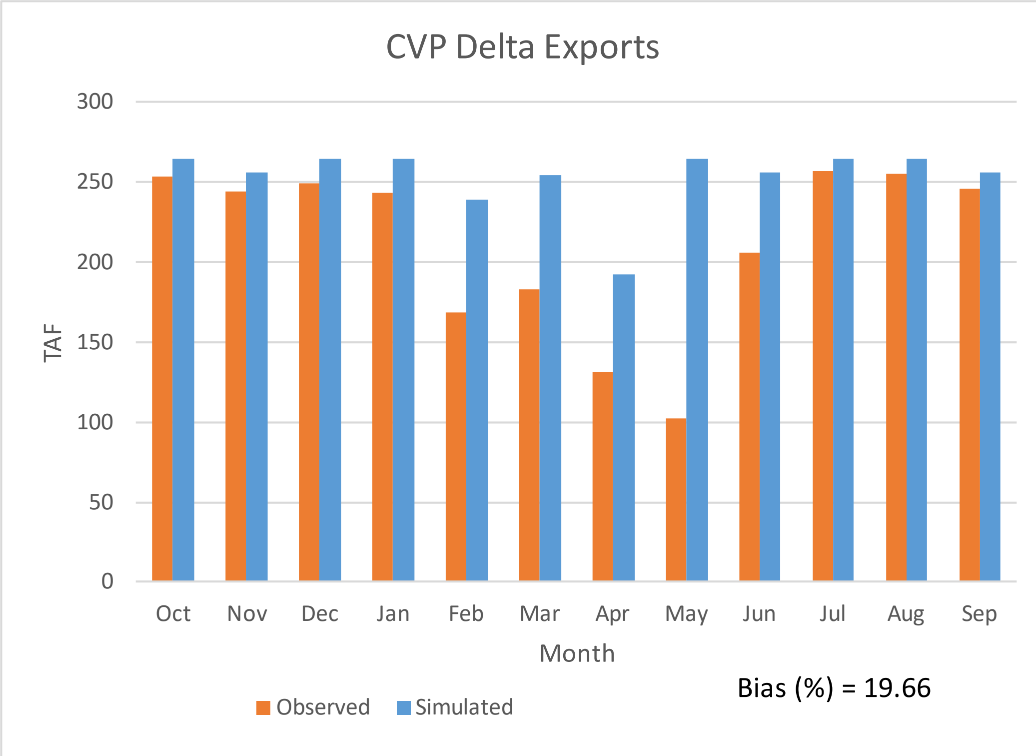


Figure A.7.10e. CVP Delta Exports, Average Monthly (Wet)

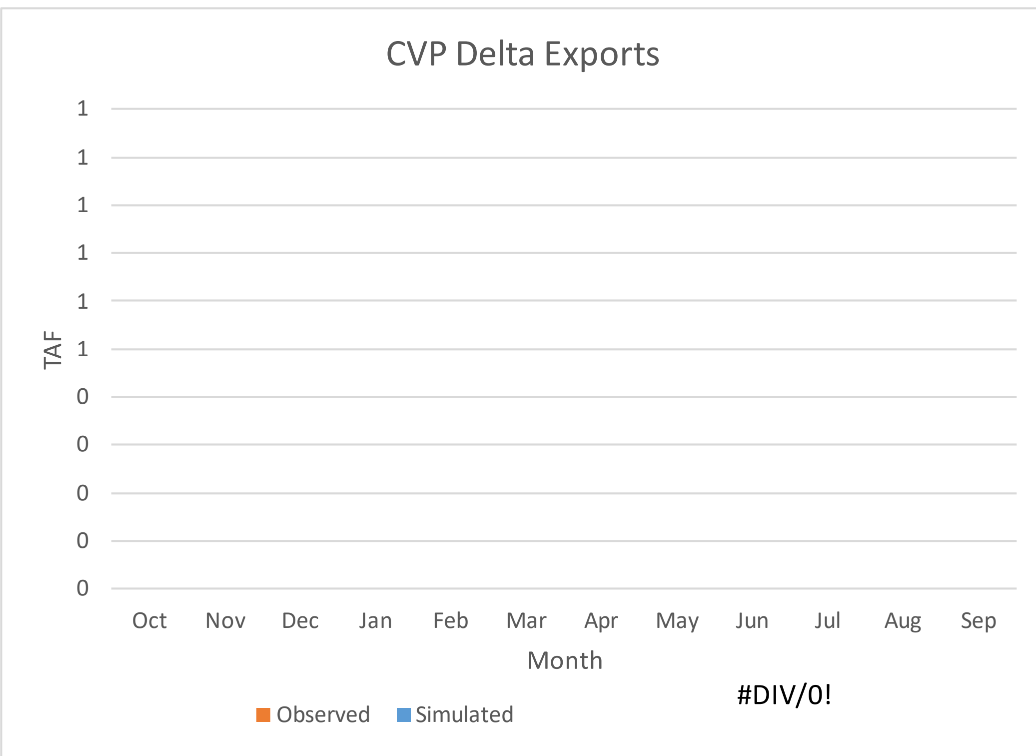


Figure A.7.10f. CVP Delta Exports, Average Monthly (Above Normal)

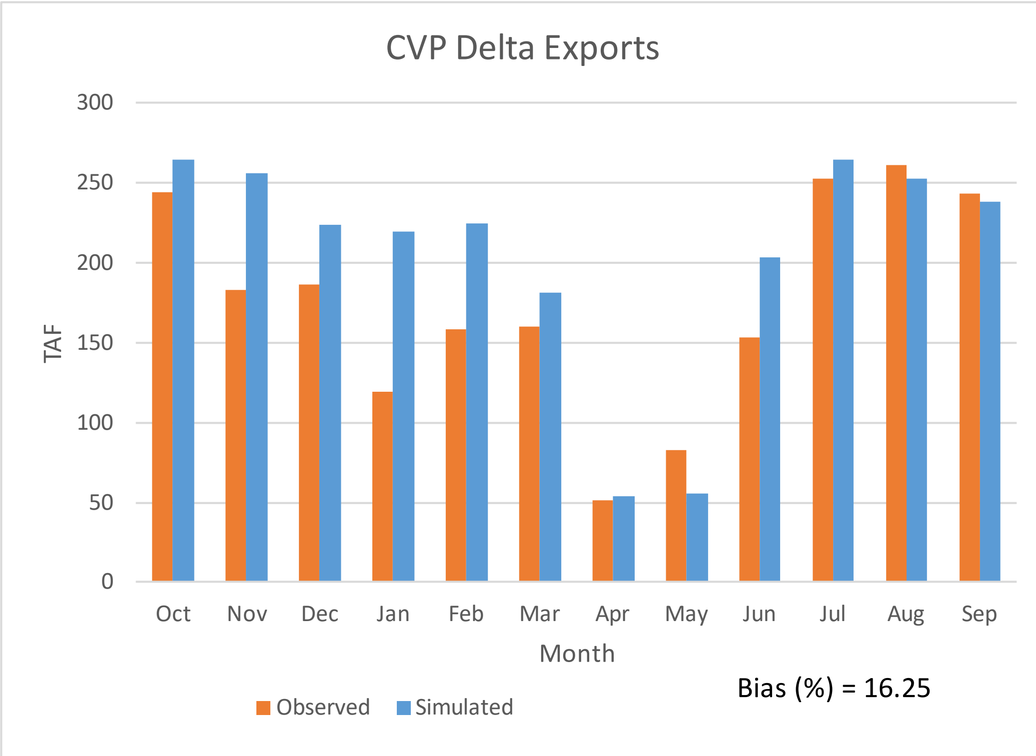


Figure A.7.10g. CVP Delta Exports, Average Monthly (Below Normal)

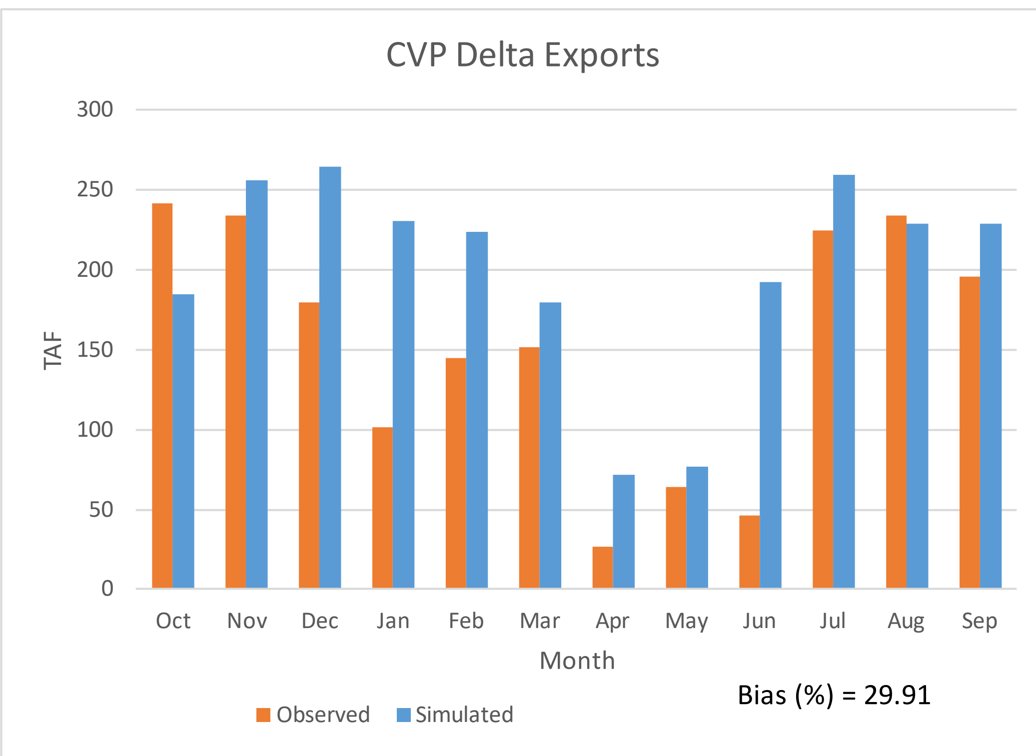


Figure A.7.10h. CVP Delta Exports, Average Monthly (Dry)

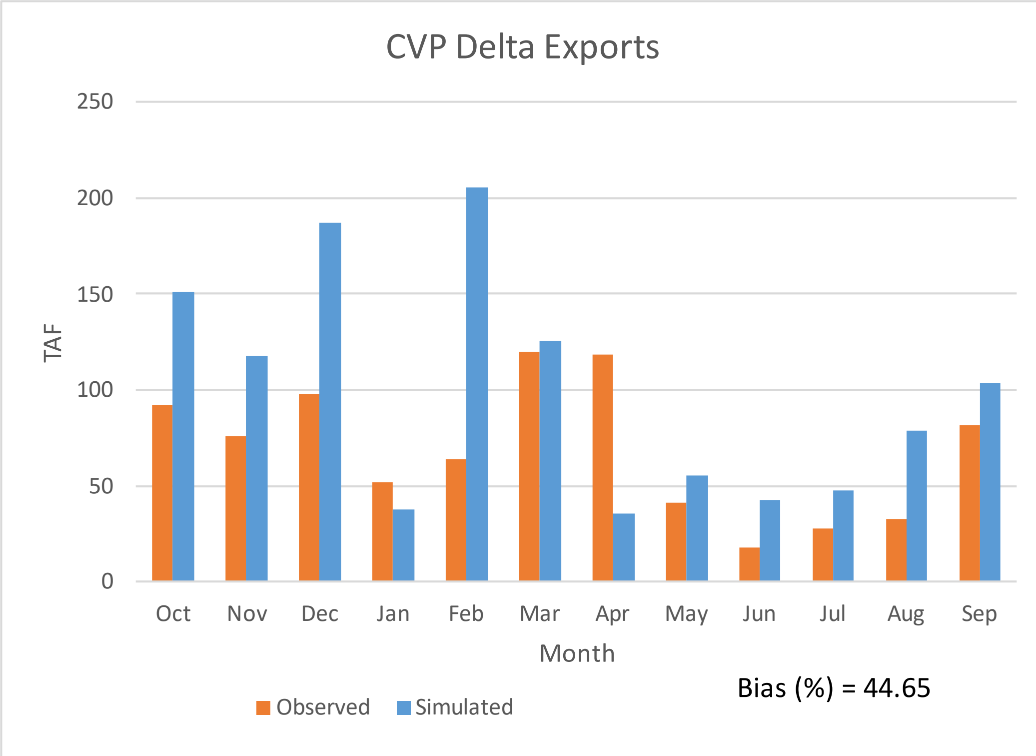


Figure A.7.10i. CVP Delta Exports, Average Monthly (Critical)

A.7.11 SWP Delta Exports

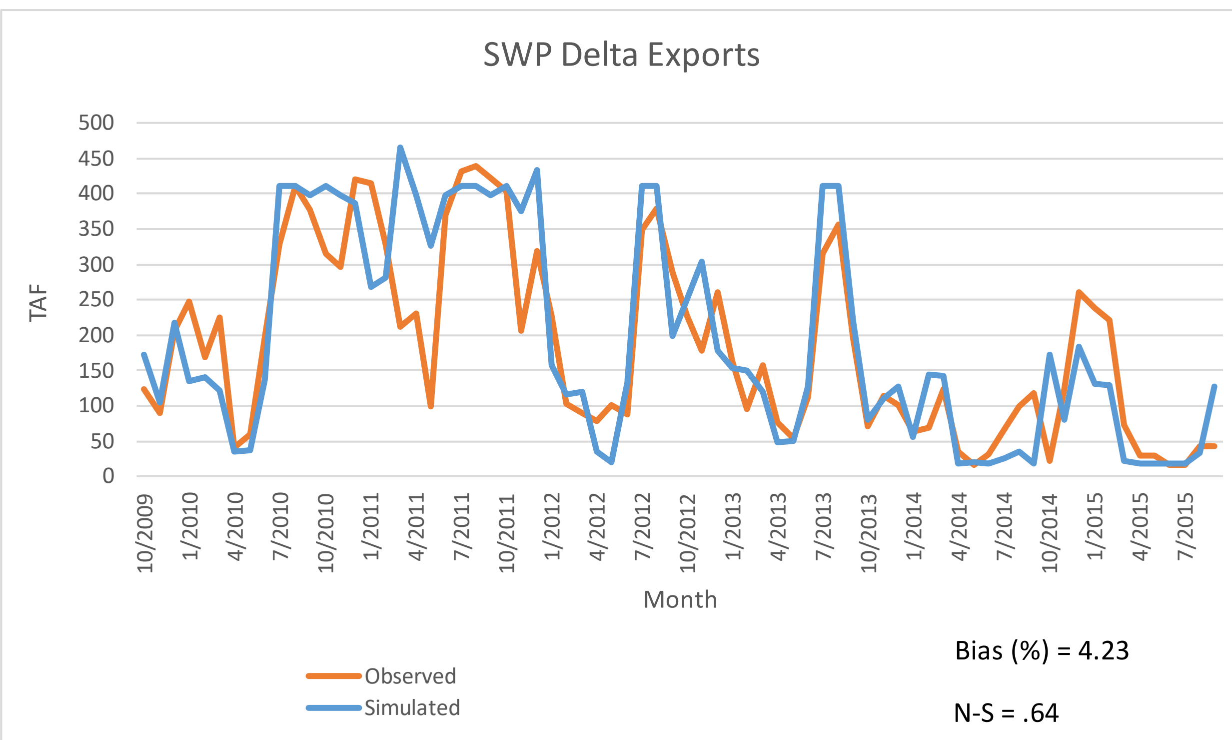


Figure A.7.11a. SWP Delta Exports, Monthly 2010 to 2015

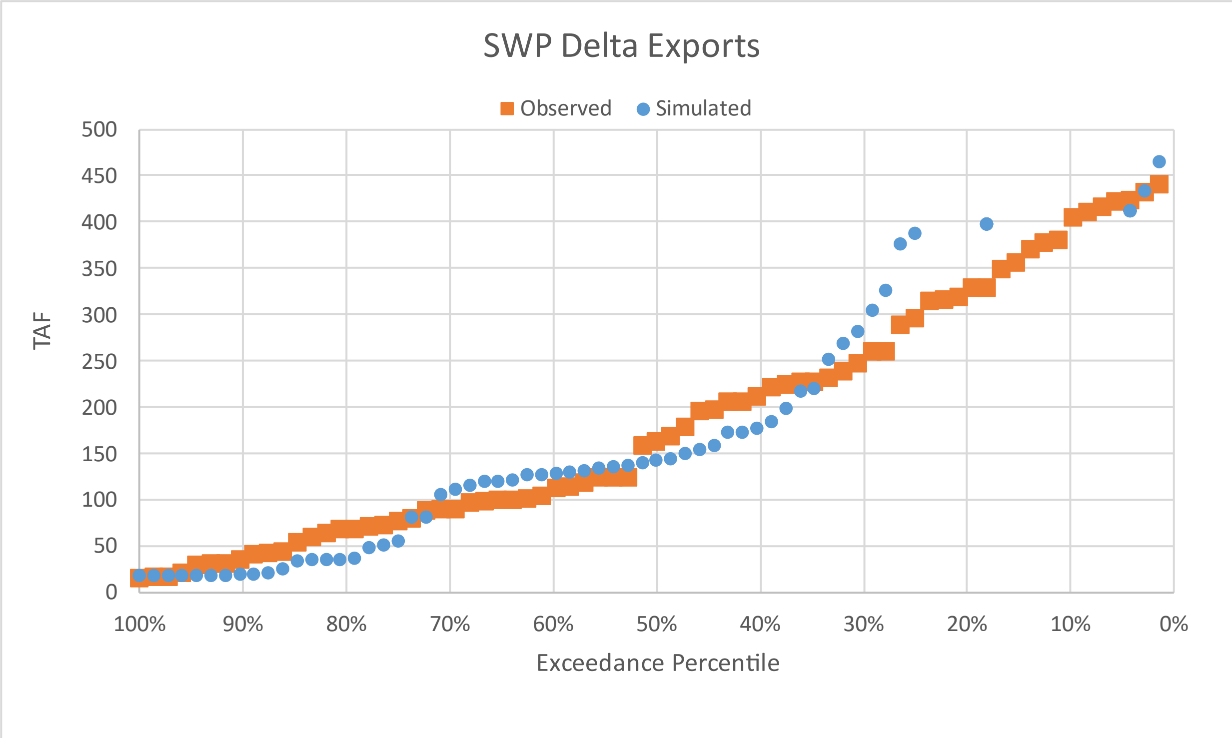


Figure A.7.11b. SWP Delta Exports, Exceedance

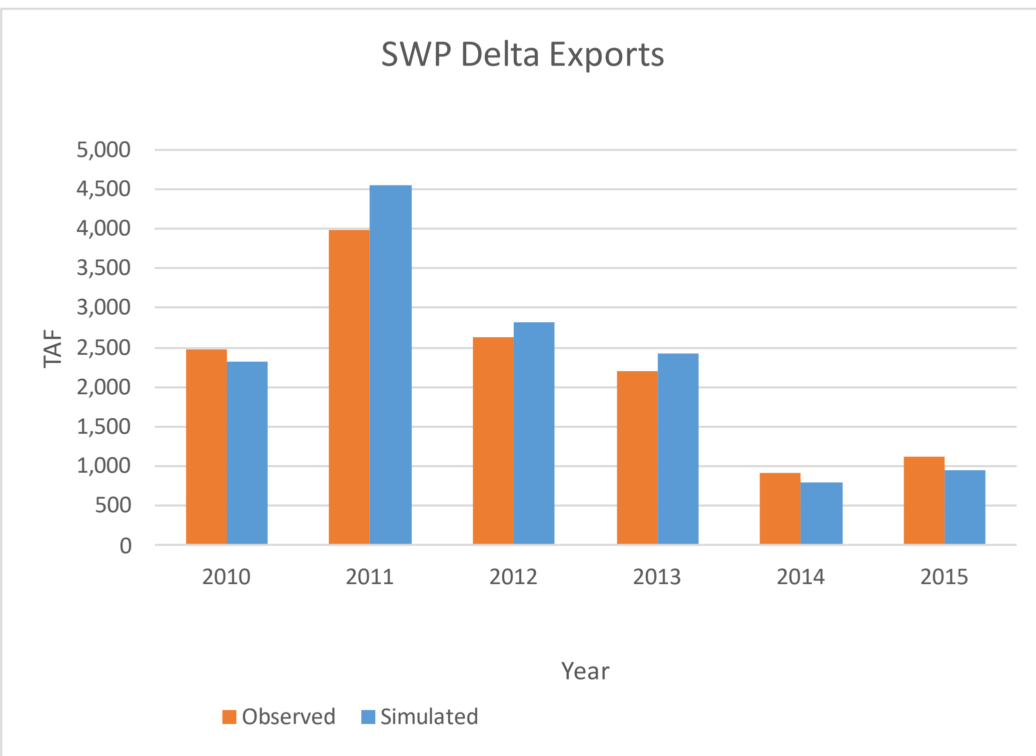


Figure A.7.11c. SWP Delta Exports, Annual 2010 to 2015

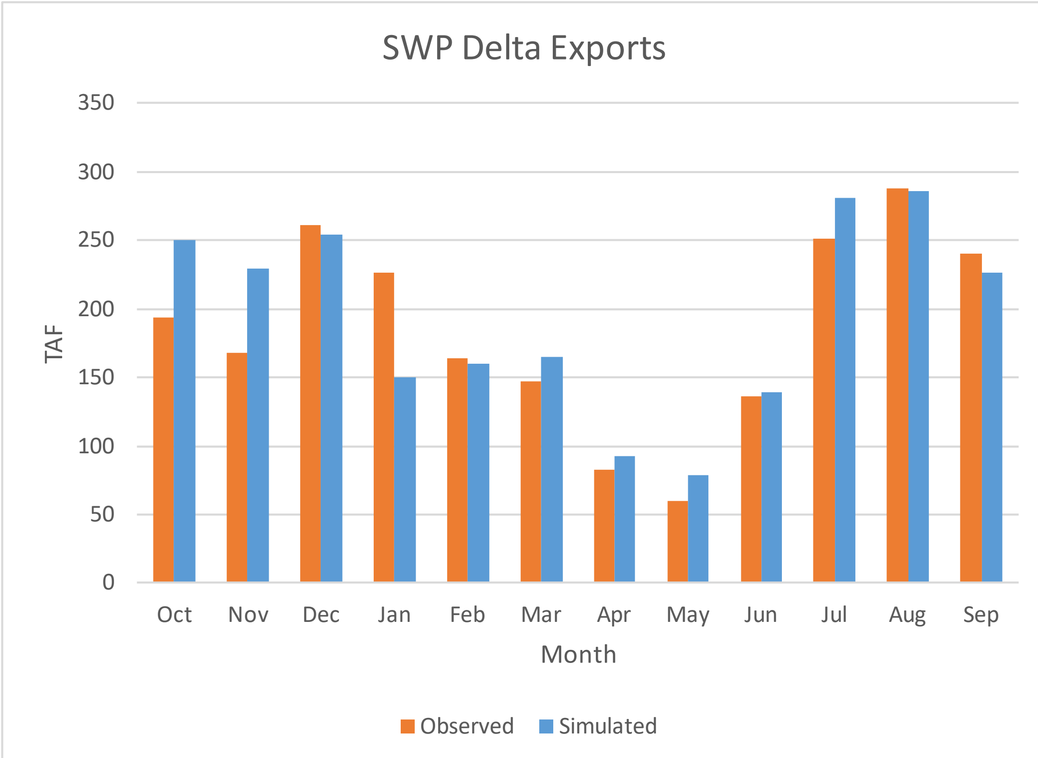


Figure A.7.11d. SWP Delta Exports, Average Monthly

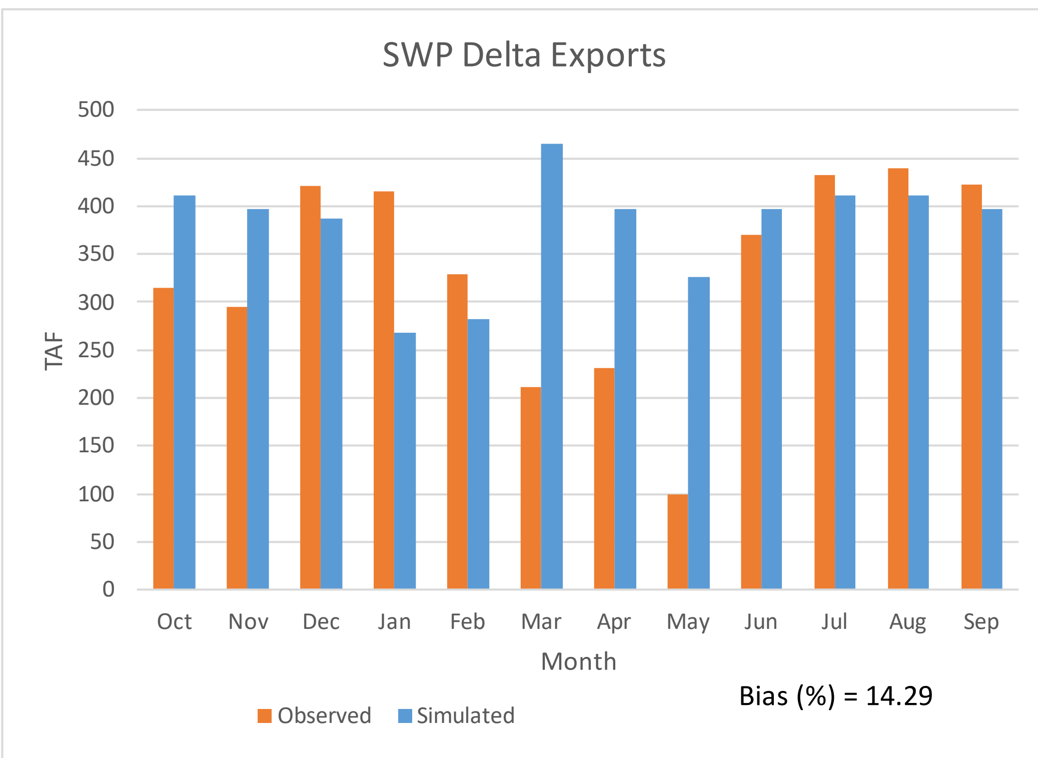


Figure A.7.11e. SWP Delta Exports, Average Monthly (Wet)

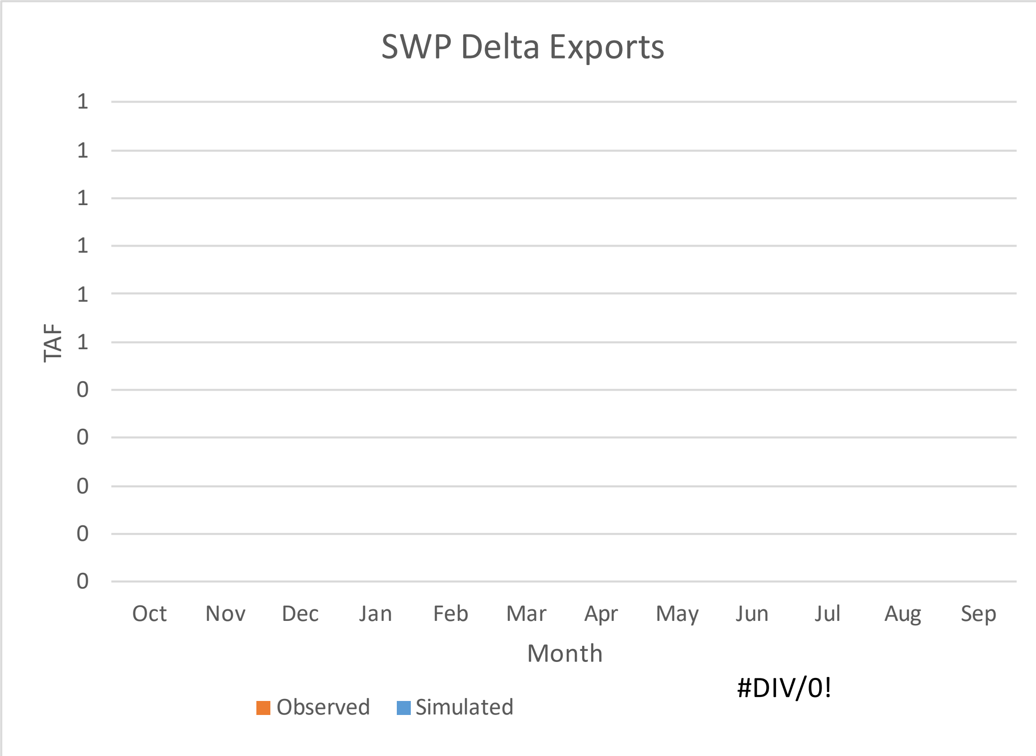


Figure A.7.11f. SWP Delta Exports, Average Monthly (Above Normal)

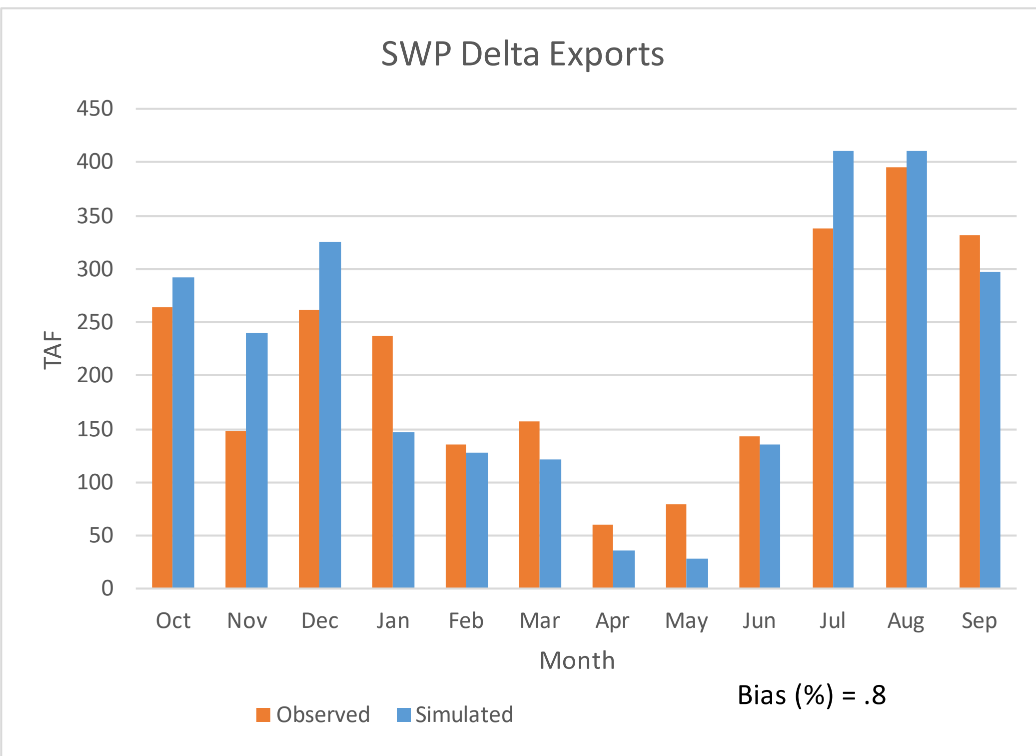


Figure A.7.11g. SWP Delta Exports, Average Monthly (Below Normal)

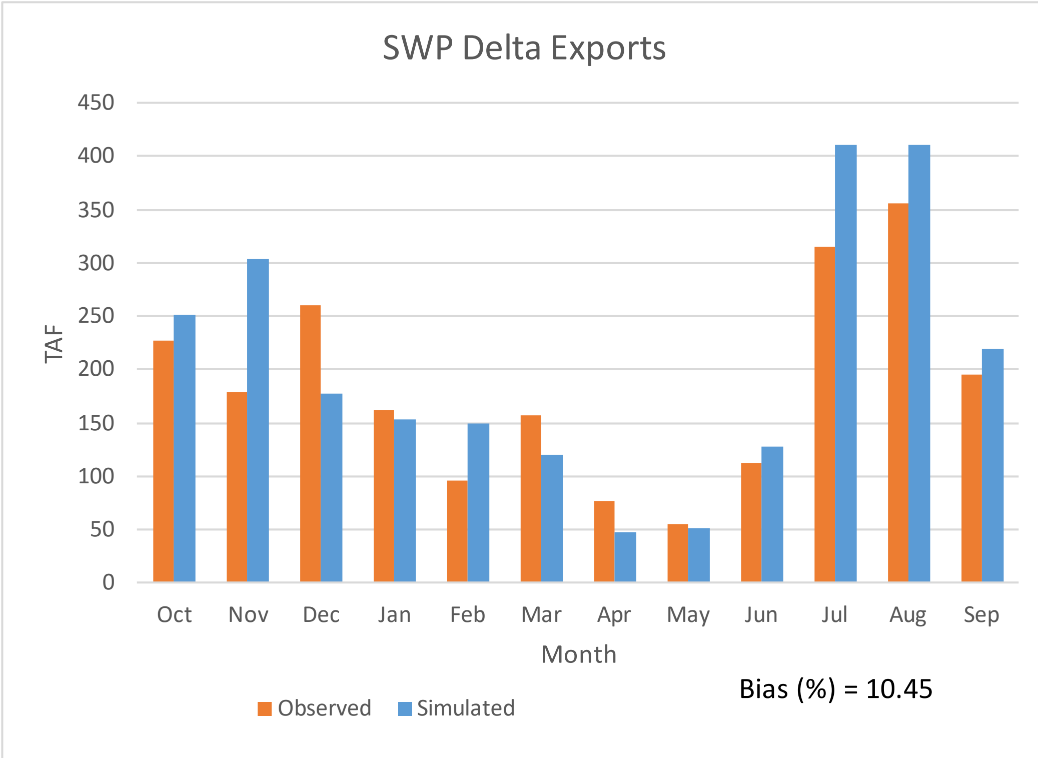


Figure A.7.11h. SWP Delta Exports, Average Monthly (Dry)

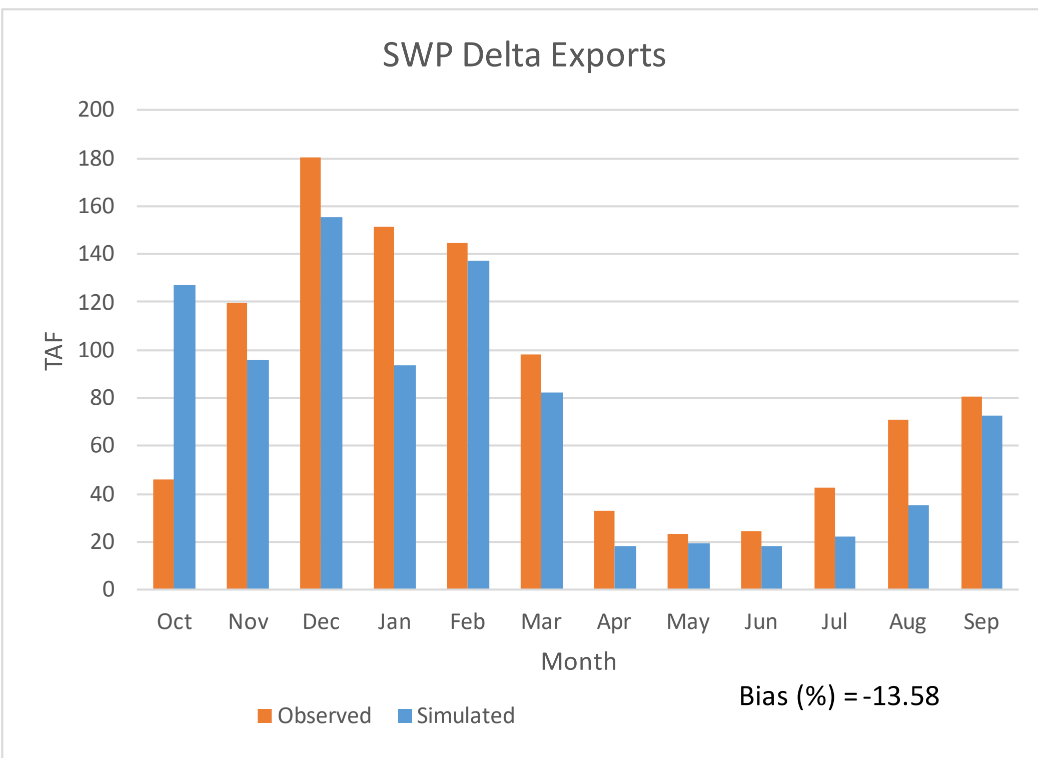


Figure A.7.11i. SWP Delta Exports, Average Monthly (Critical)

A.7.12 Combined Delta Exports

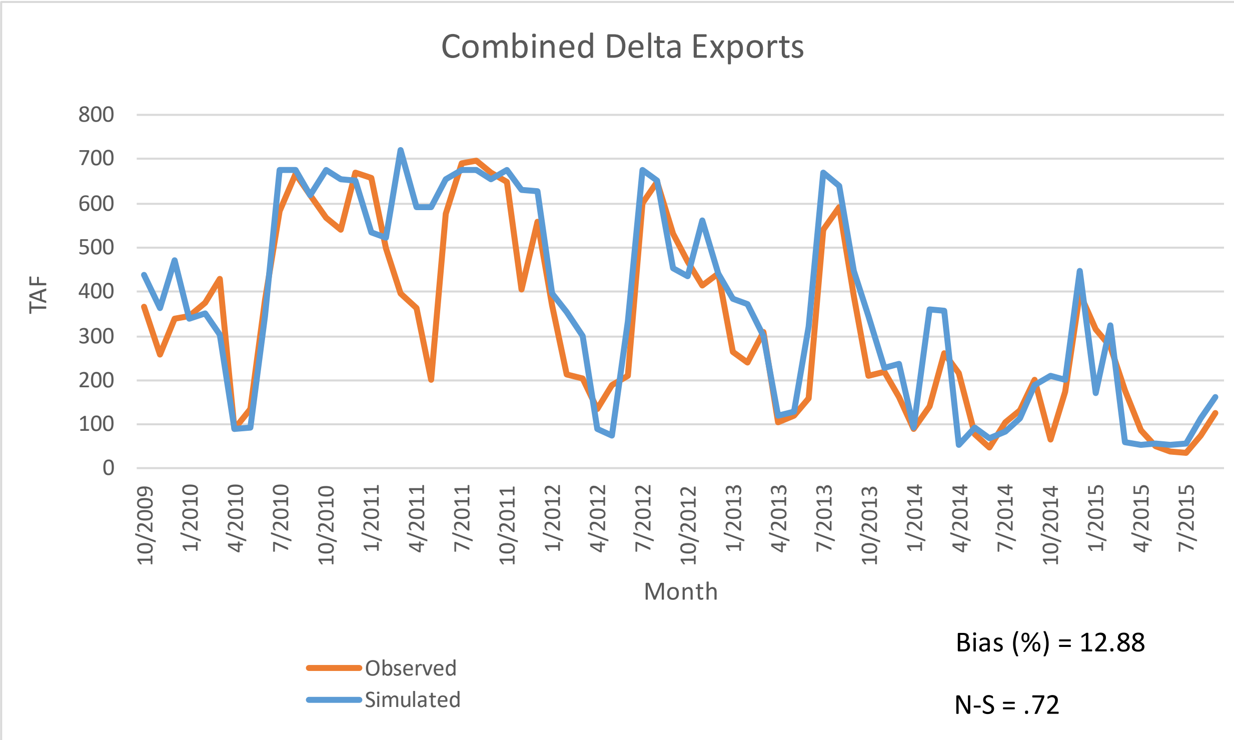


Figure A.7.12a. Combined Delta Exports, Monthly 2010 to 2015

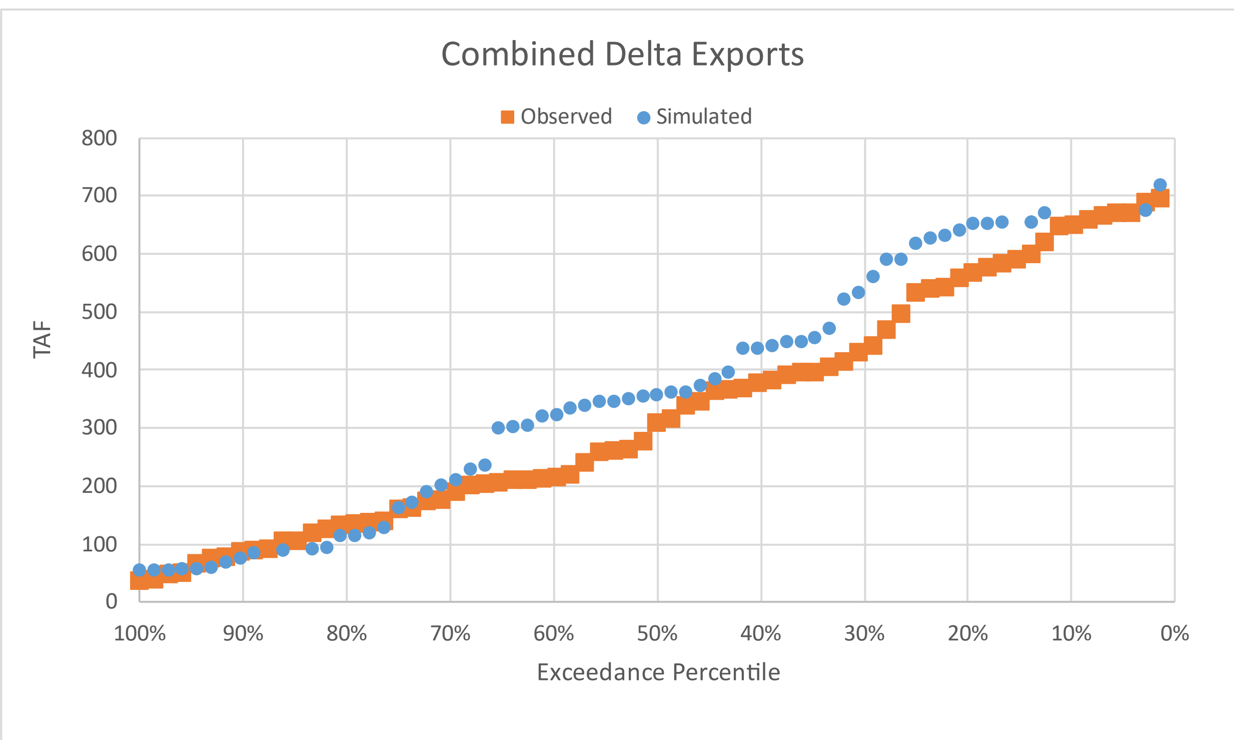


Figure A.7.12b. Combined Delta Exports, Exceedance

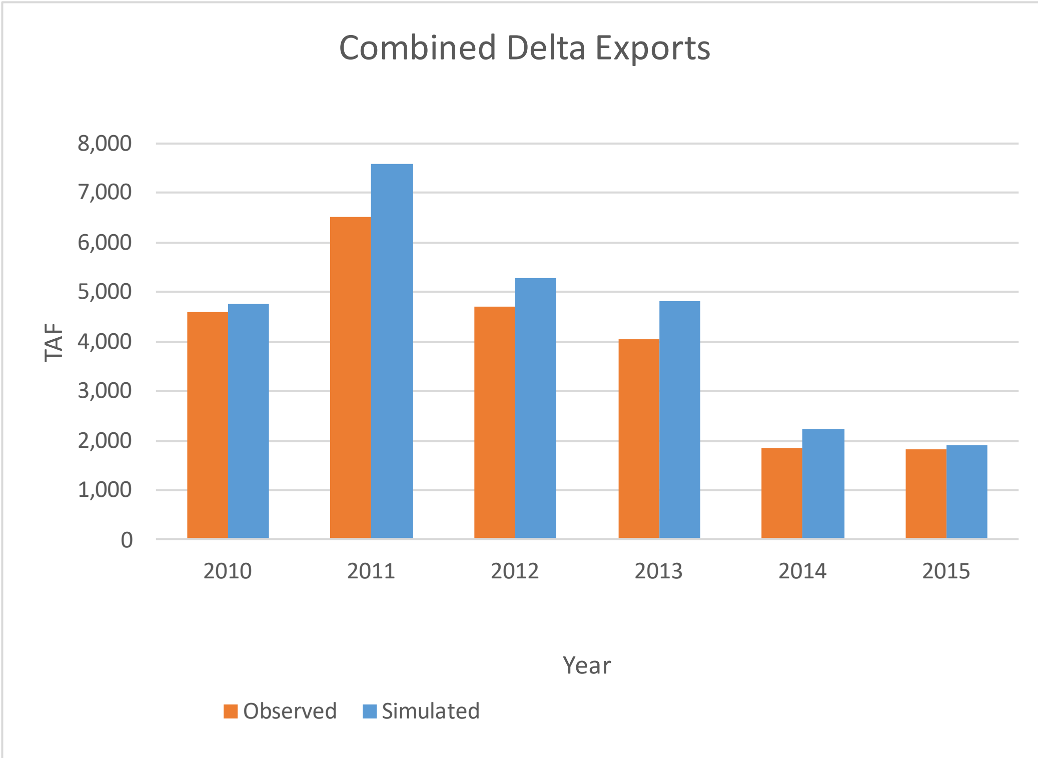


Figure A.7.12c. Combined Delta Exports, Annual 2010 to 2015

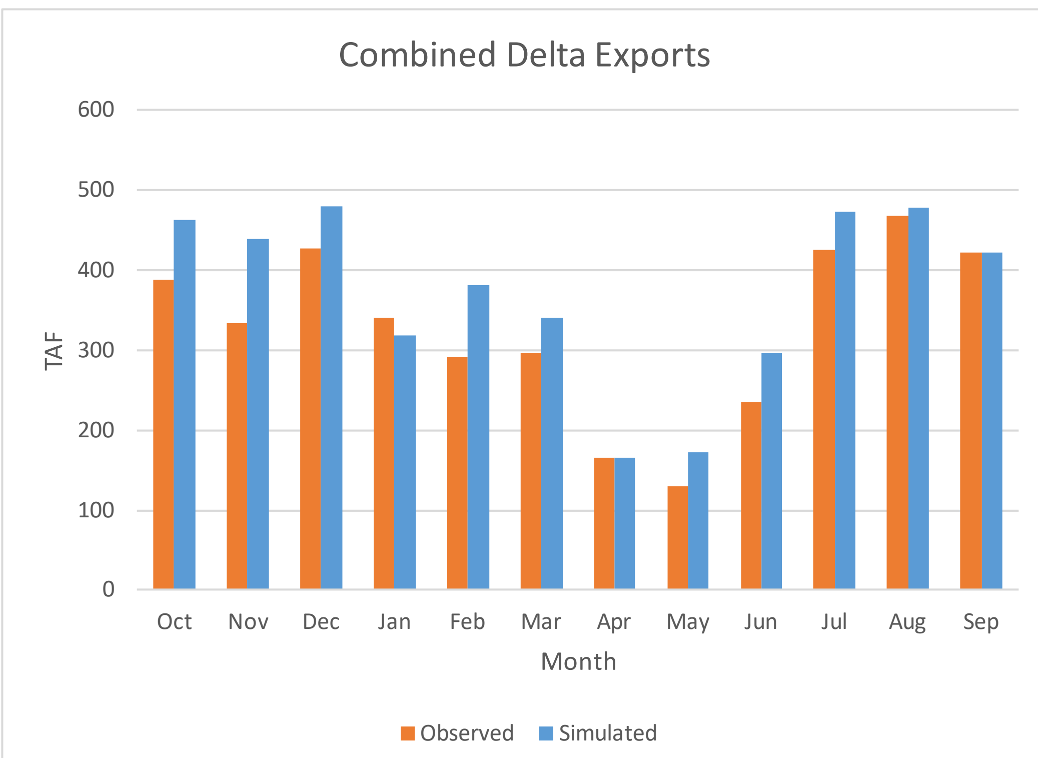


Figure A.7.12d. Combined Delta Exports, Average Monthly

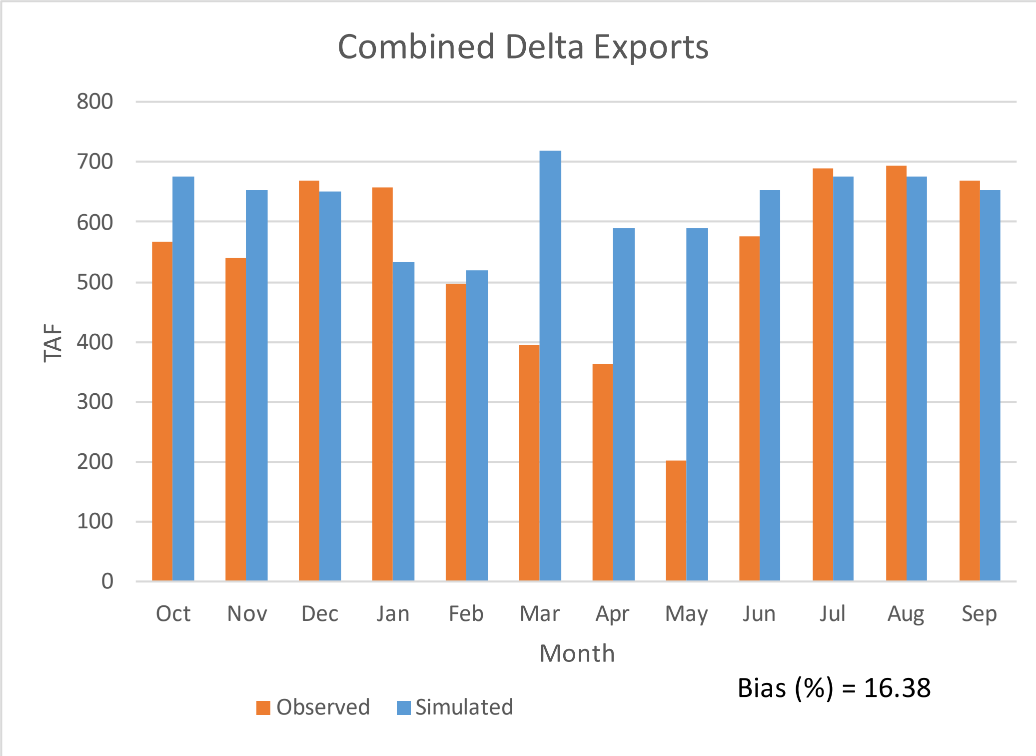


Figure A.7.12e. Combined Delta Exports, Average Monthly (Wet)

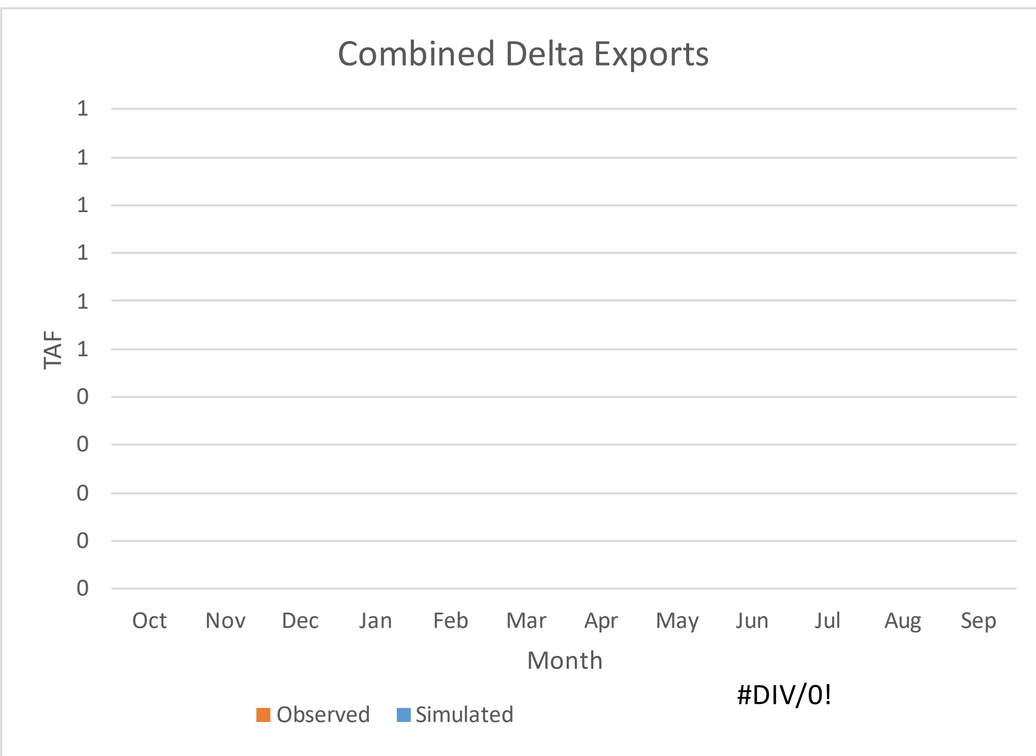


Figure A.7.12f. Combined Delta Exports, Average Monthly (Above Normal)

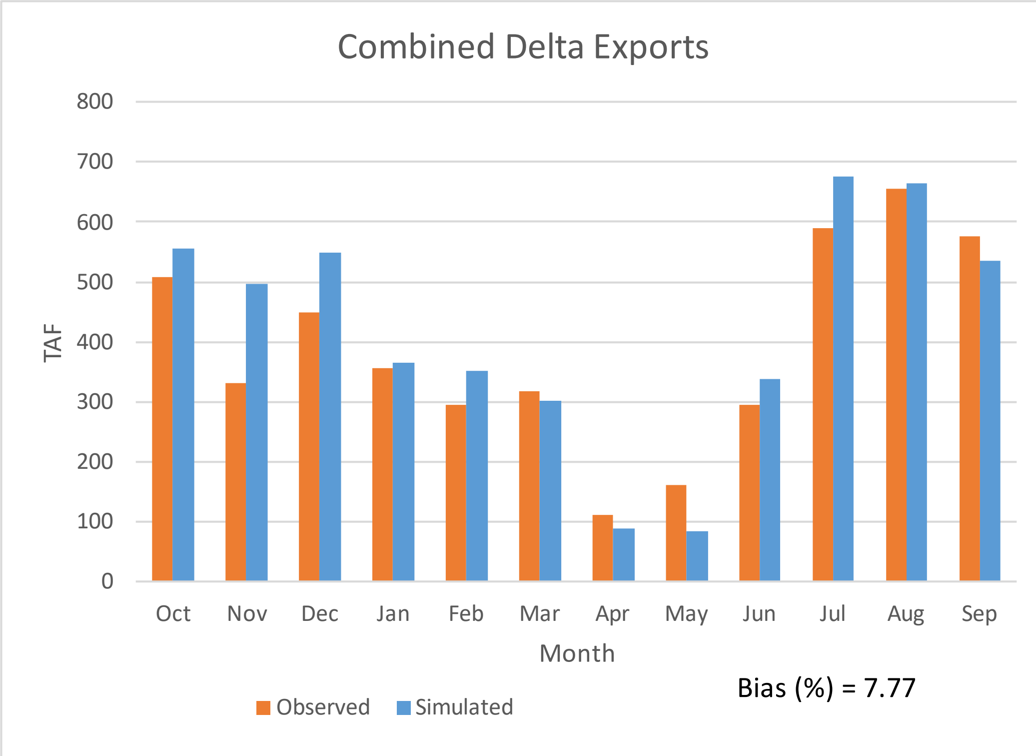


Figure A.7.12g. Combined Delta Exports, Average Monthly (Below Normal)

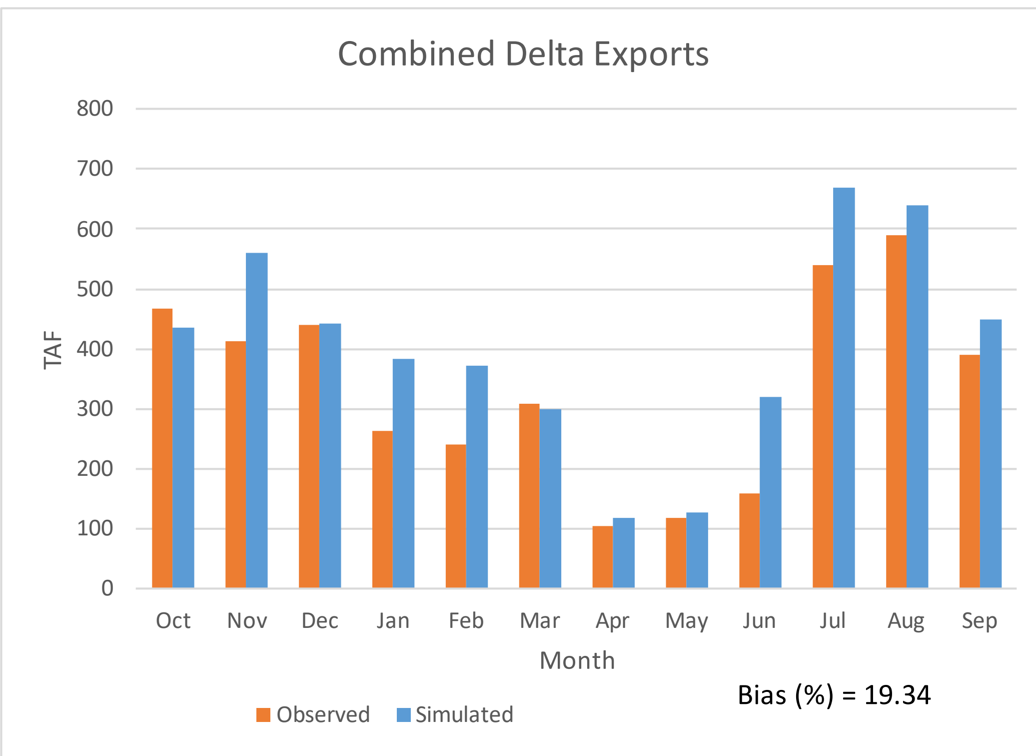


Figure A.7.12h. Combined Delta Exports, Average Monthly (Dry)

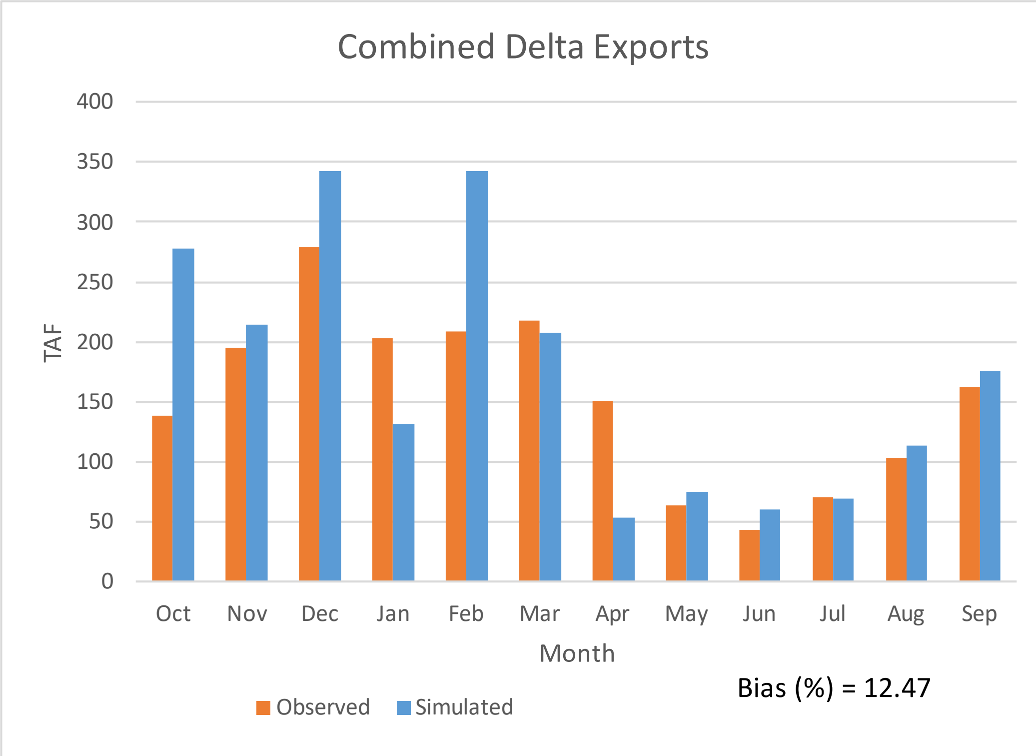


Figure A.7.12i. Combined Delta Exports, Average Monthly (Critical)

A.7.13 Net Delta Outflow

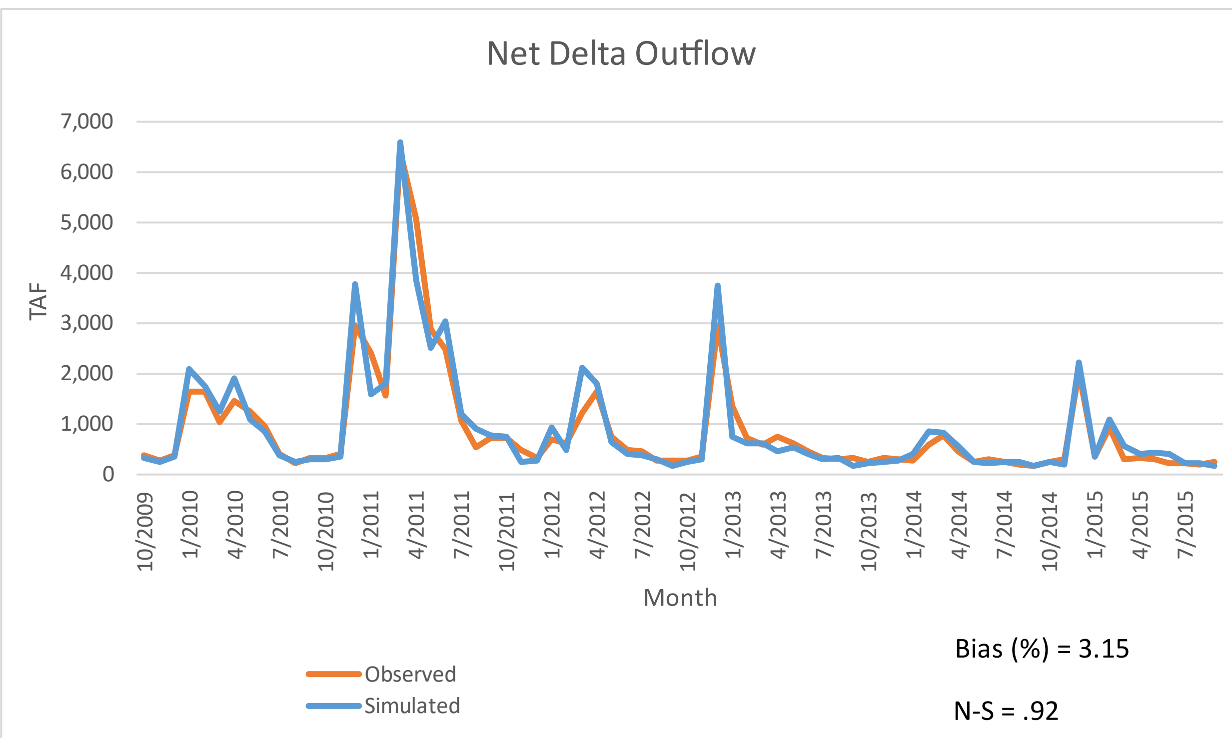


Figure A.7.13a. Net Delta Outflow, Monthly 2010 to 2015

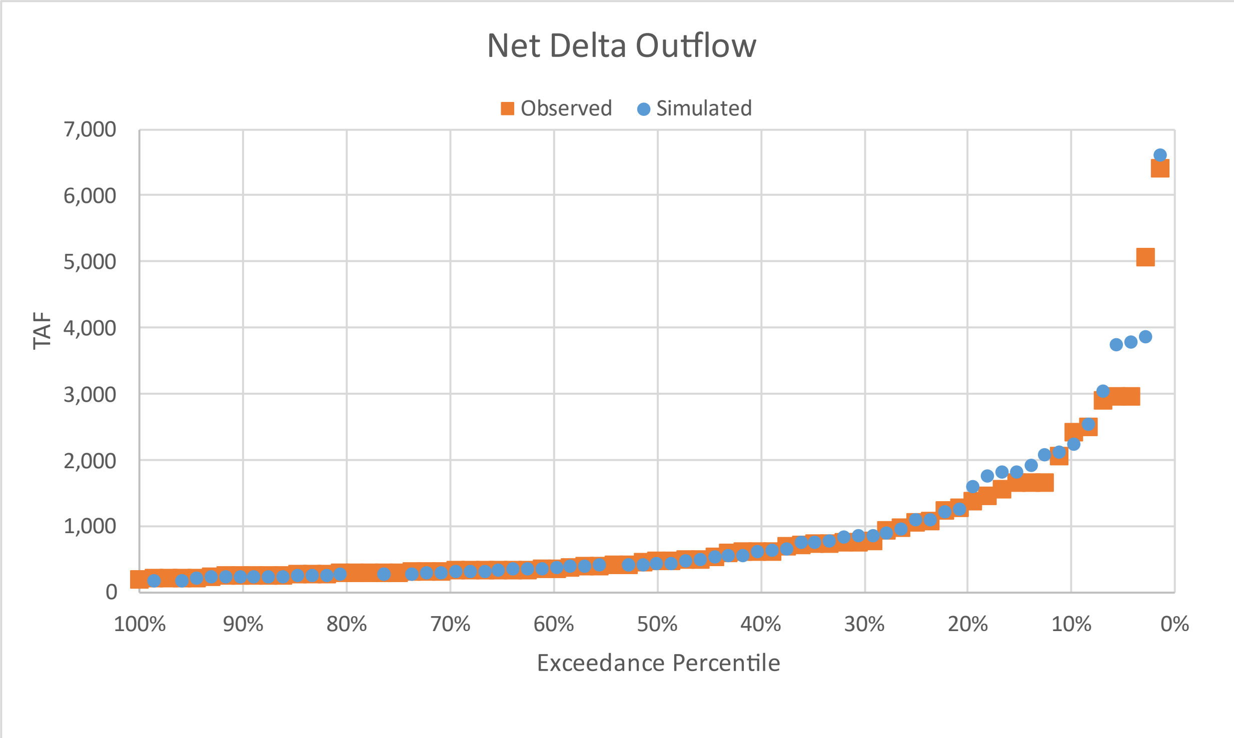


Figure A.7.13b. Net Delta Outflow, Exceedance

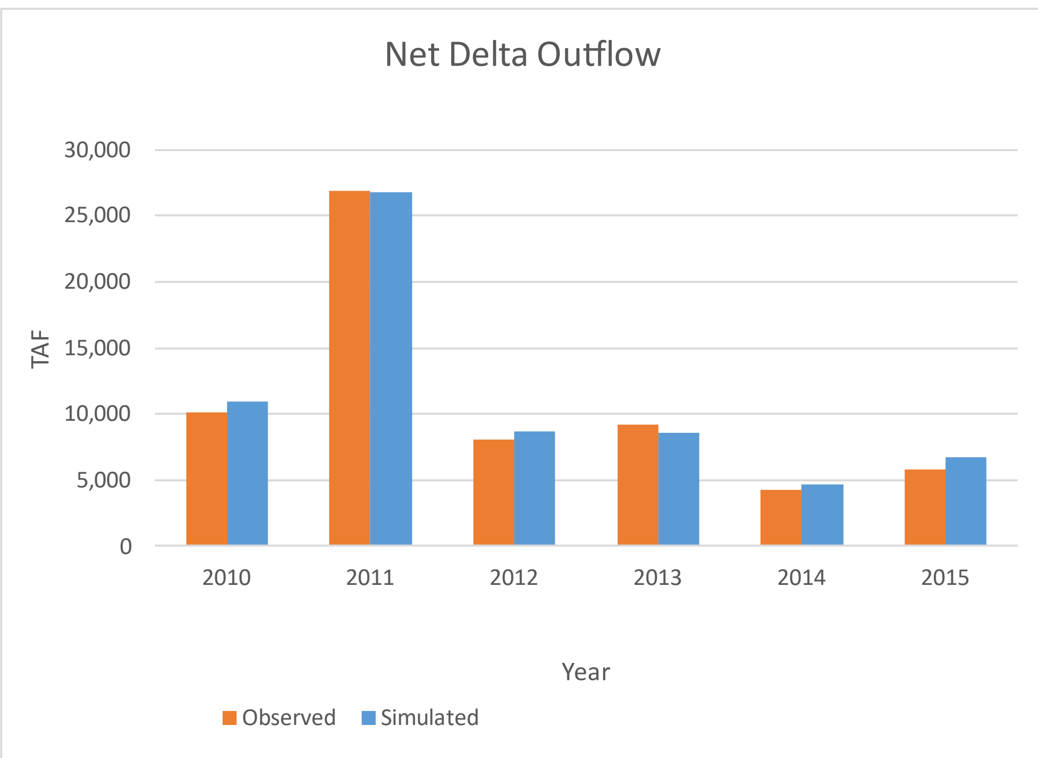


Figure A.7.13c. Net Delta Outflow, Annual 2010 to 2015

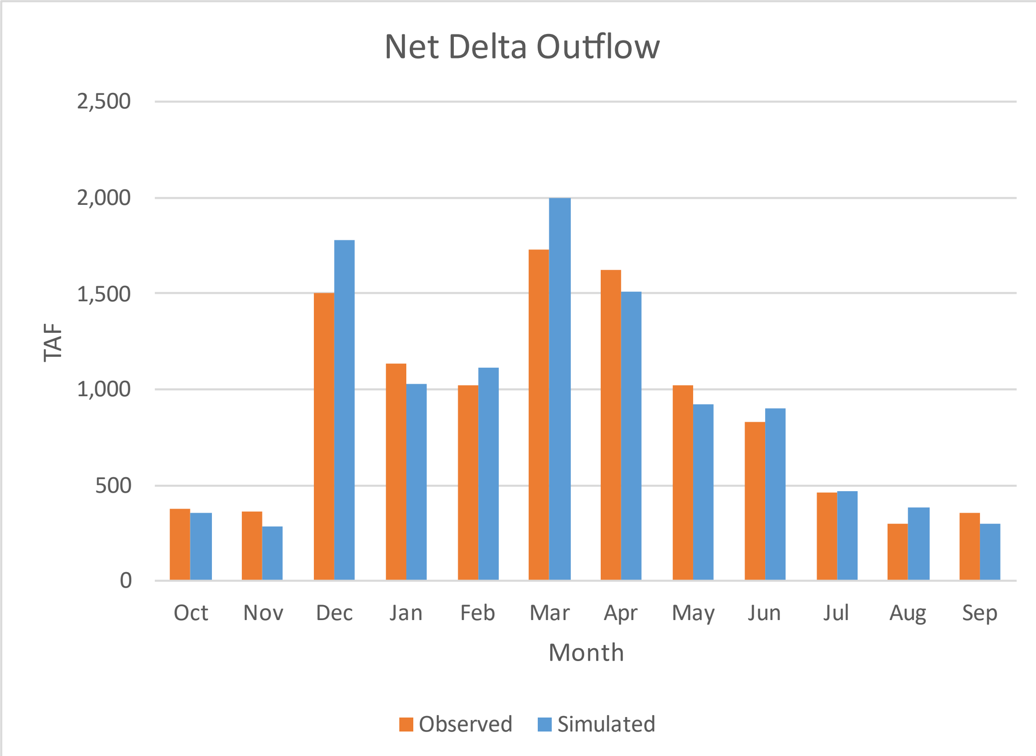


Figure A.7.13d. Net Delta Outflow, Average Monthly

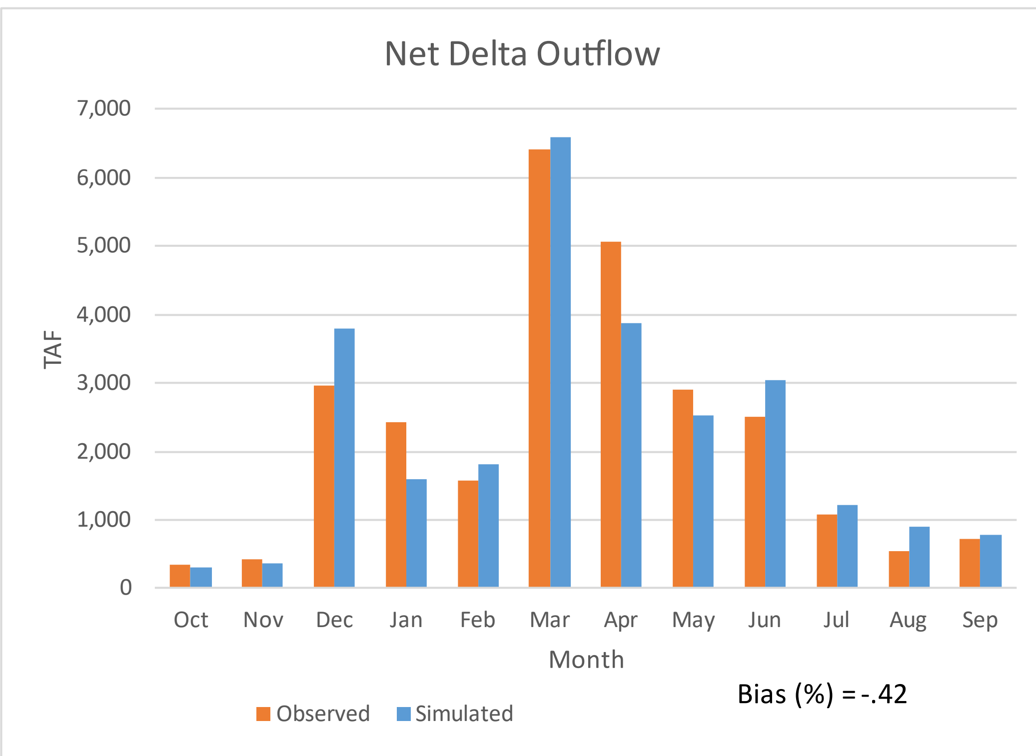


Figure A.7.13e. Net Delta Outflow, Average Monthly (Wet)

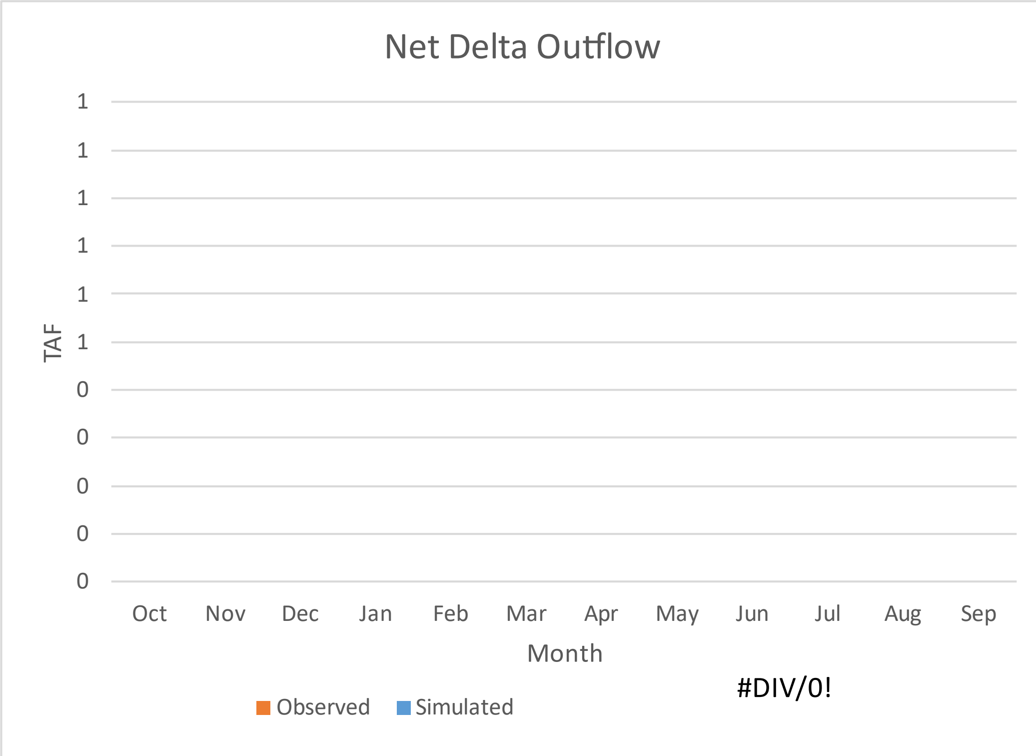


Figure A.7.13f. Net Delta Outflow, Average Monthly (Above Normal)

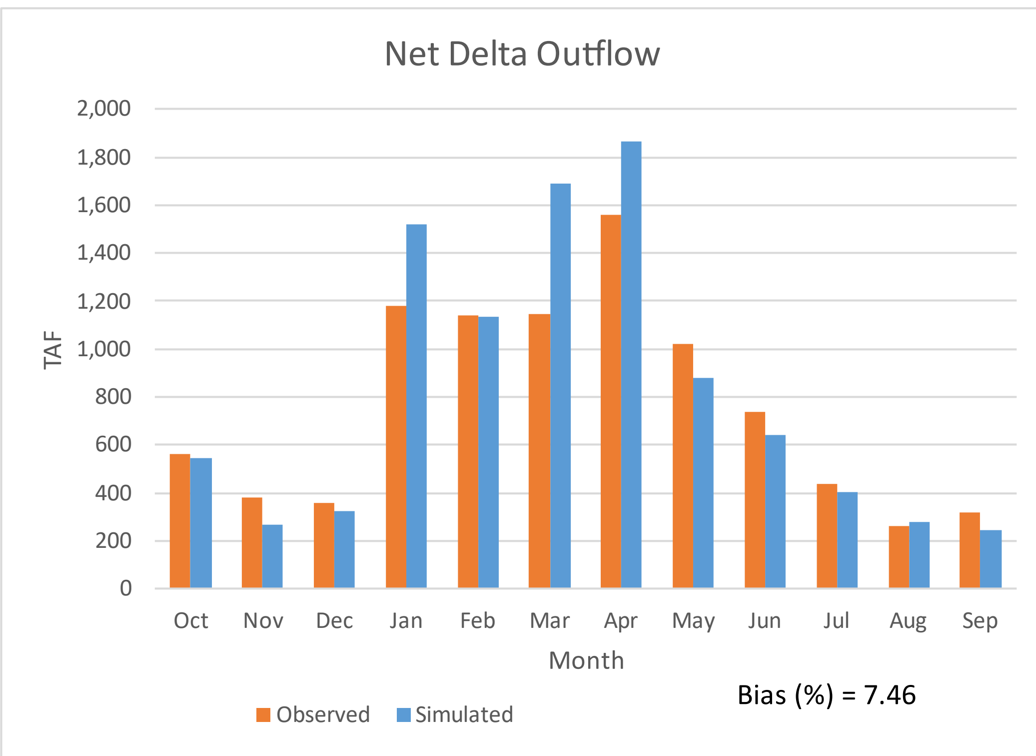


Figure A.7.13g. Net Delta Outflow, Average Monthly (Below Normal)

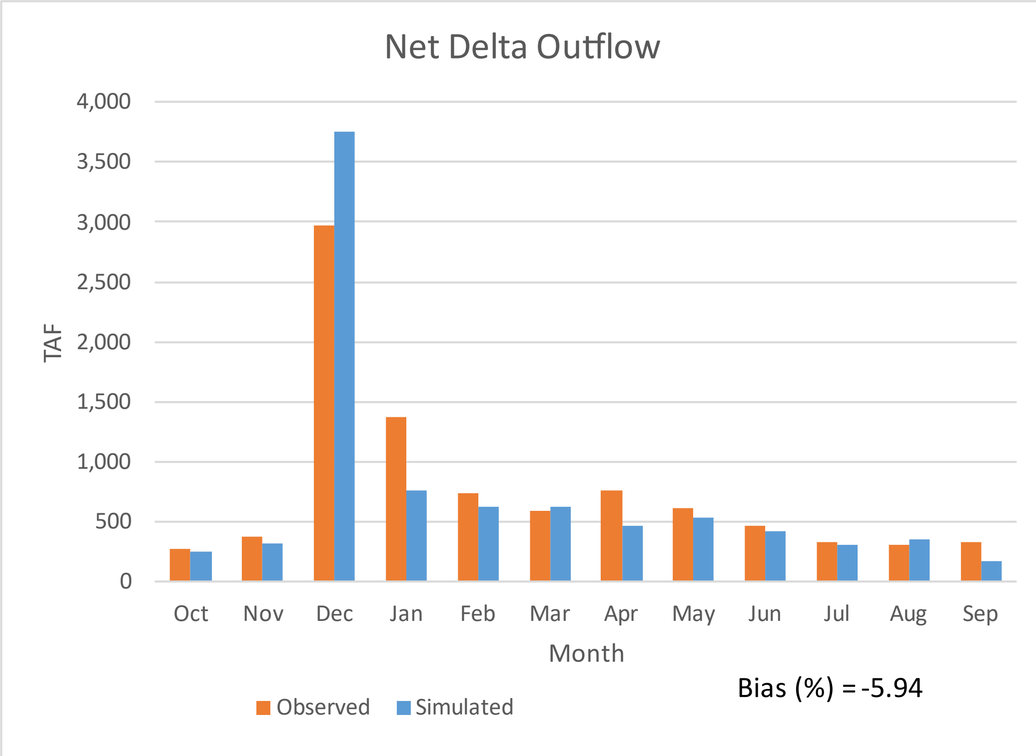


Figure A.7.13h. Net Delta Outflow, Average Monthly (Dry)

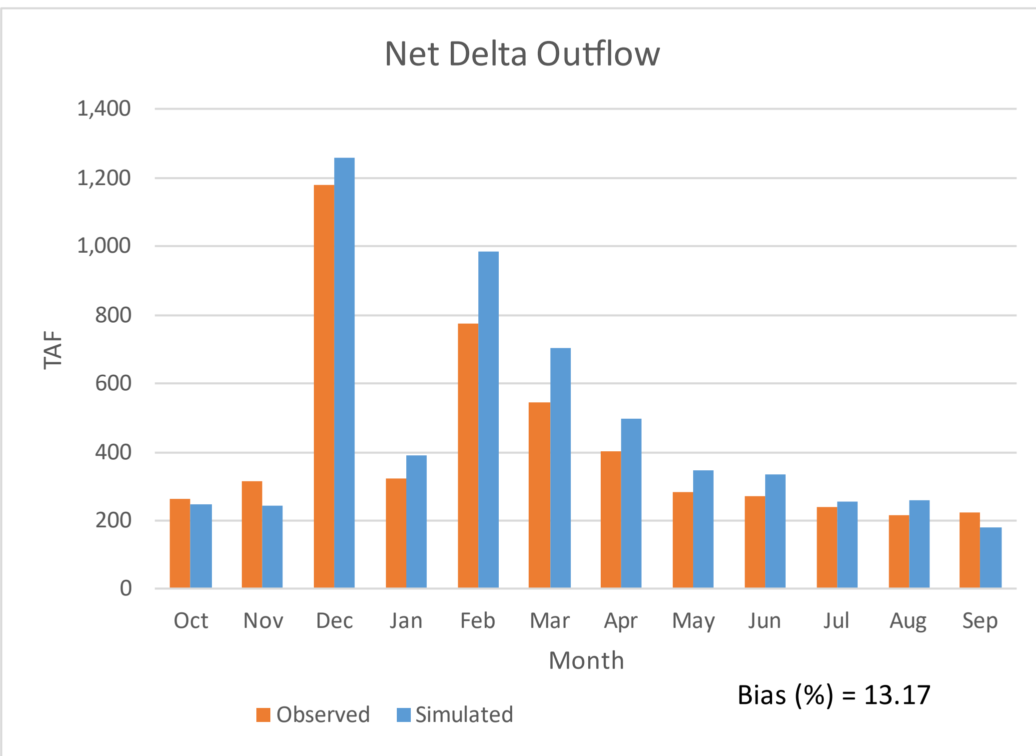


Figure A.7.13i. Net Delta Outflow, Average Monthly (Critical)

A.8 Non-Project Streamflow Validation

The performance of the model for streams not influenced by CVP and SWP operations are presented in this section. Streamflows are compared to historical observations for water years 1996 – 2015 as this period provides a range of hydrologic conditions and contains the period from which demands were derived for SacWAM (land use is based on data for 1998-2007, urban demands are based on 1996-2010). Results are presented for the following streams and locations:

1. Butte Creek near Durham
2. Yuba River near Marysville
3. Bear River near Wheatland
4. Cache Creek at Rumsey
5. Putah Creek below Putah Diversion Dam
6. Mokelumne River at Woodbridge
7. Calaveras River below New Hogan Dam
8. Stony Creek below Black Butte Dam
9. Cache Creek at Yolo
10. Cosumnes River at Michigan Bar
11. Folsom Lake inflow
12. Lake Oroville inflow

Results are presented for water years 1996-2015 in the form of: (1) time series of monthly flows, (2) monthly flow exceedence, (3) time series of annual flows, and (4) average monthly flows. Subsequently, average monthly flows are presented by water year type (Sacramento Valley 40-30-30 index).

A.8.1 Butte Creek near Durham

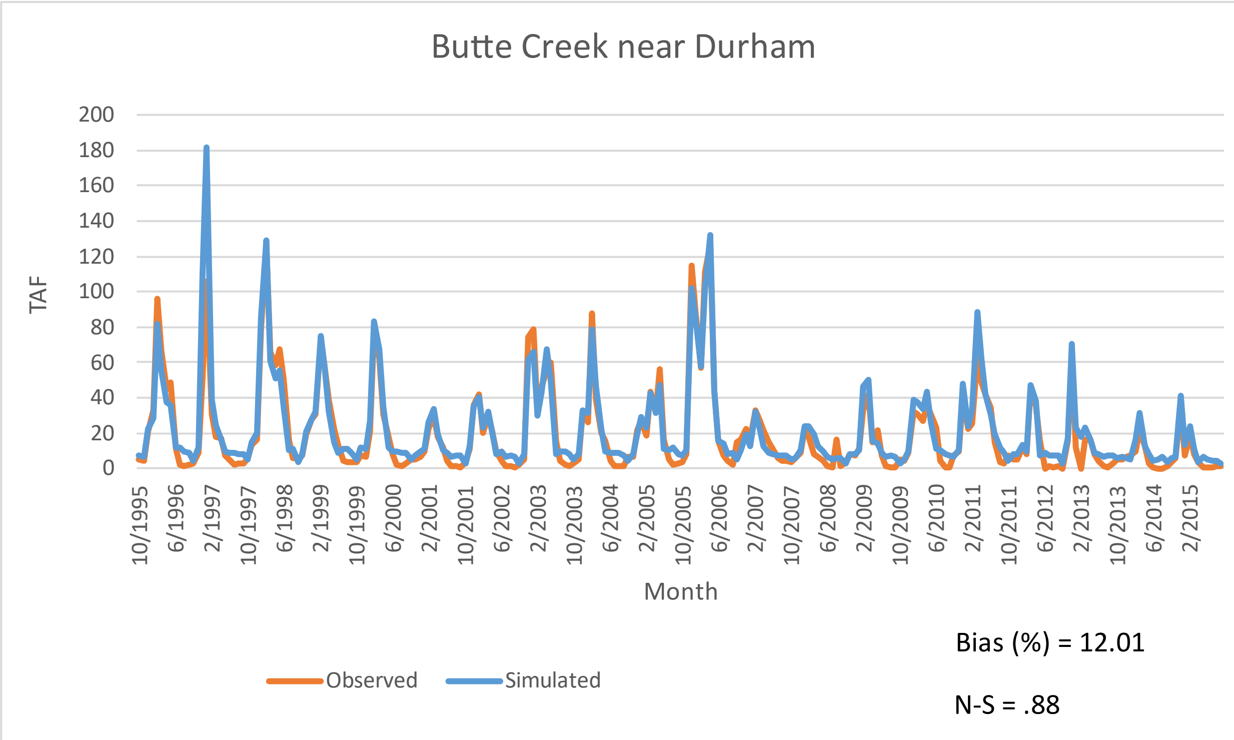


Figure A.8.1a. Butte Creek near Durham, Monthly 1996 to 2015

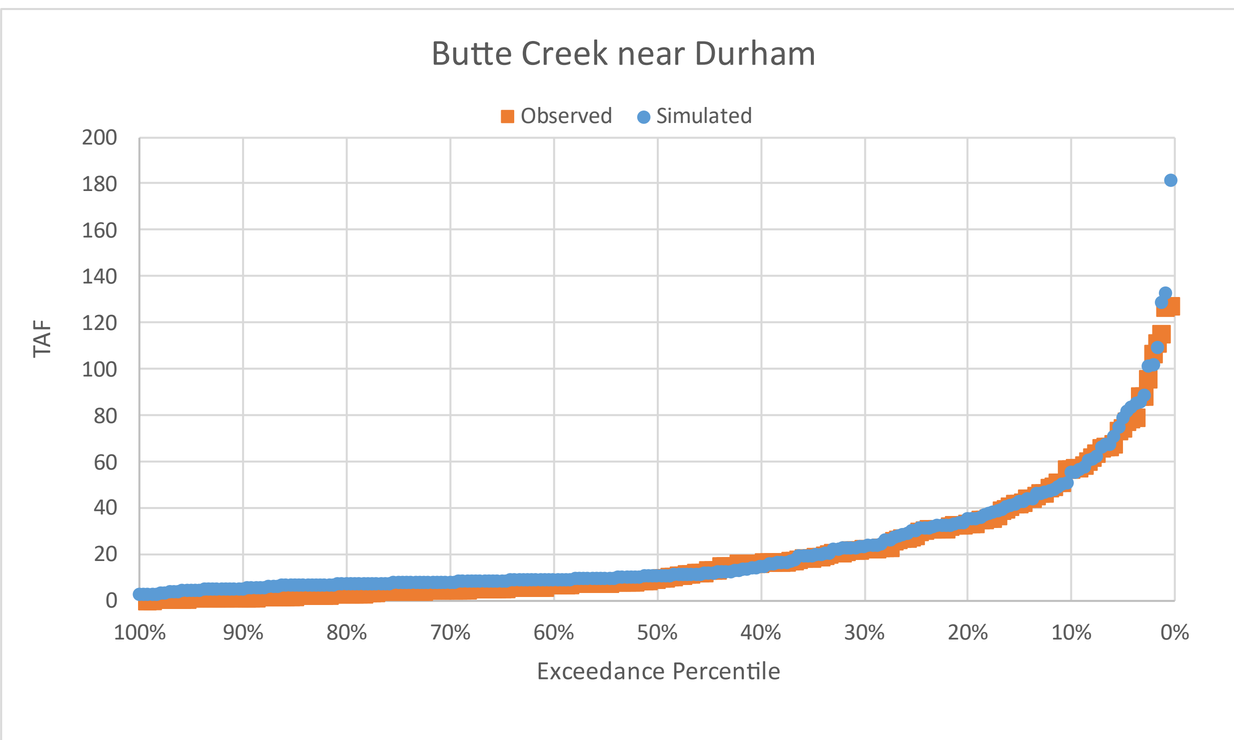


Figure A.8.1b. Butte Creek near Durham, Exceedance

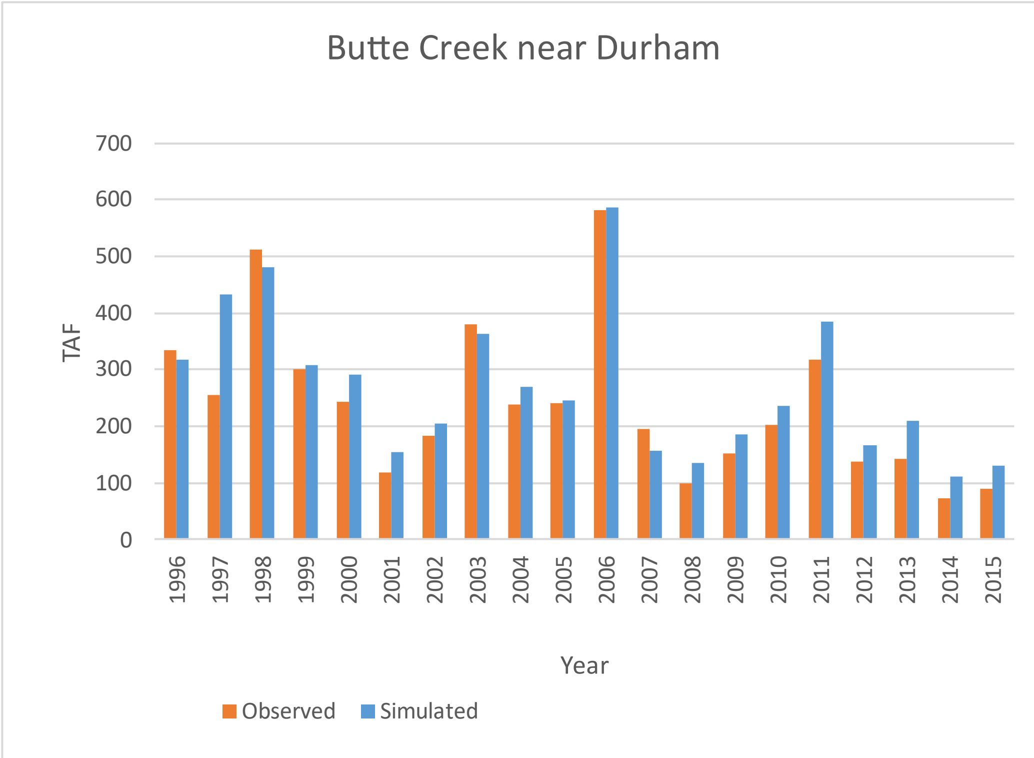


Figure A.8.1c. Butte Creek near Durham, Annual 1996 to 2015

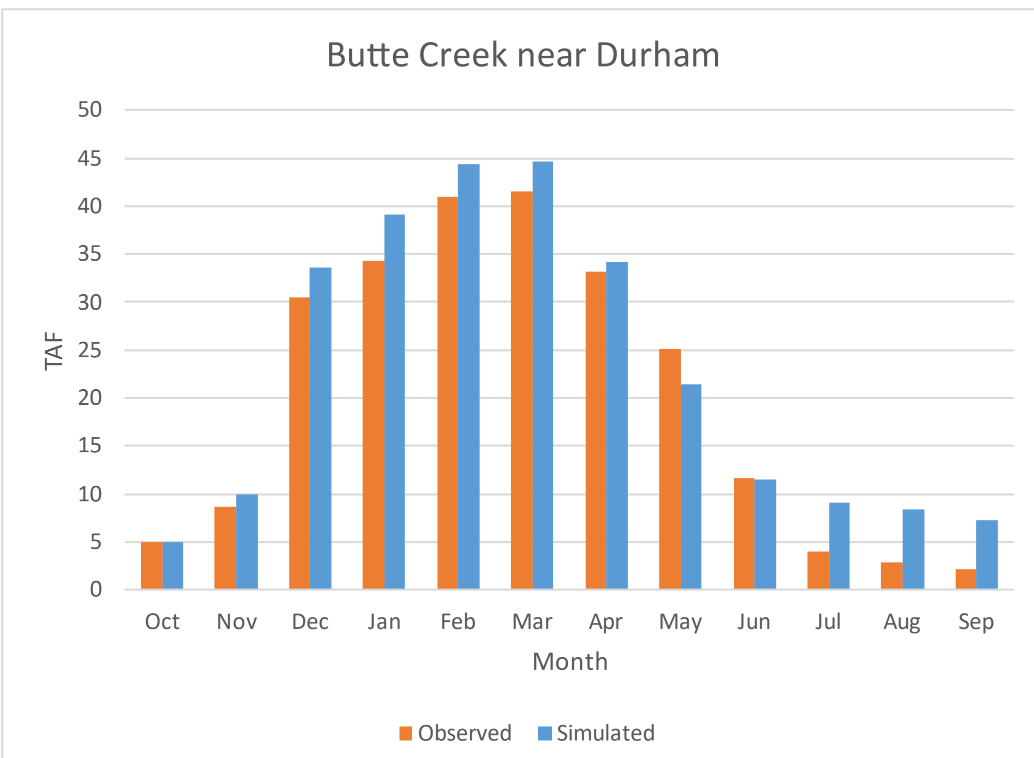


Figure A.8.1d. Butte Creek near Durham, Average Monthly

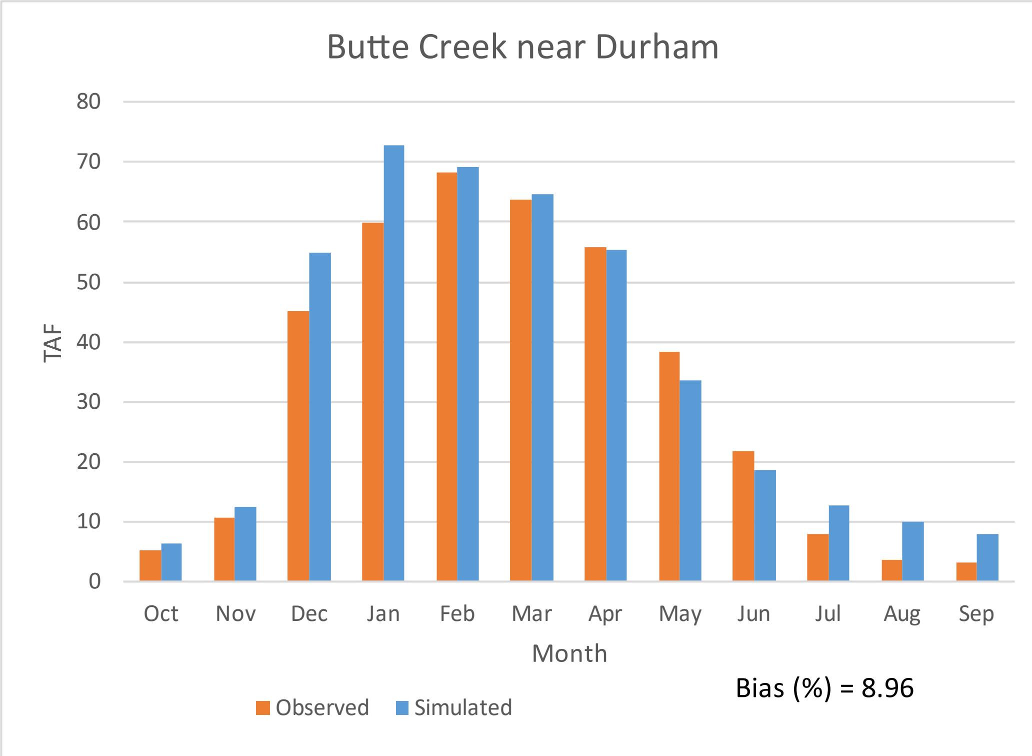


Figure A.8.1e. Butte Creek near Durham, Average Monthly (Wet)

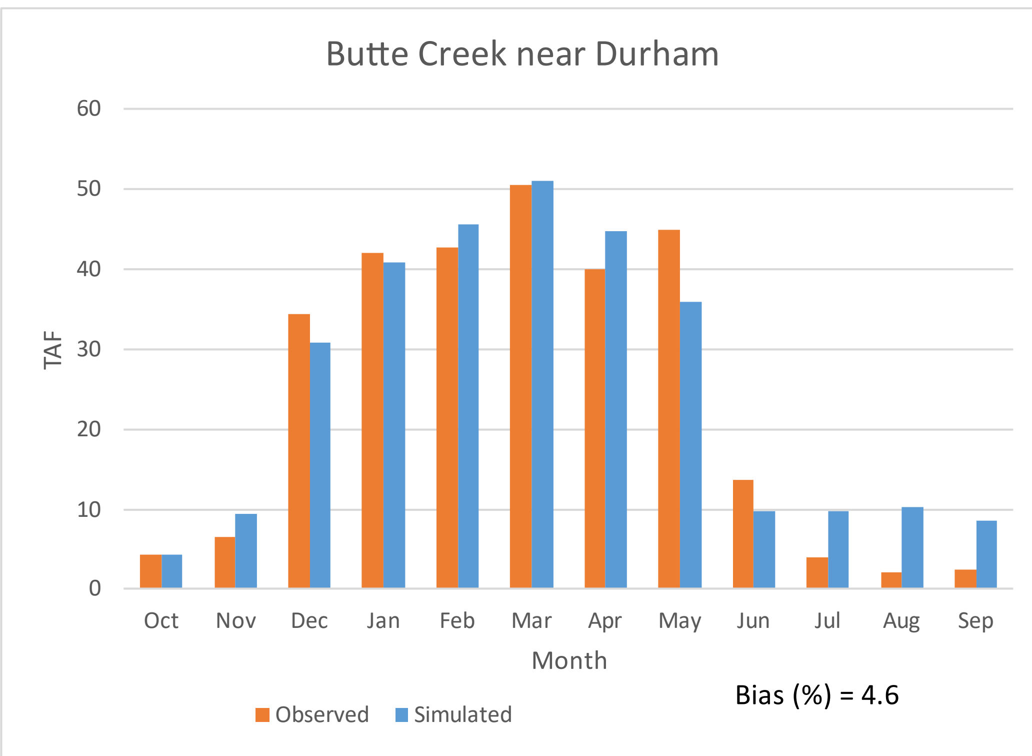


Figure A.8.1f. Butte Creek near Durham, Average Monthly (Above Normal)

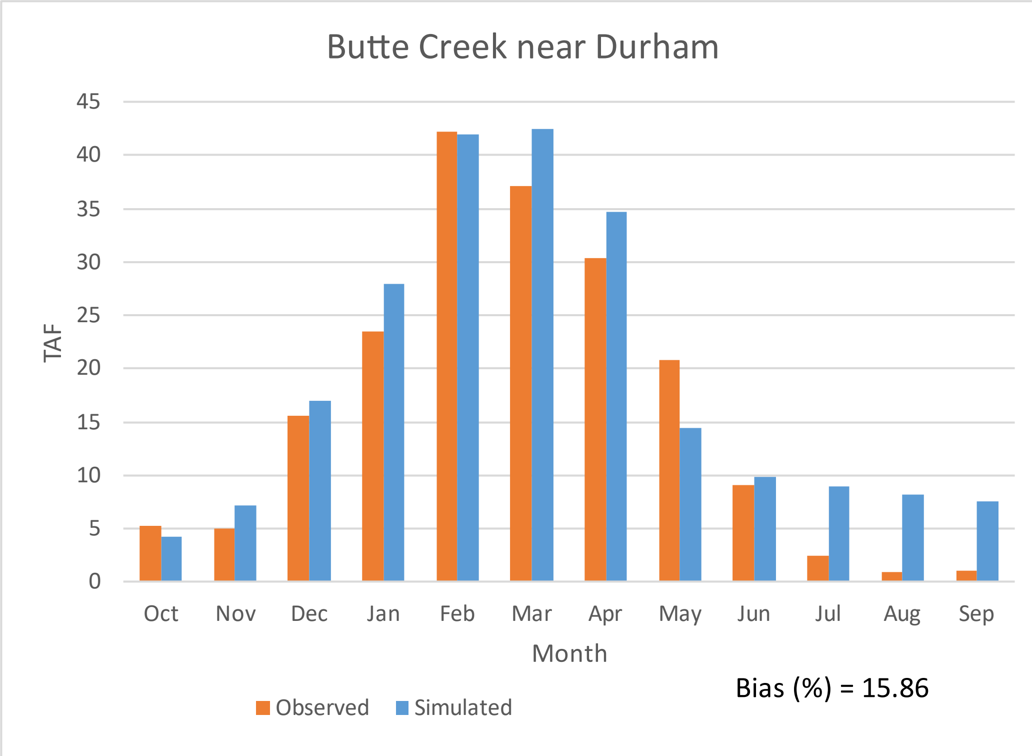


Figure A.8.1g. Butte Creek near Durham, Average Monthly (Below Normal)

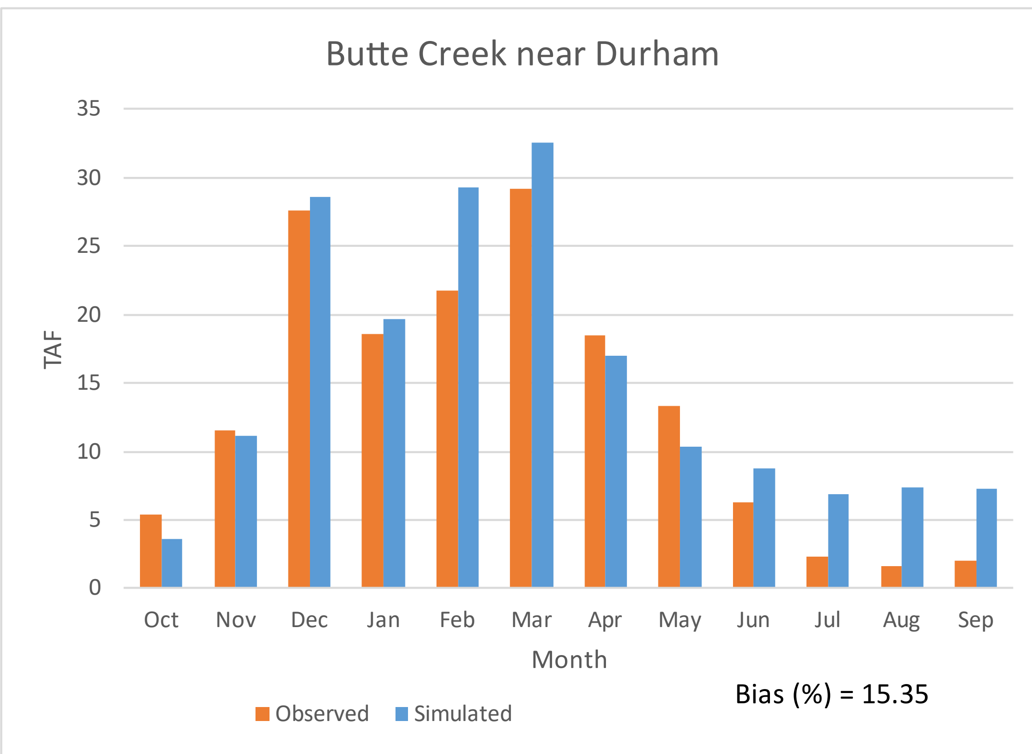


Figure A.8.1h. Butte Creek near Durham, Average Monthly (Dry)

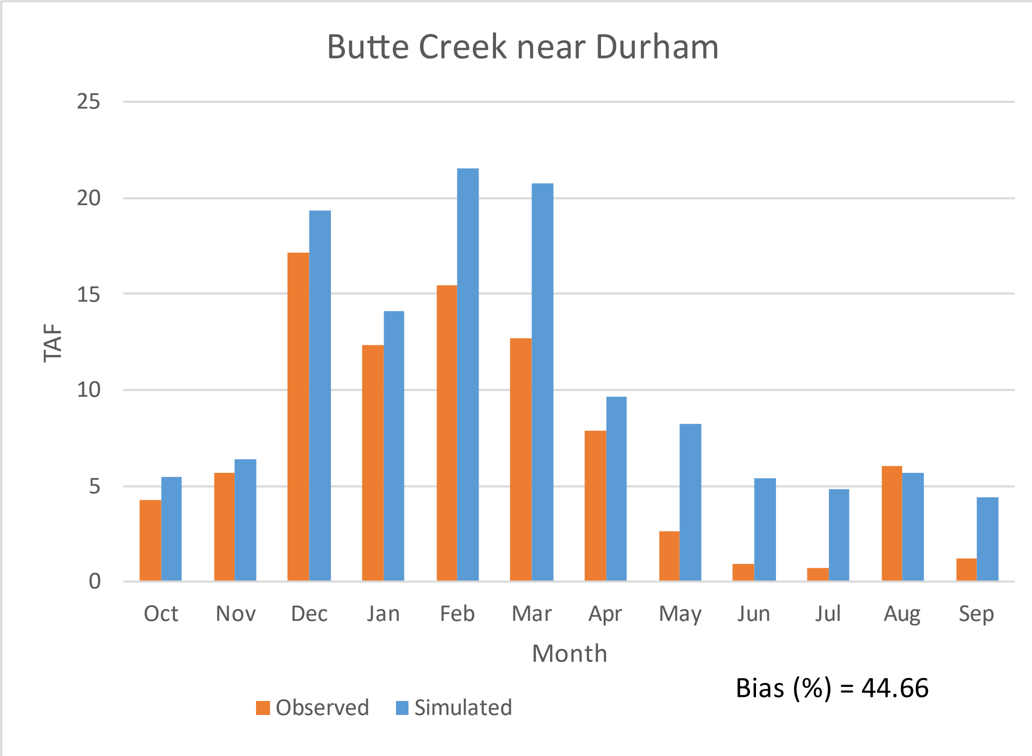


Figure A.8.1i. Butte Creek near Durham, Average Monthly (Critical)

A.8.2 Yuba River near Marysville

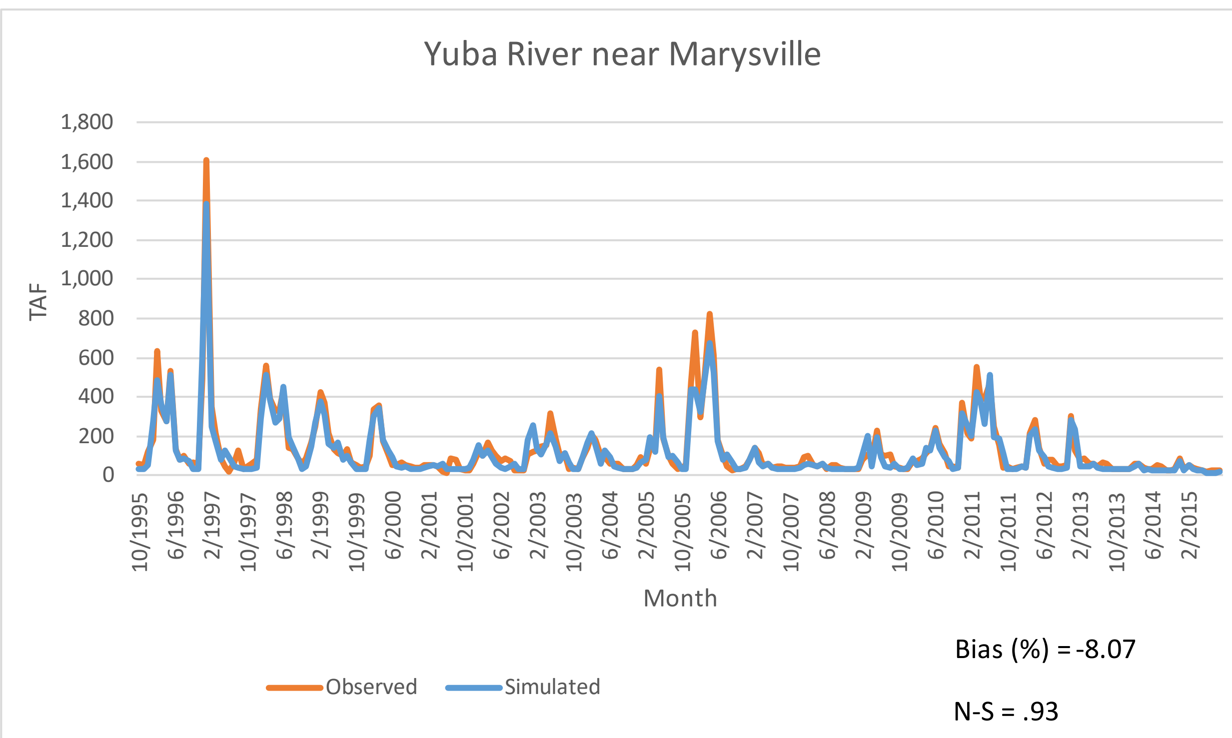


Figure A.8.2a. Yuba River near Marysville, Monthly 1996 to 2015

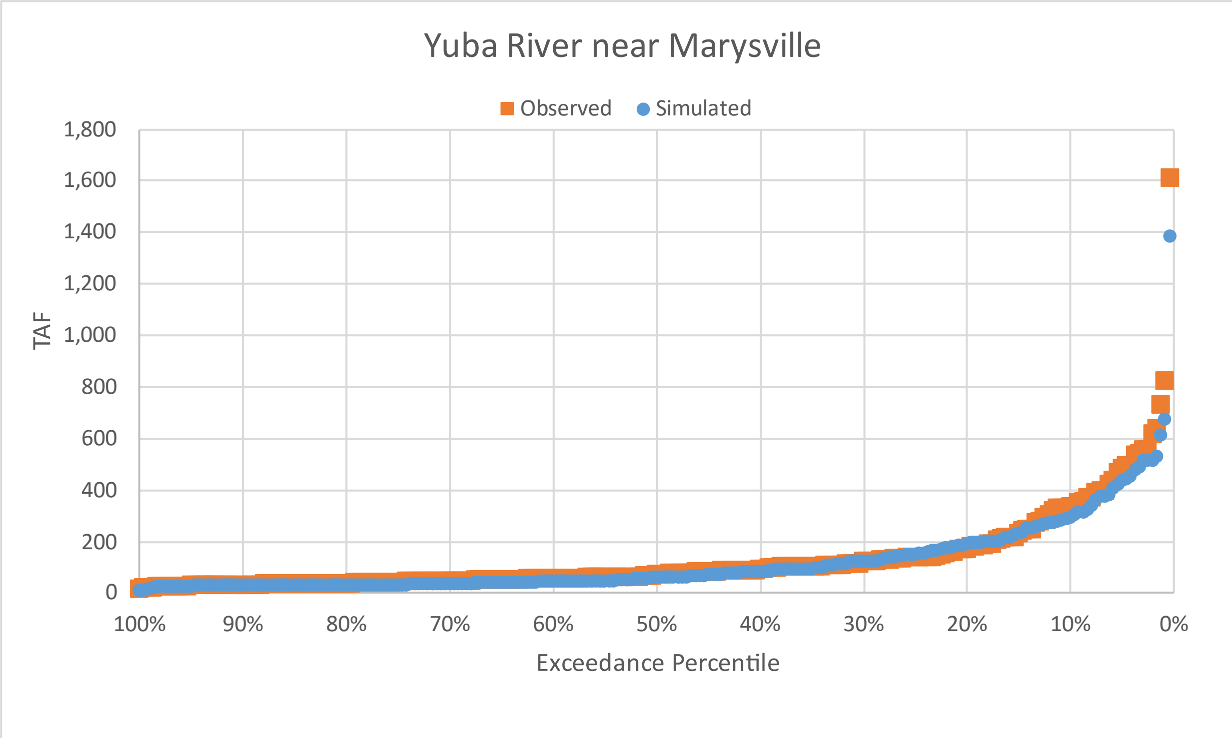


Figure A.8.2b. Yuba River near Marysville, Exceedance

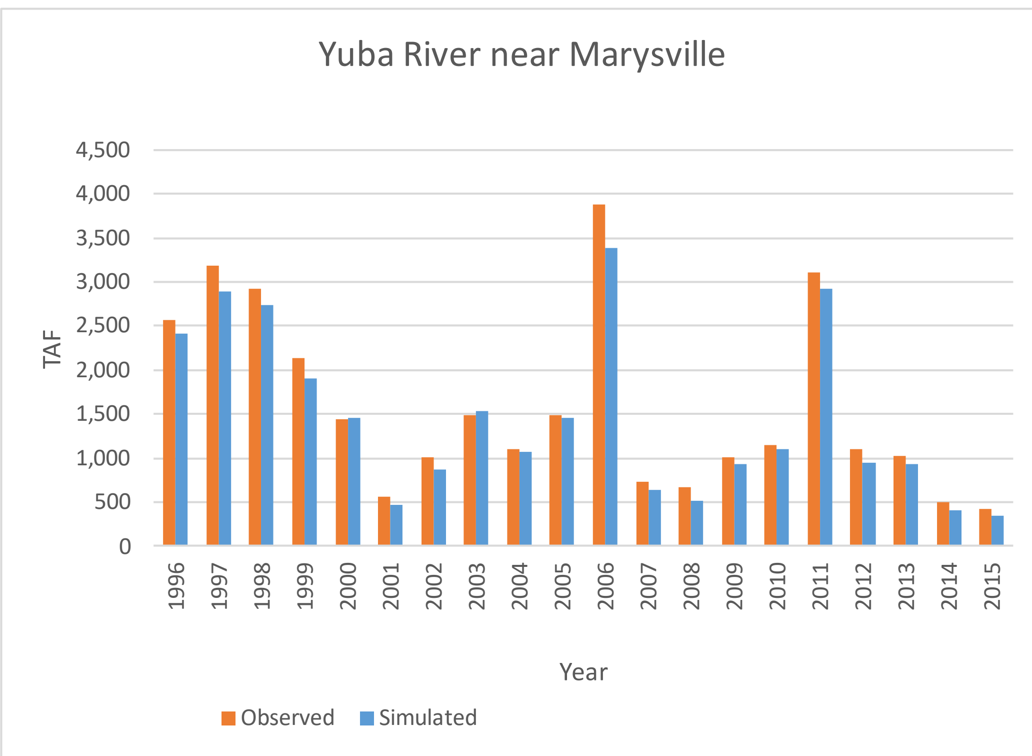


Figure A.8.2c. Yuba River near Marysville, Annual 1996 to 2015

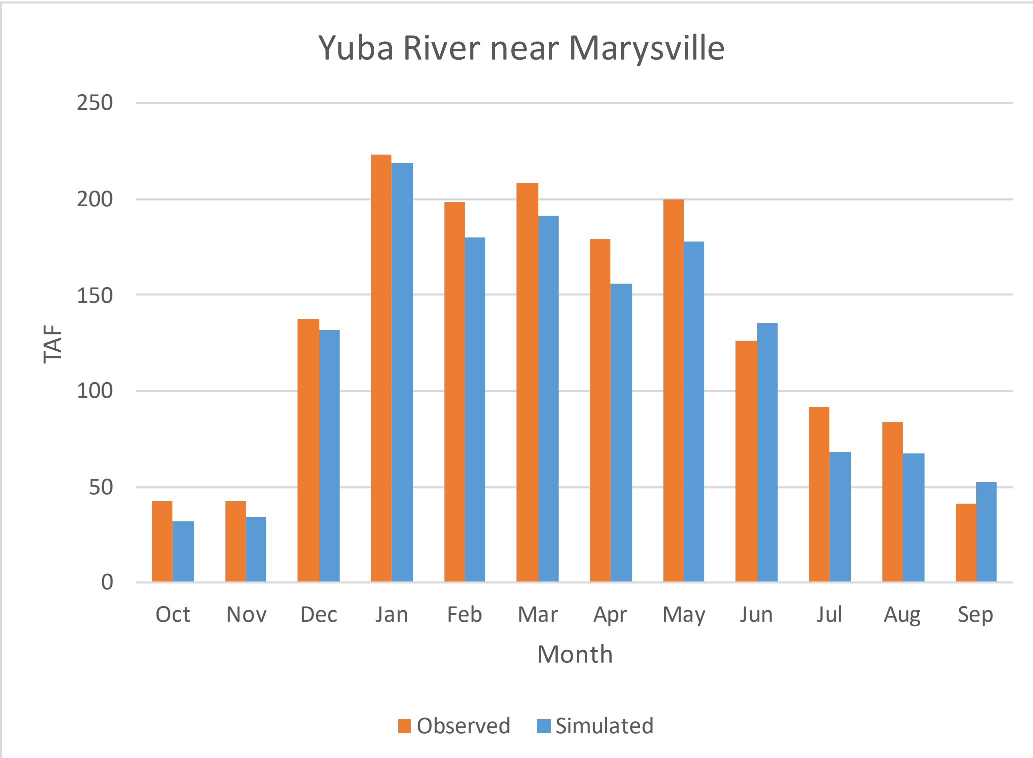


Figure A.8.2d. Yuba River near Marysville, Average Monthly

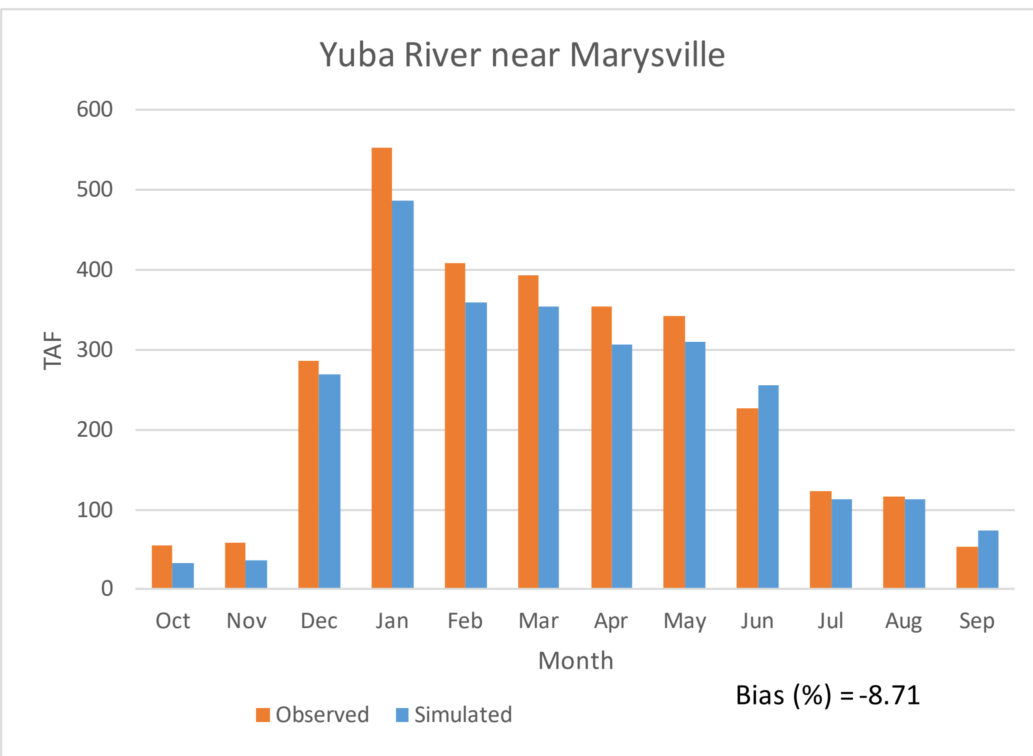


Figure A.8.2e. Yuba River near Marysville, Average Monthly (Wet)

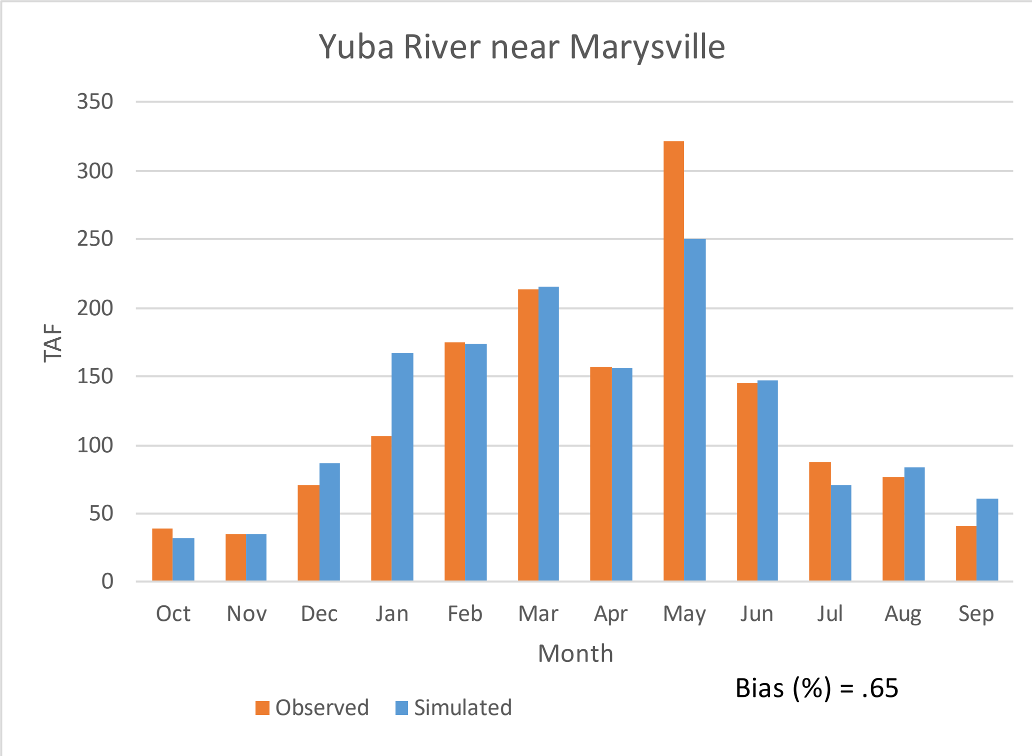


Figure A.8.2f. Yuba River near Marysville, Average Monthly (Above Normal)

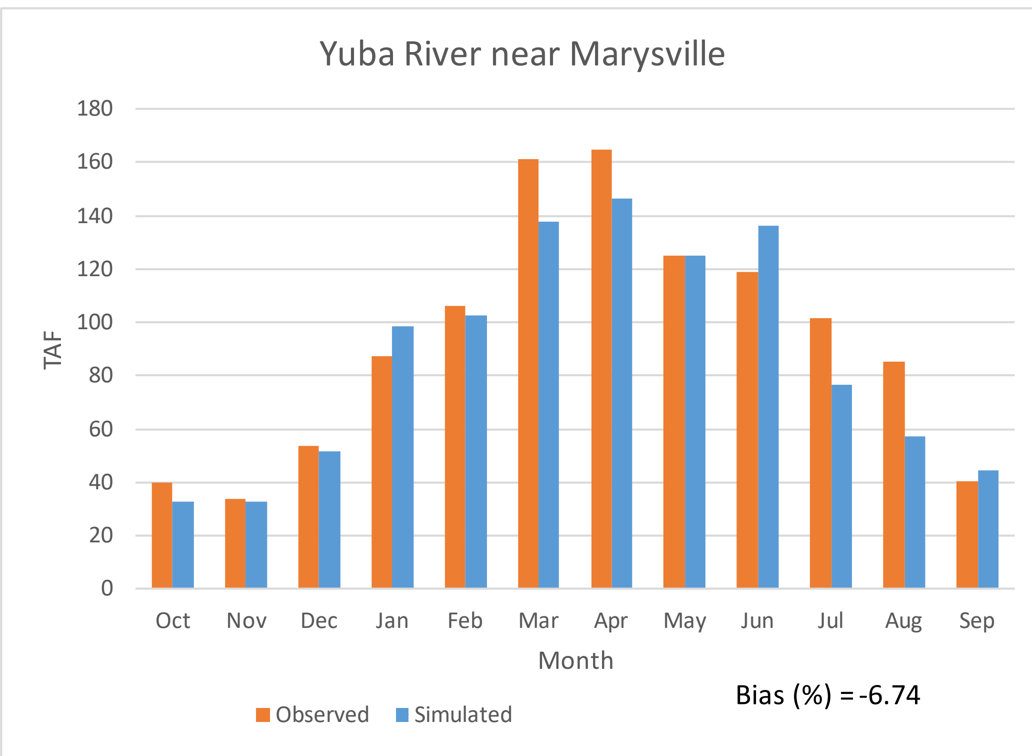


Figure A.8.2g. Yuba River near Marysville, Average Monthly (Below Normal)

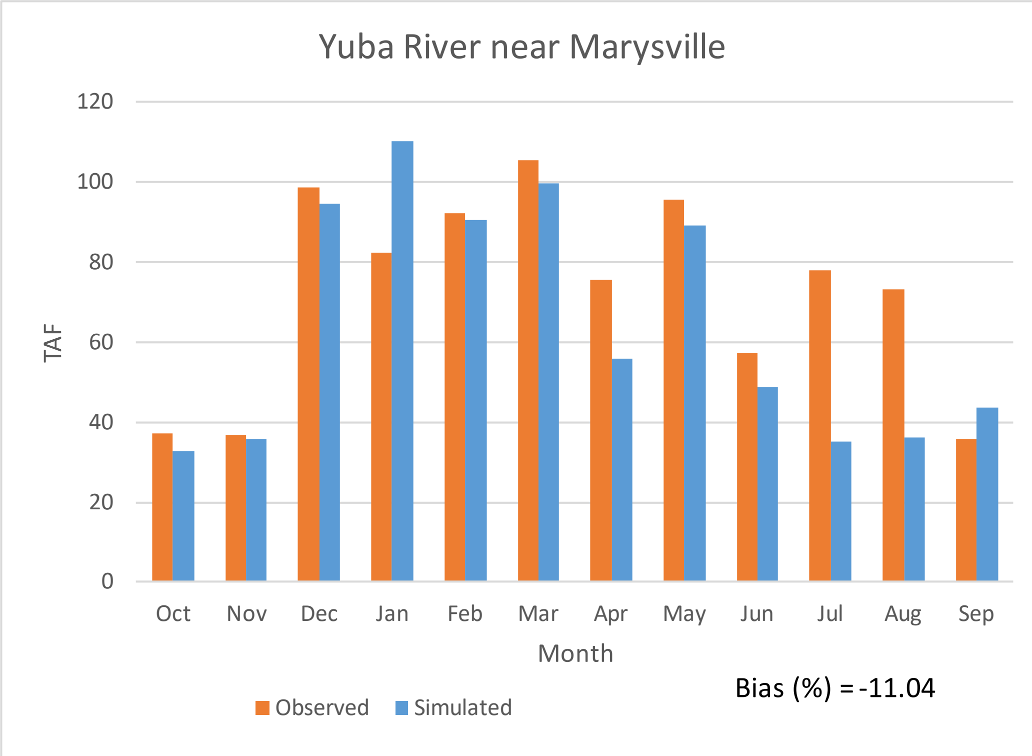


Figure A.8.2h. Yuba River near Marysville, Average Monthly (Dry)

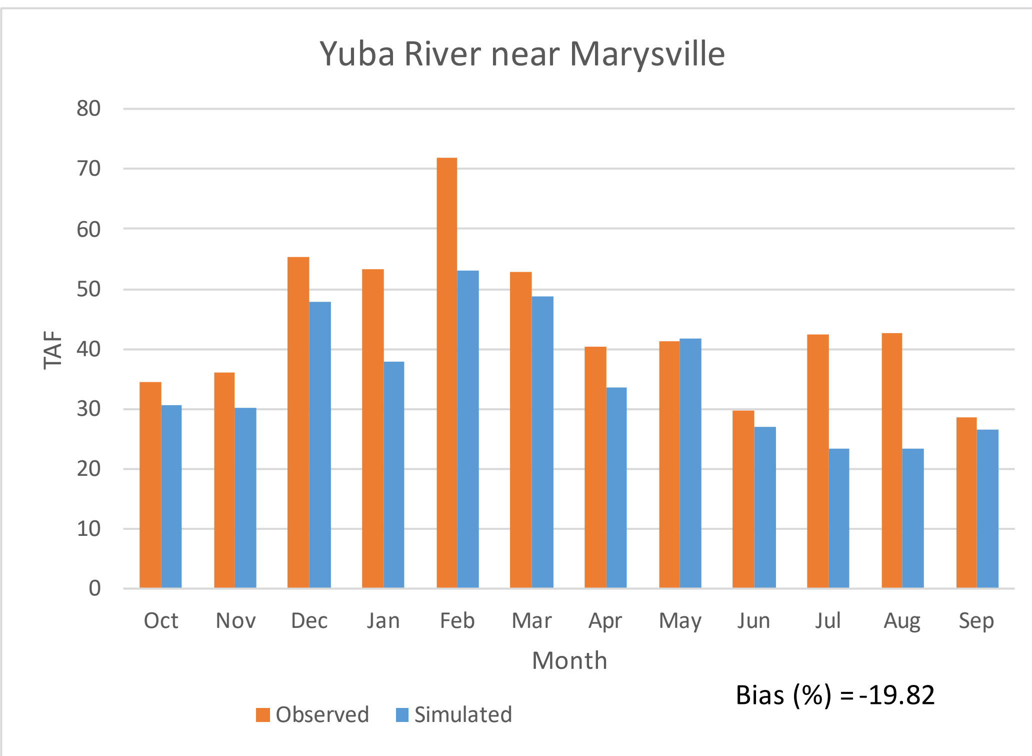


Figure A.8.2i. Yuba River near Marysville, Average Monthly (Critical)

A.8.3 Bear River near Wheatland

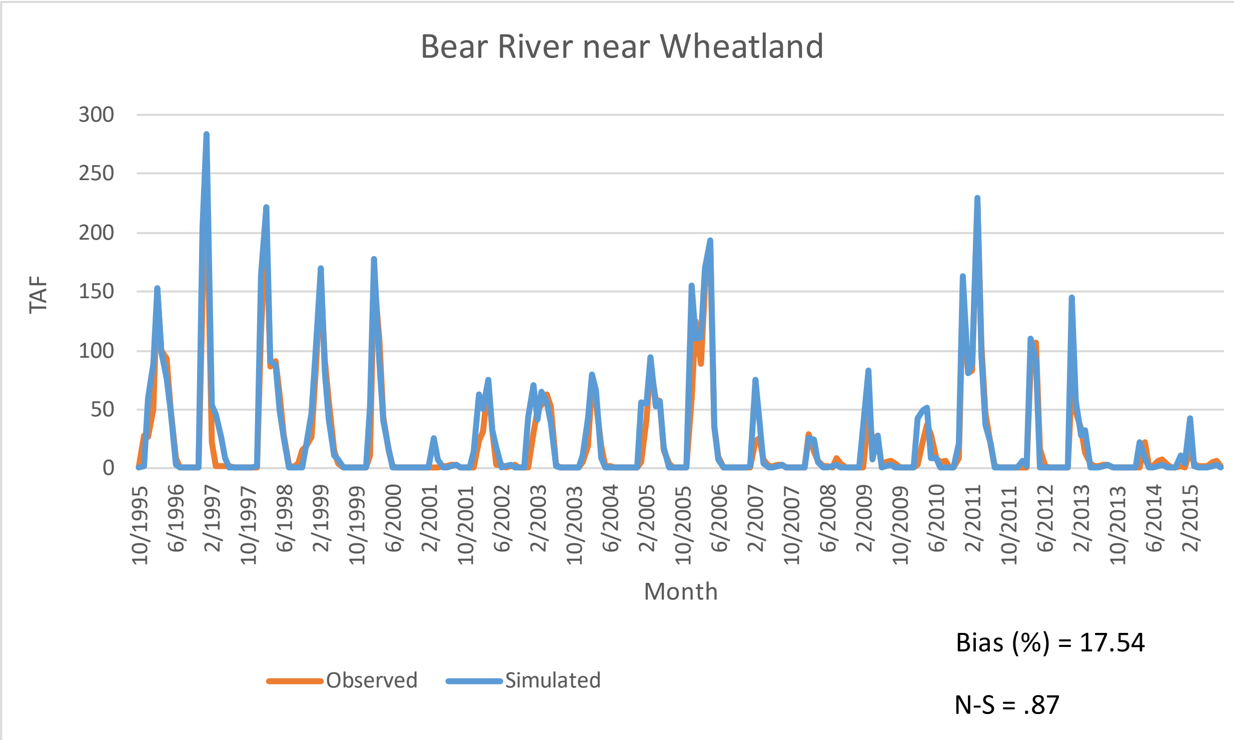


Figure A.8.3a. Bear River near Wheatland, Monthly 1996 to 2015

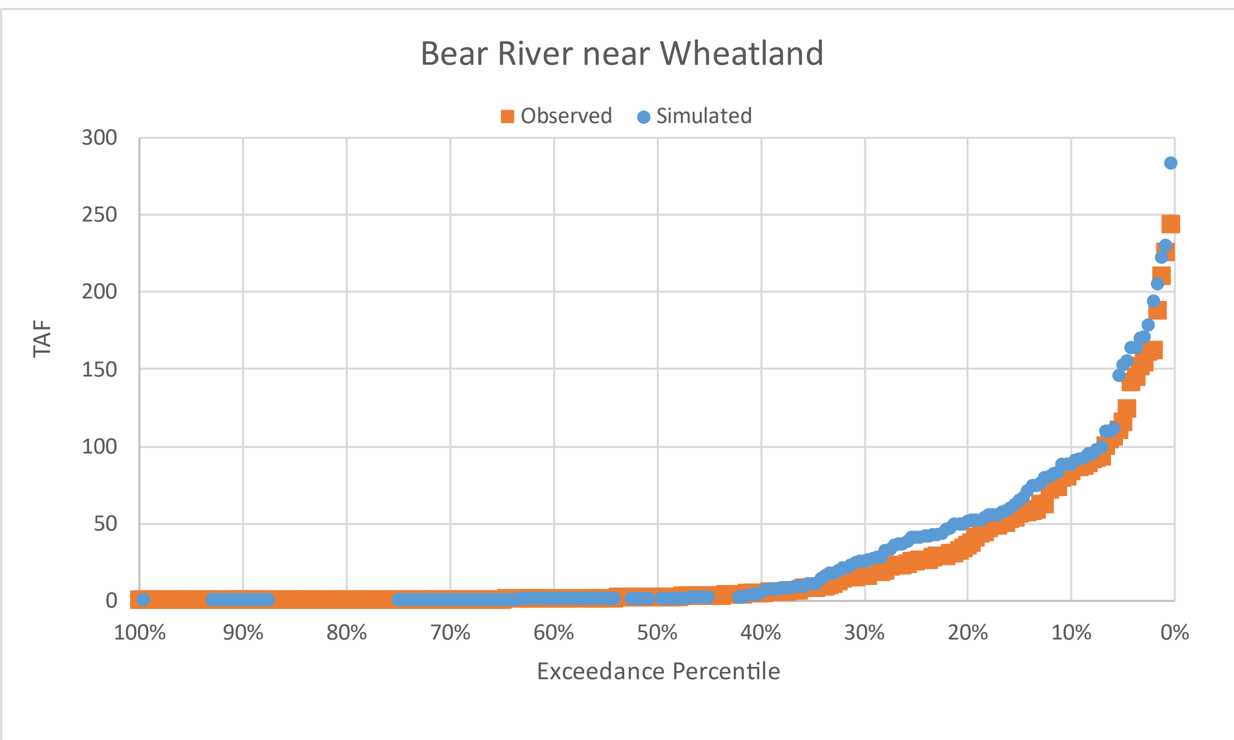


Figure A.8.3b. Bear River near Wheatland, Exceedance

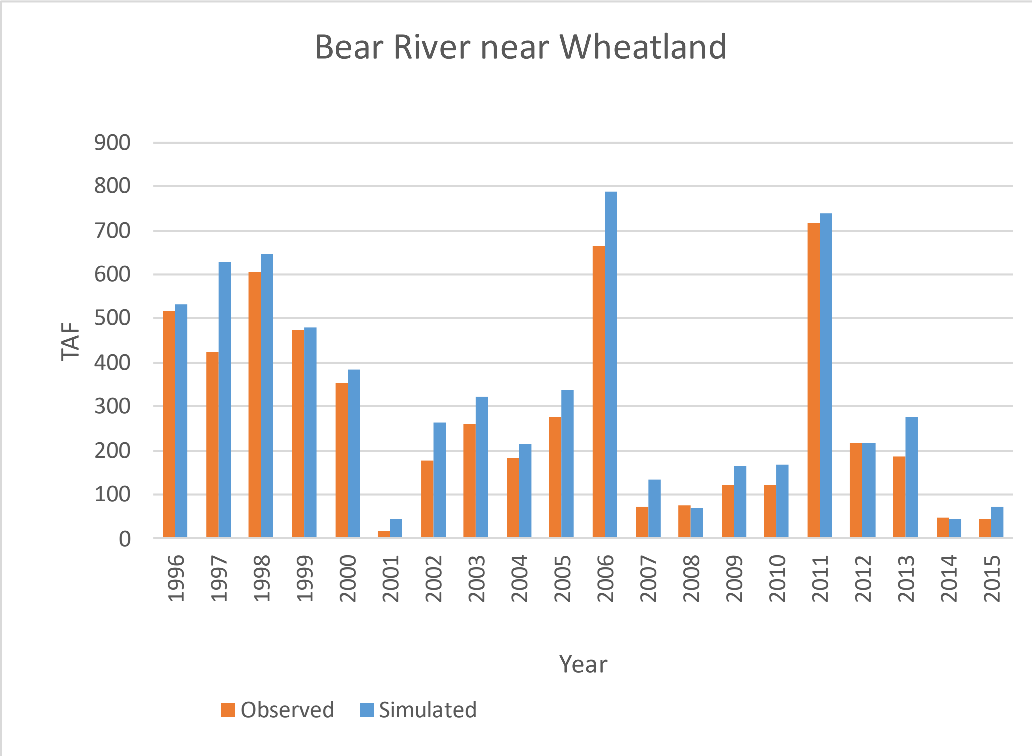


Figure A.8.3c. Bear River near Wheatland, Annual 1996 to 2015

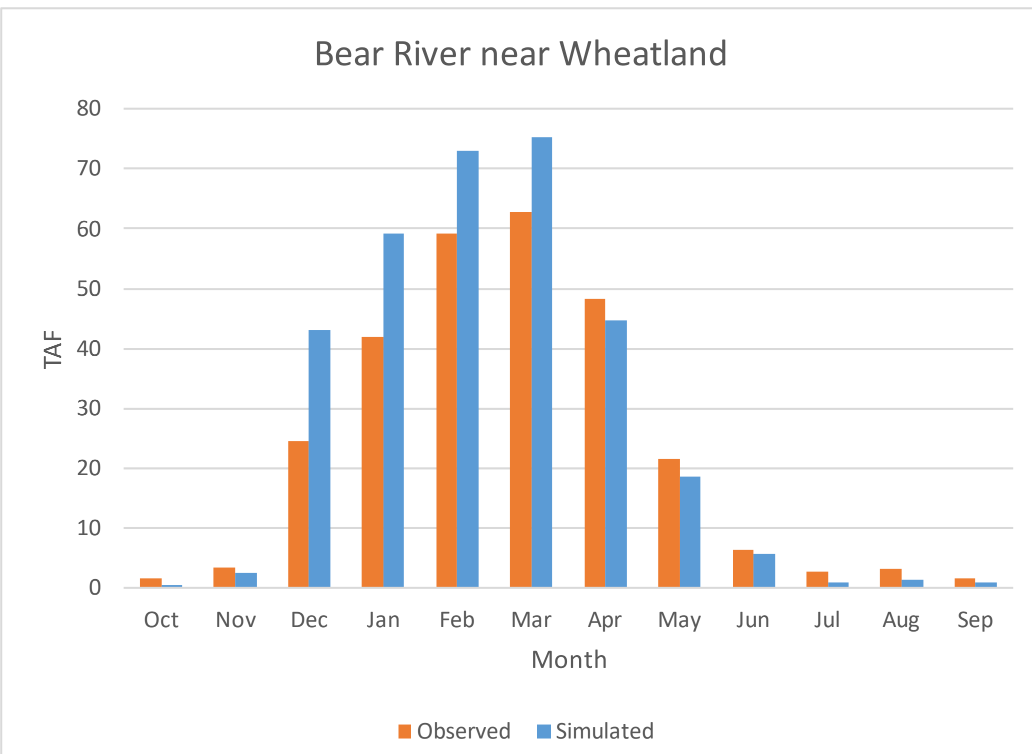


Figure A.8.3d. Bear River near Wheatland, Average Monthly

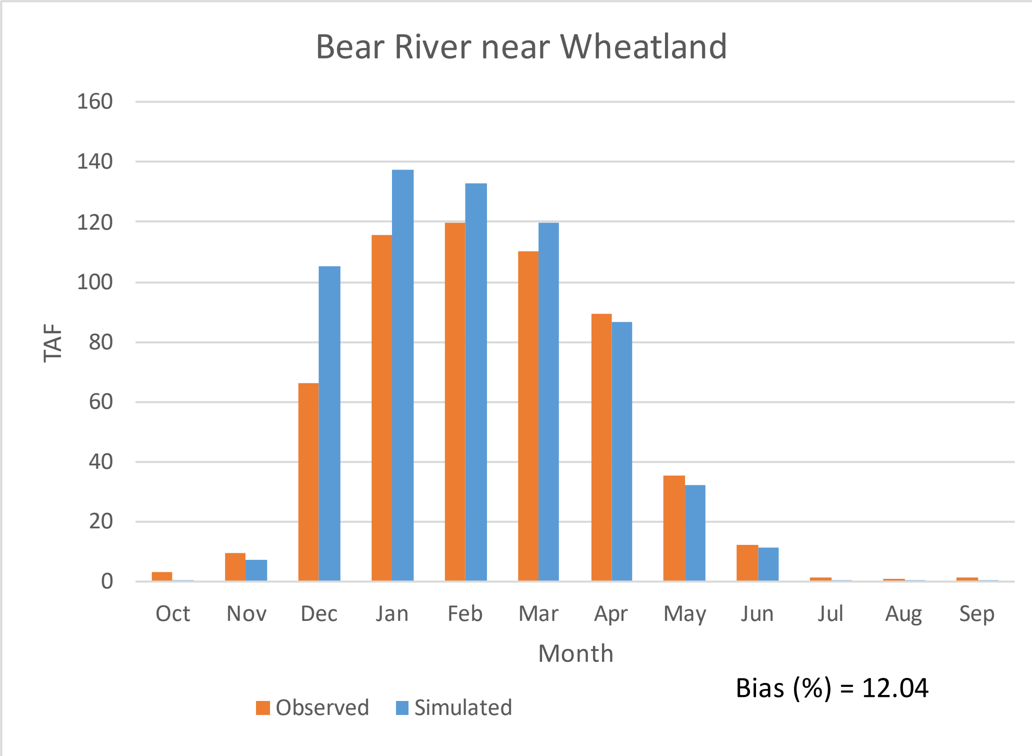


Figure A.8.3e. Bear River near Wheatland, Average Monthly (Wet)

Bear River near Wheatland, Average Monthly (Above Normal)

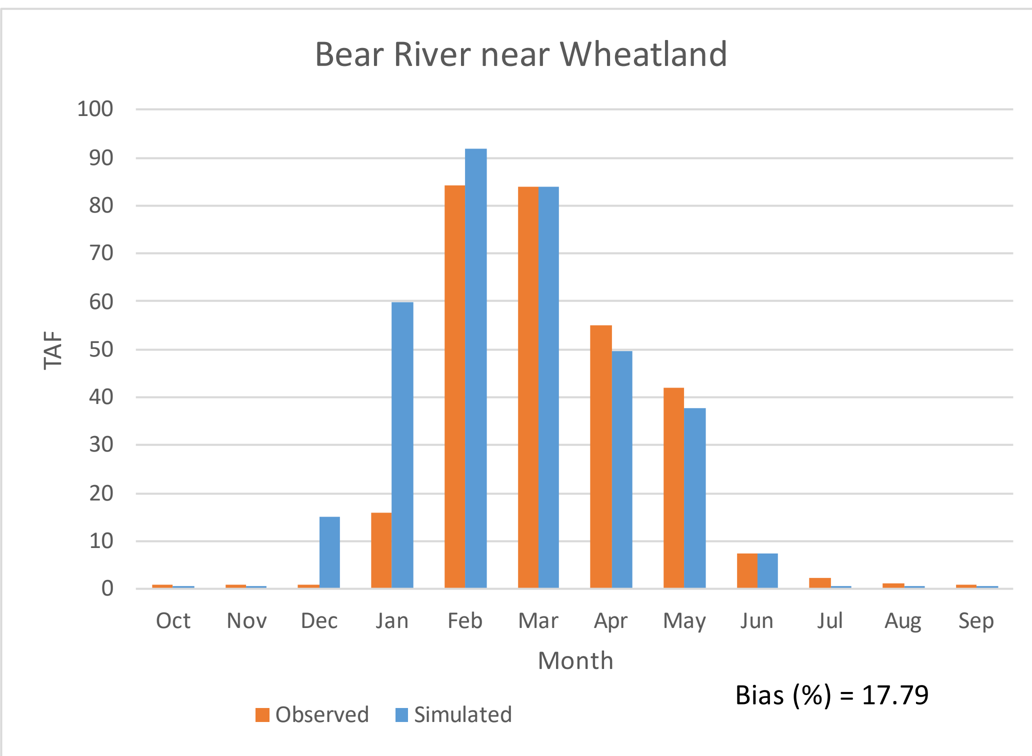


Figure A.8.3f. Bear River near Wheatland, Average Monthly (Above Normal)

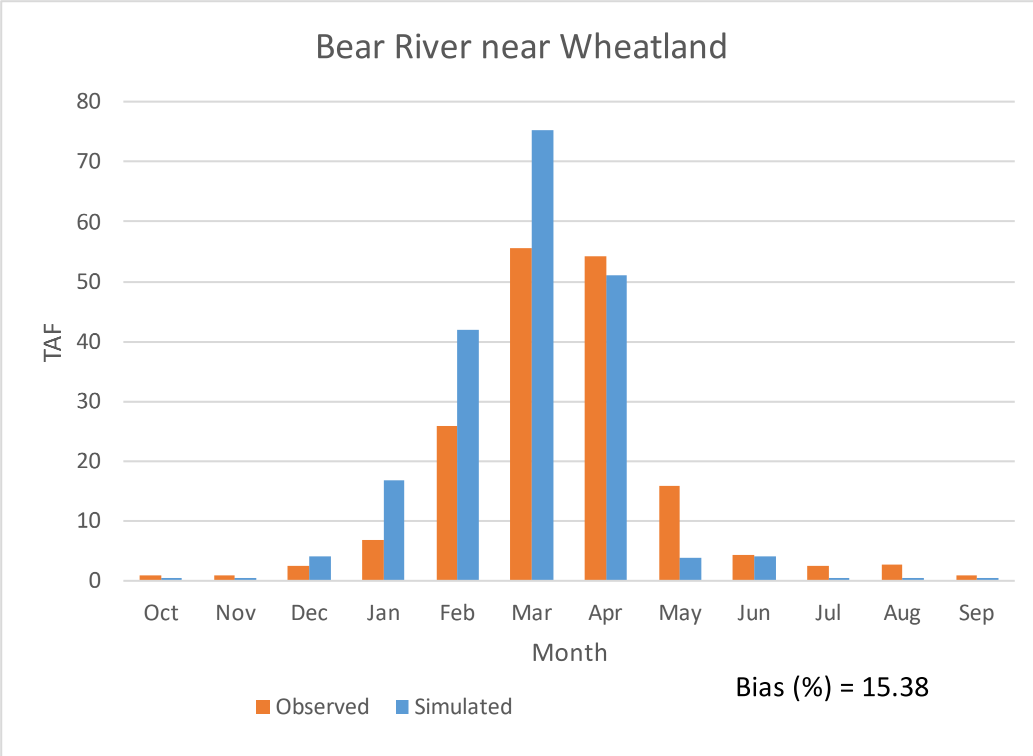


Figure A.8.3g. Bear River near Wheatland, Average Monthly (Below Normal)

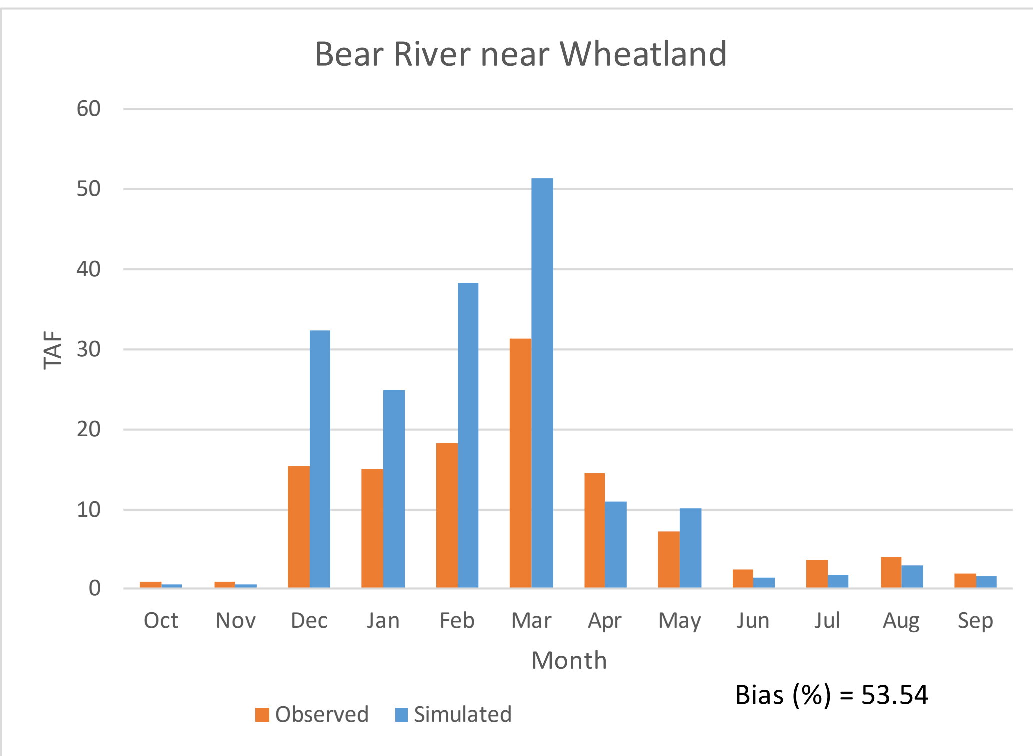


Figure A.8.3h. Bear River near Wheatland, Average Monthly (Dry)

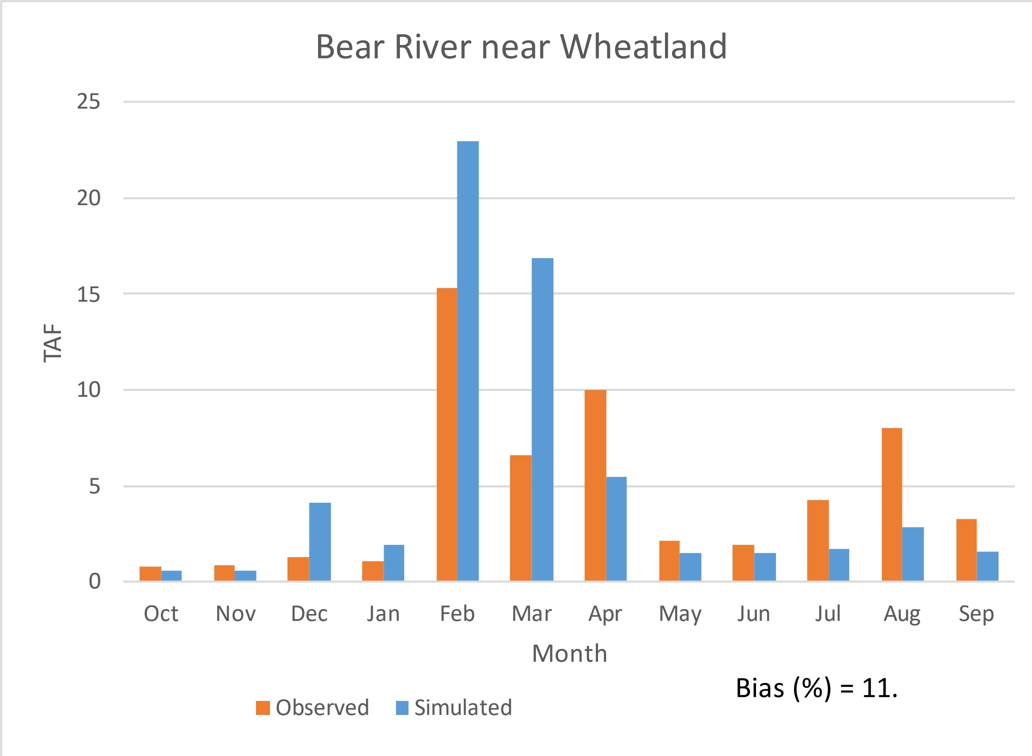


Figure A.8.3i. Bear River near Wheatland, Average Monthly (Critical)

A.8.4 Cache Creek at Rumsey

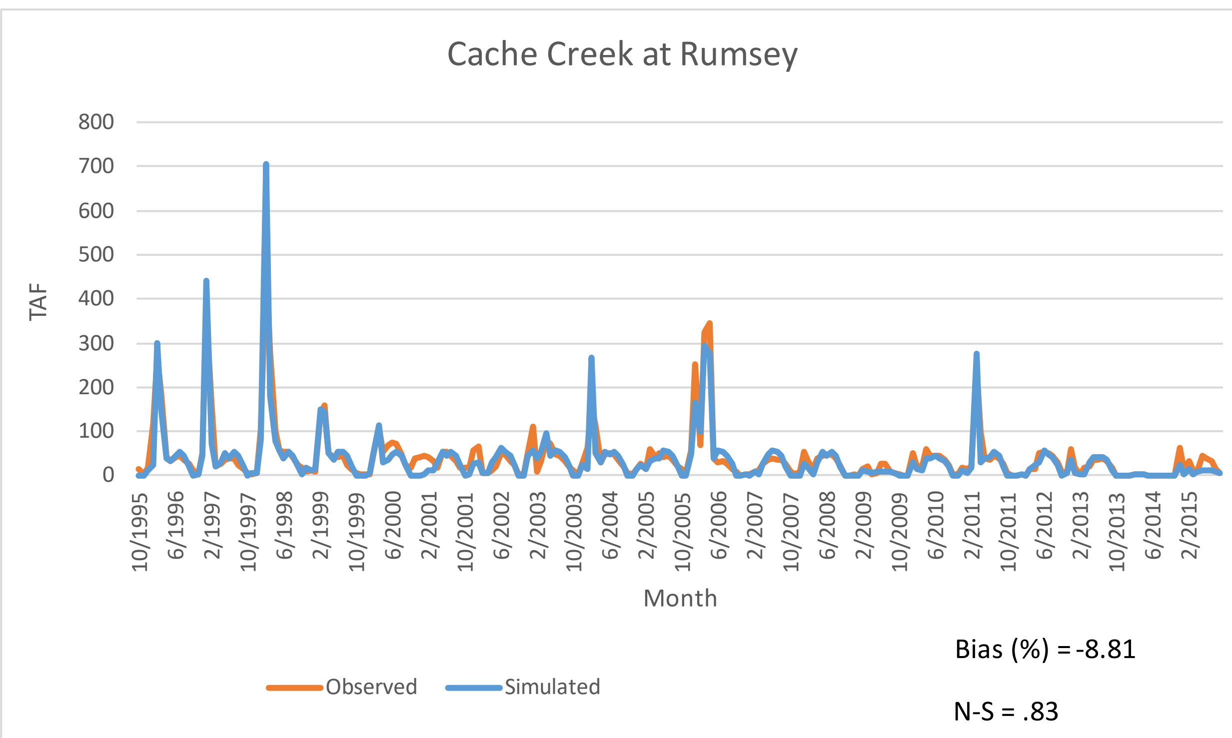


Figure A.8.4a. Cache Creek at Rumsey, Monthly 1996 to 2015

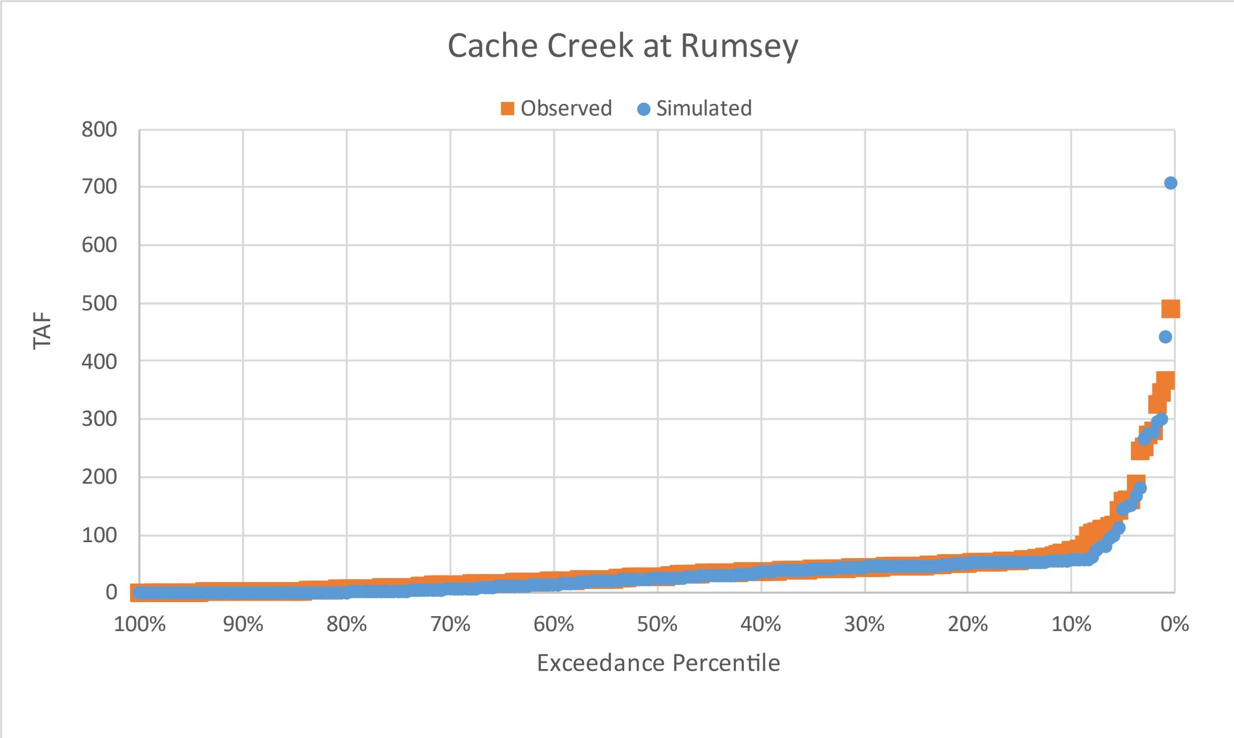


Figure A.8.4b. Cache Creek at Rumsey, Exceedance

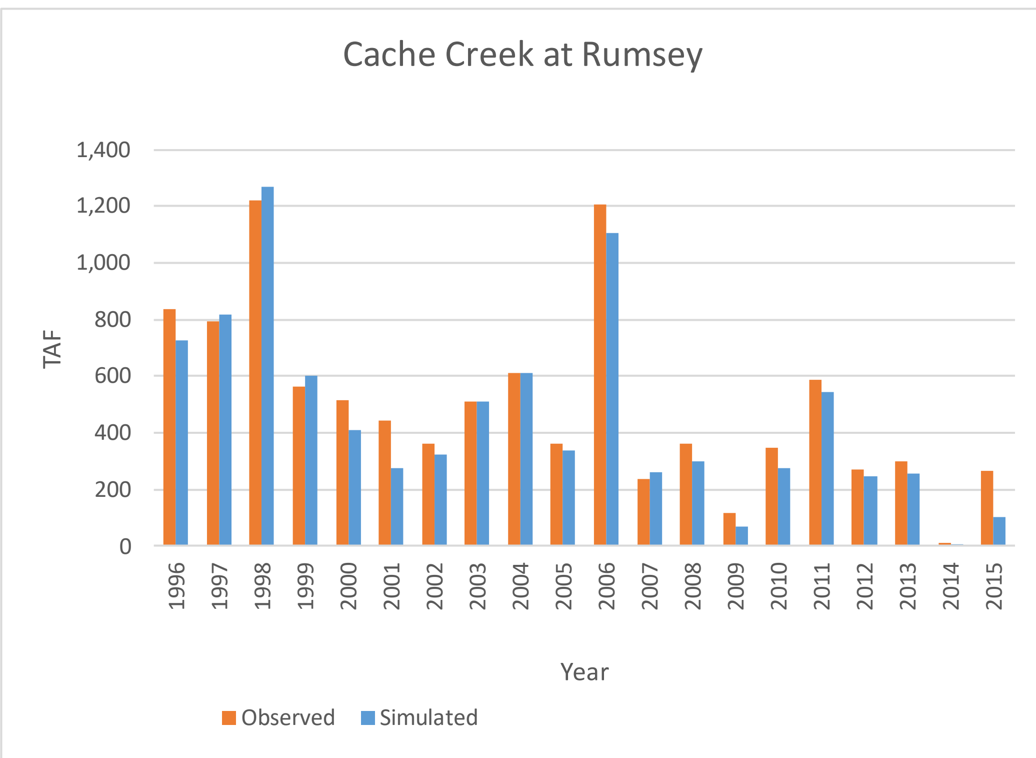


Figure A.8.4c. Cache Creek at Rumsey, Annual 1996 to 2015

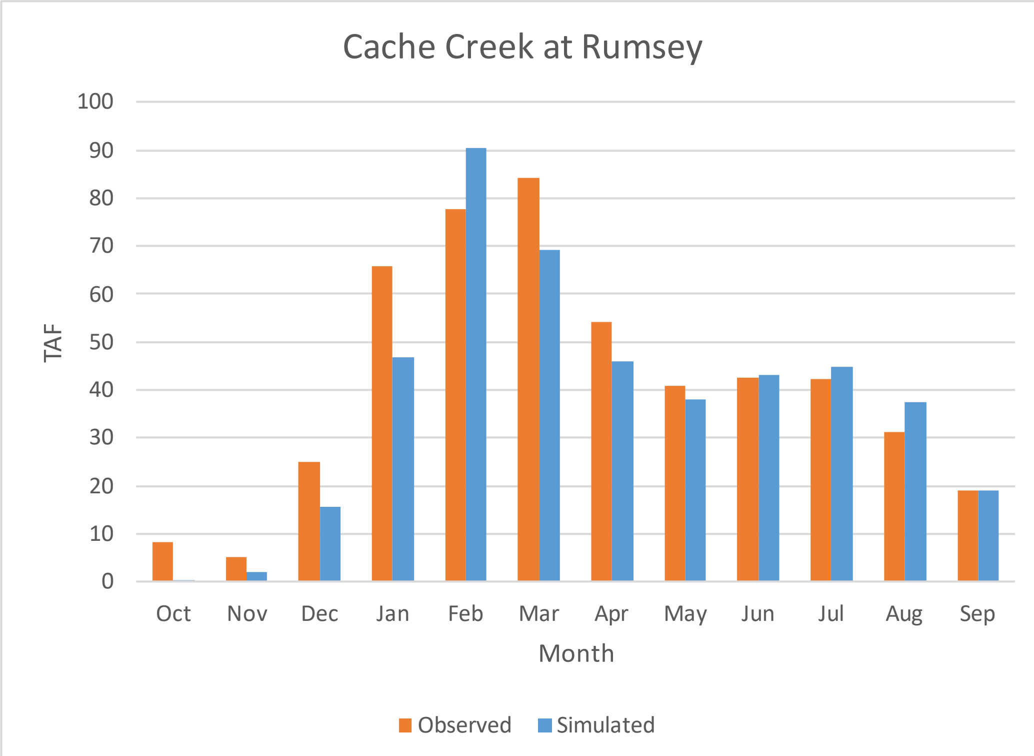


Figure A.8.4d. Cache Creek at Rumsey, Average Monthly

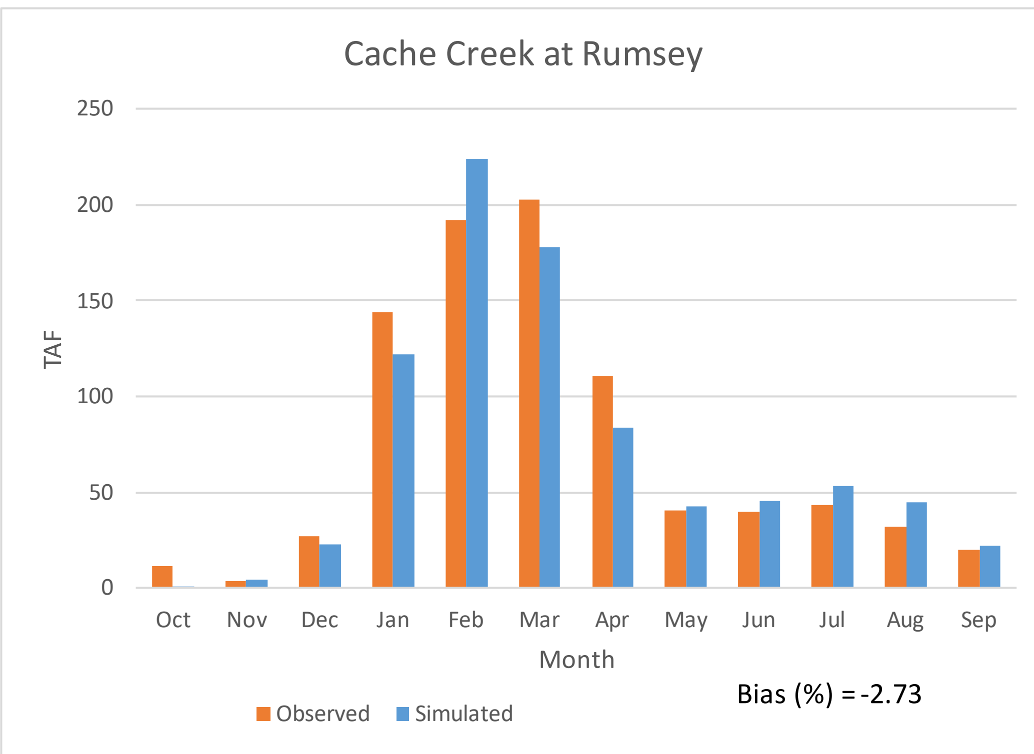


Figure A.8.4e. Cache Creek at Rumsey, Average Monthly (Wet)

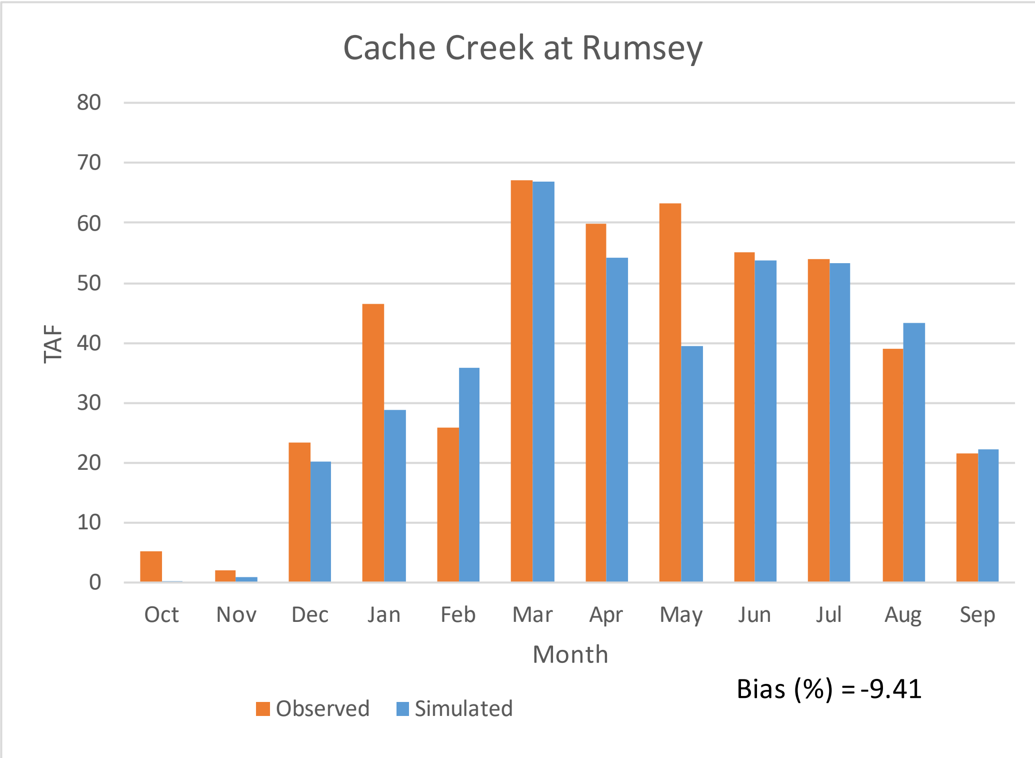


Figure A.8.4f. Cache Creek at Rumsey, Average Monthly (Above Normal)

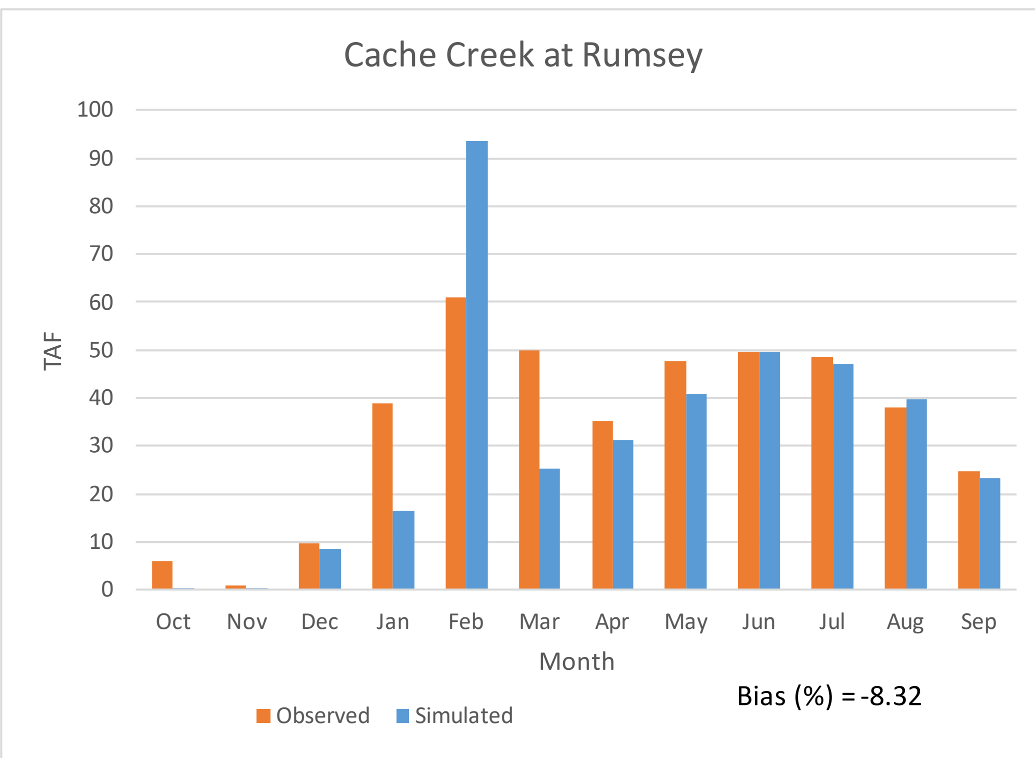


Figure A.8.4g. Cache Creek at Rumsey, Average Monthly (Below Normal)

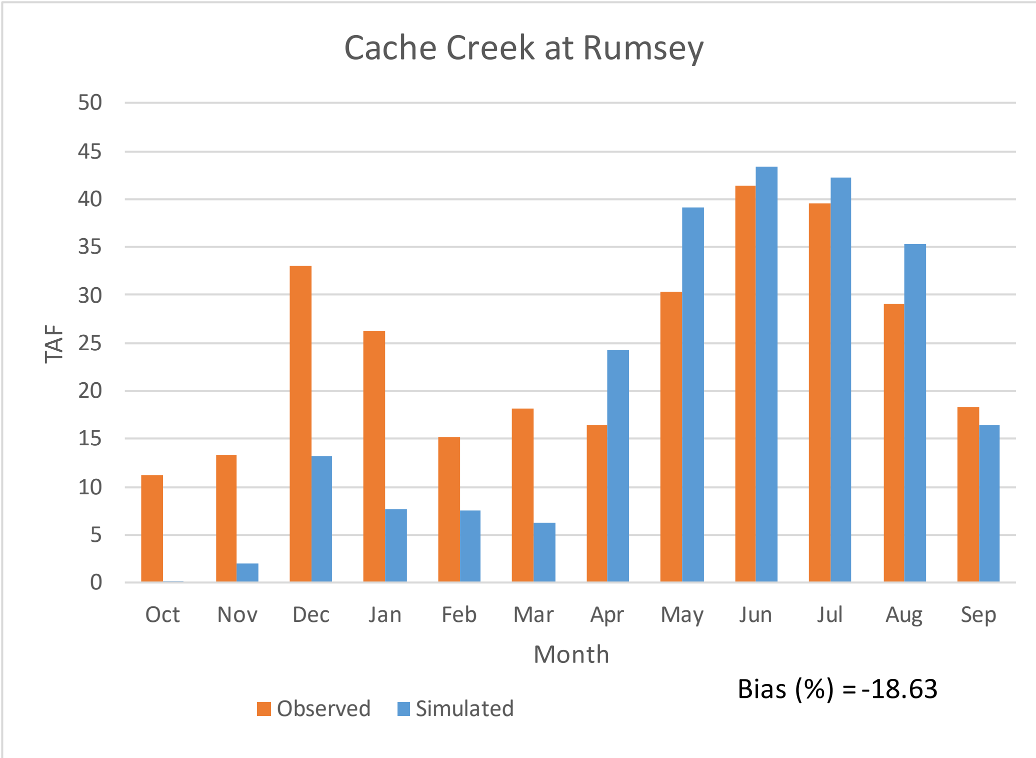


Figure A.8.4h. Cache Creek at Rumsey, Average Monthly (Dry)

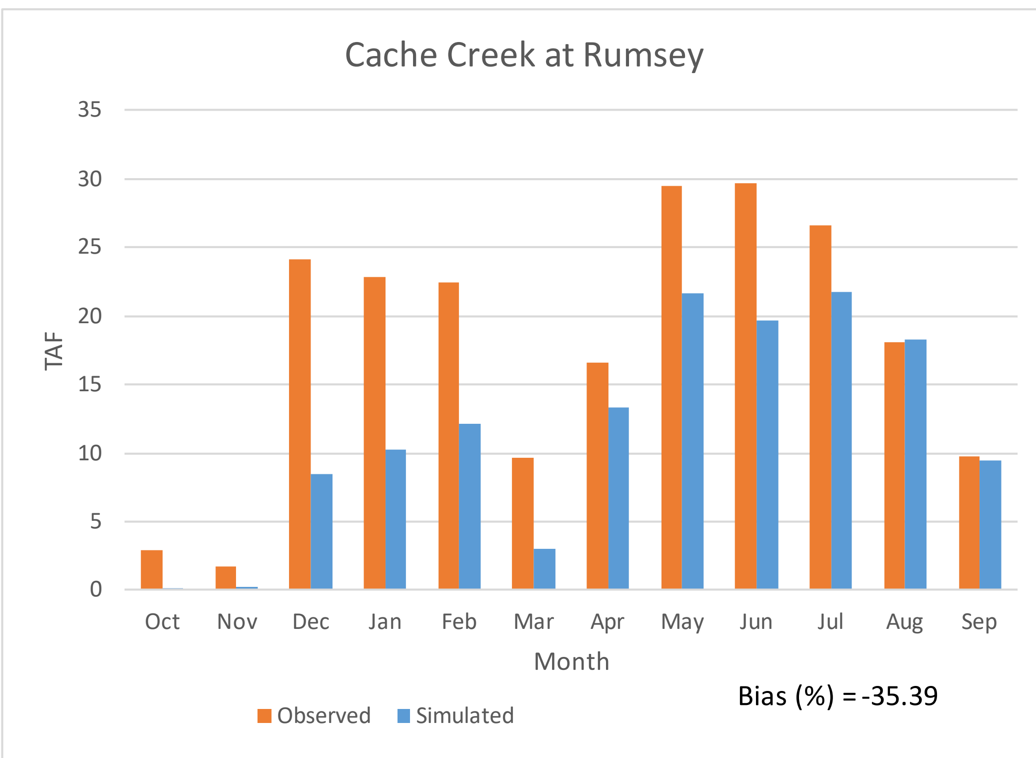


Figure A.8.4i. Cache Creek at Rumsey, Average Monthly (Critical)

A.8.5 Putah Creek below Putah Diversion Dam

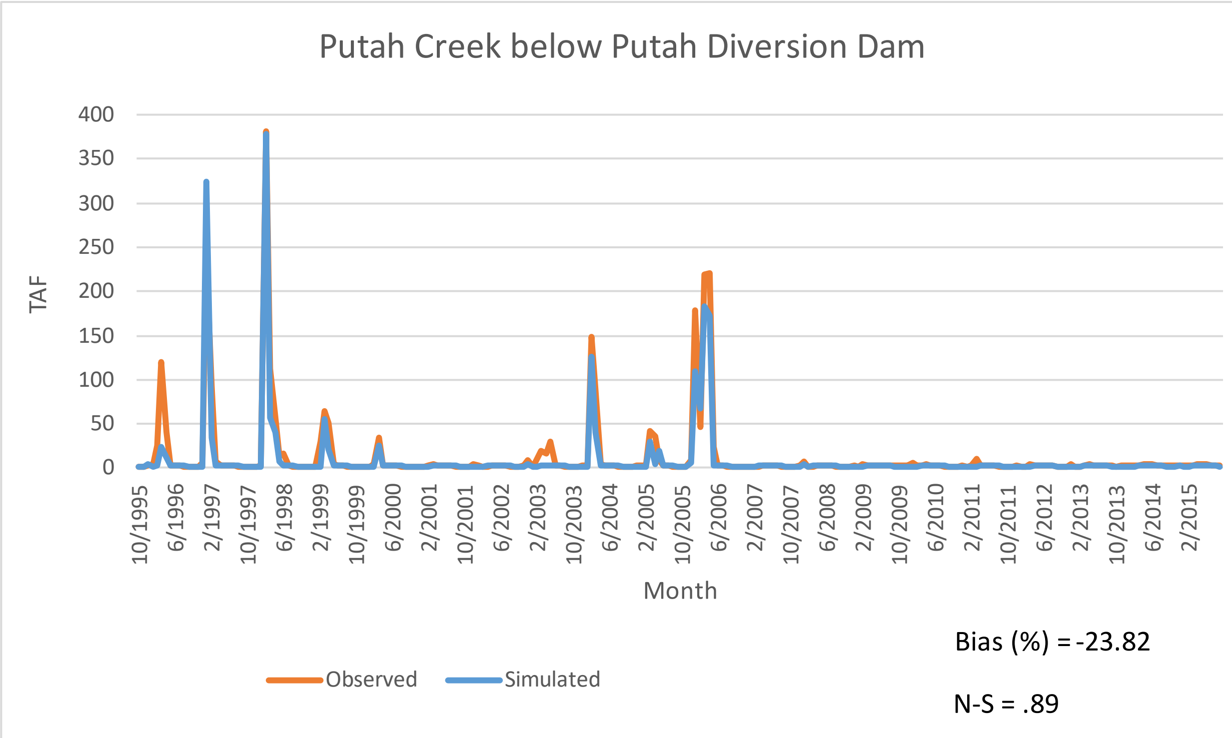


Figure A.8.5a. Putah Creek Below Putah Diversion Dam, Monthly 1996 to 2015

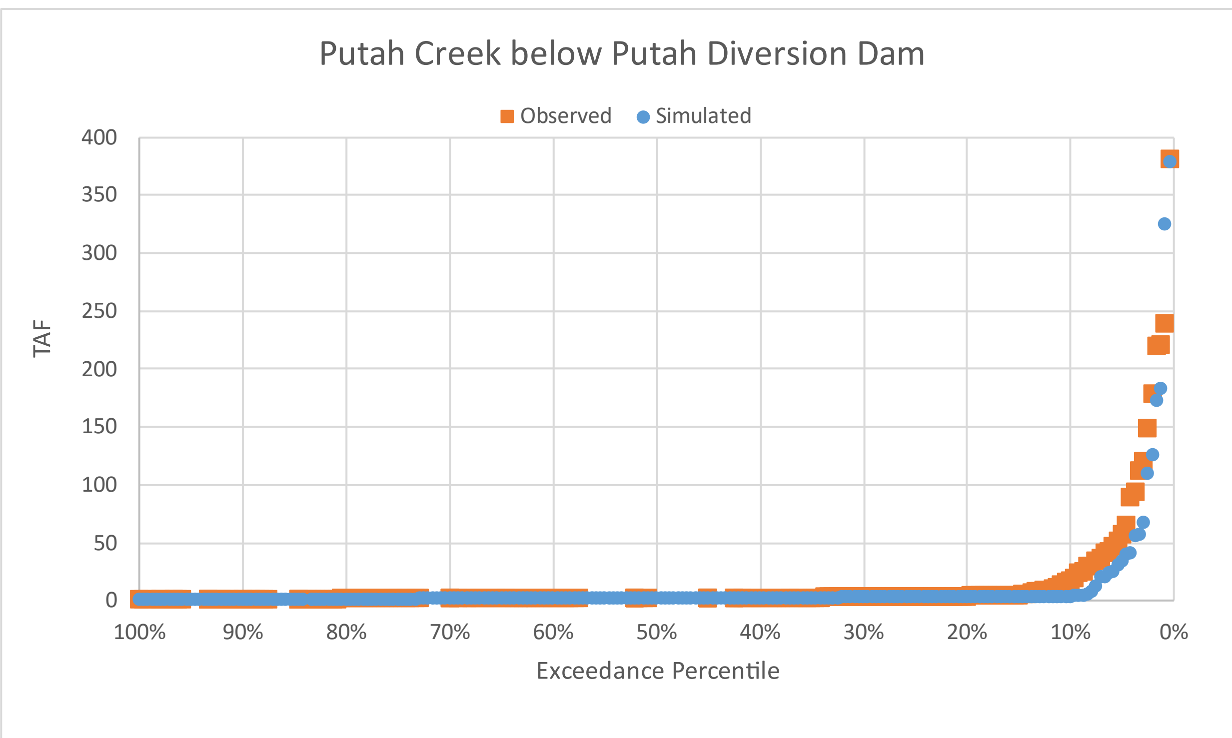


Figure A.8.5b. Putah Creek Below Putah Diversion Dam, Exceedance

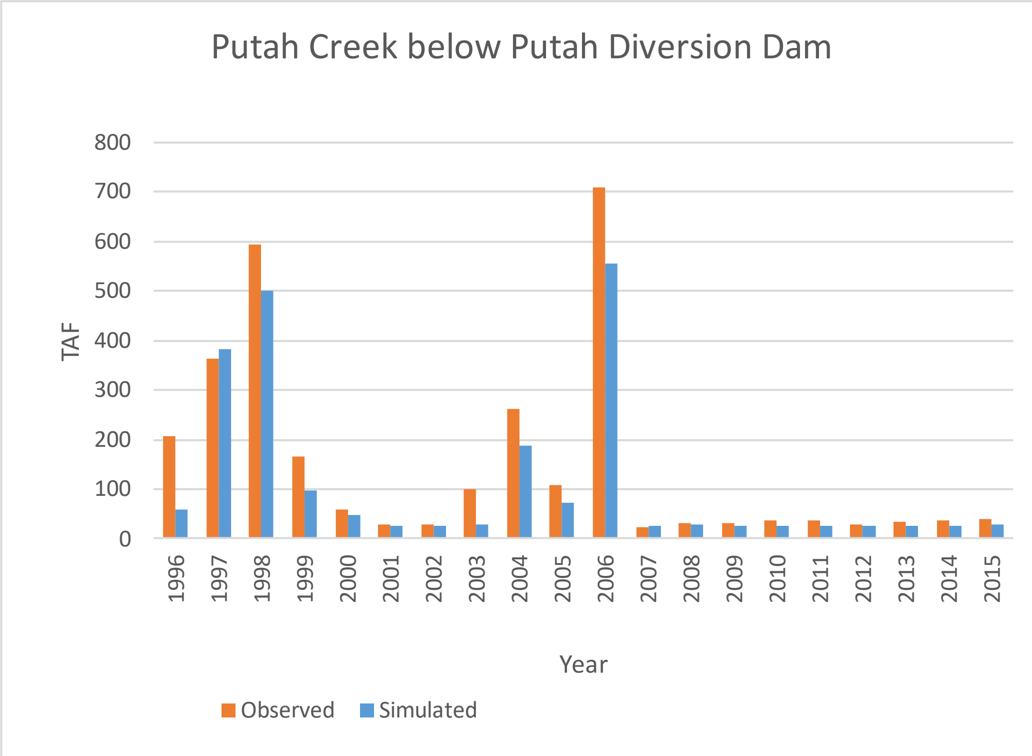


Figure A.8.5c. Putah Creek Below Putah Diversion Dam, Annual 1996 to 2015

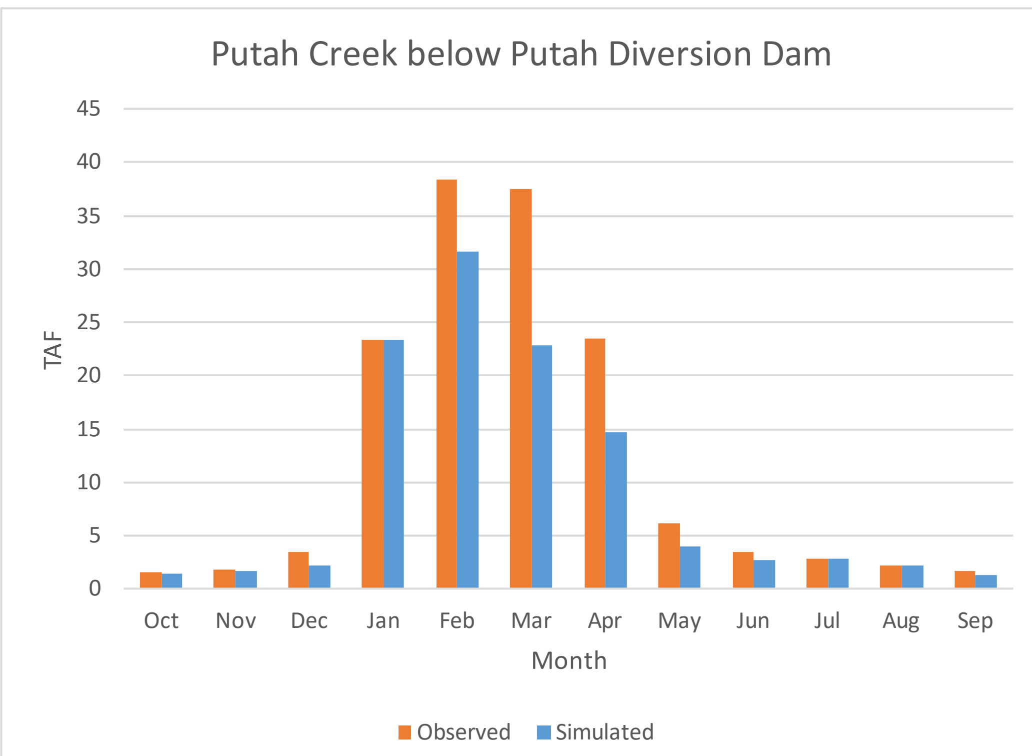


Figure A.8.5d. Putah Creek Below Putah Diversion Dam, Average Monthly

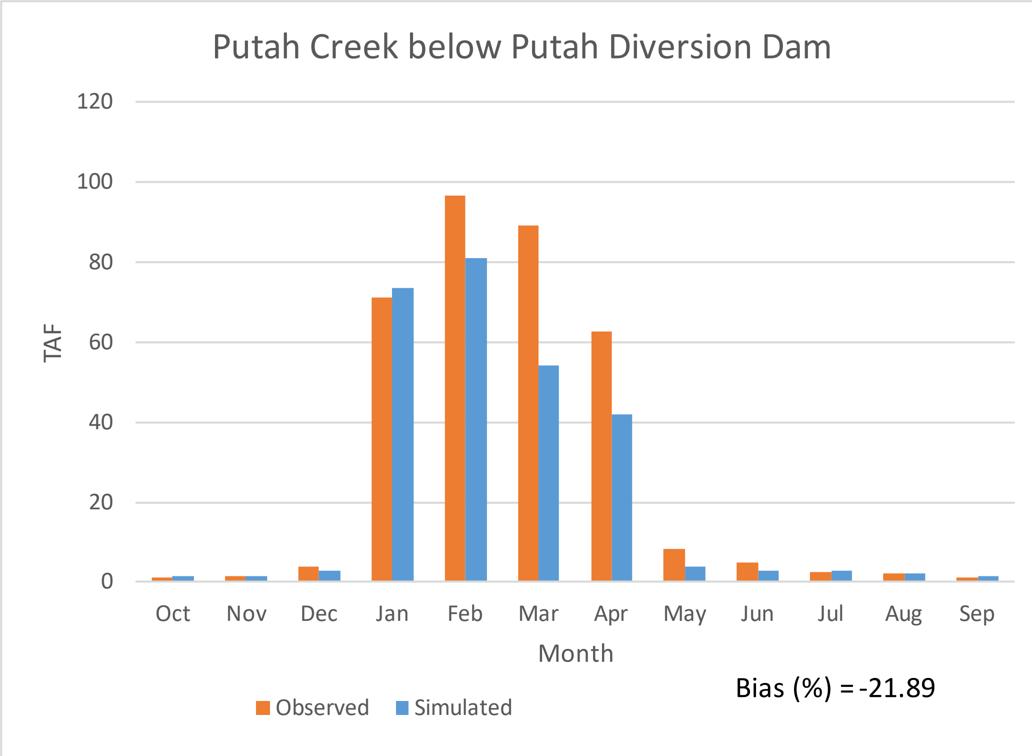


Figure A.8.5e. Putah Creek Below Putah Diversion Dam, Average Monthly (Wet)

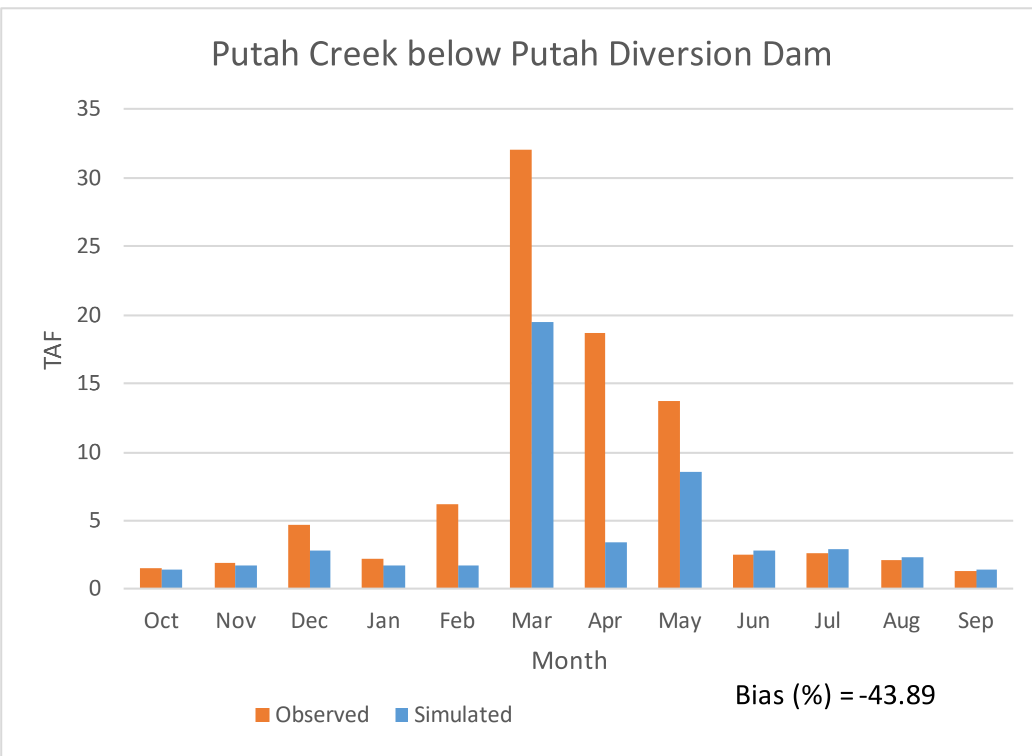


Figure A.8.5f. Putah Creek Below Putah Diversion Dam, Average Monthly (Above Normal)

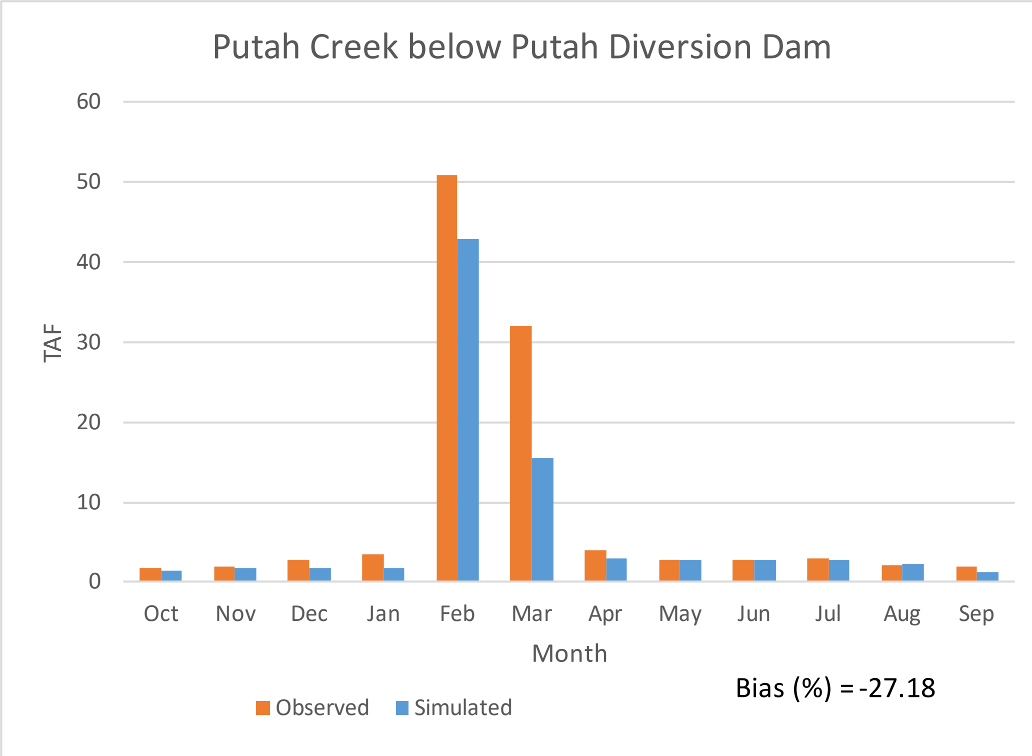


Figure A.8.5g. Putah Creek Below Putah Diversion Dam, Average Monthly (Below Normal)

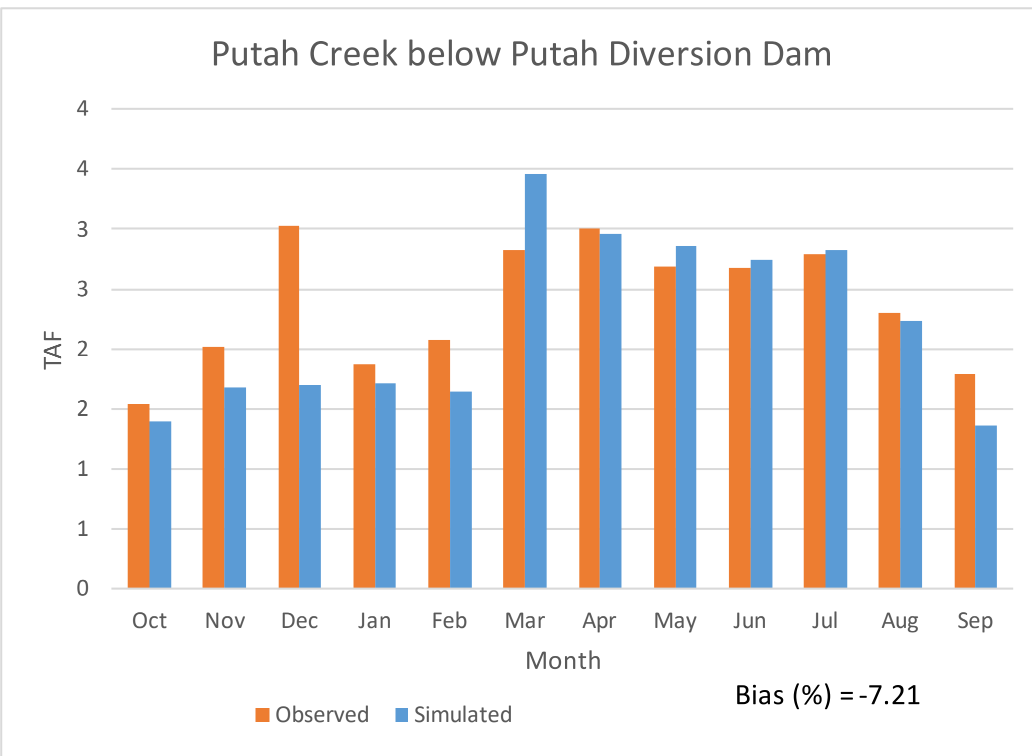


Figure A.8.5h. Putah Creek Below Putah Diversion Dam, Average Monthly (Dry)

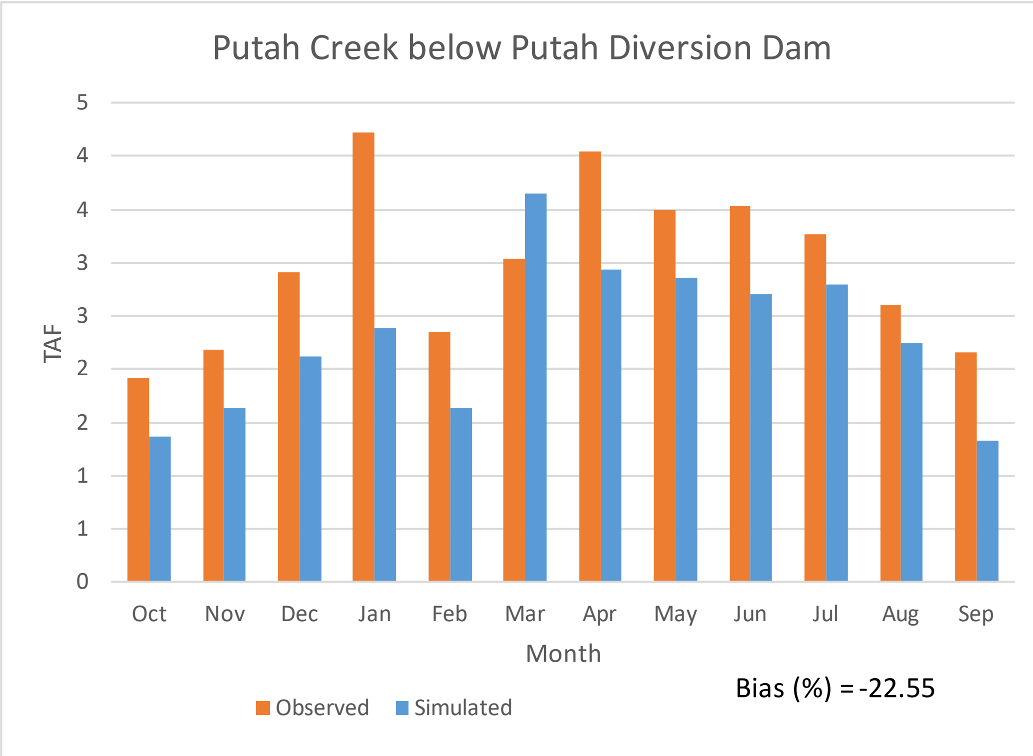


Figure A.8.5i. Putah Creek Below Putah Diversion Dam, Average Monthly (Critical)

A.8.6 Mokelumne River at Woodbridge

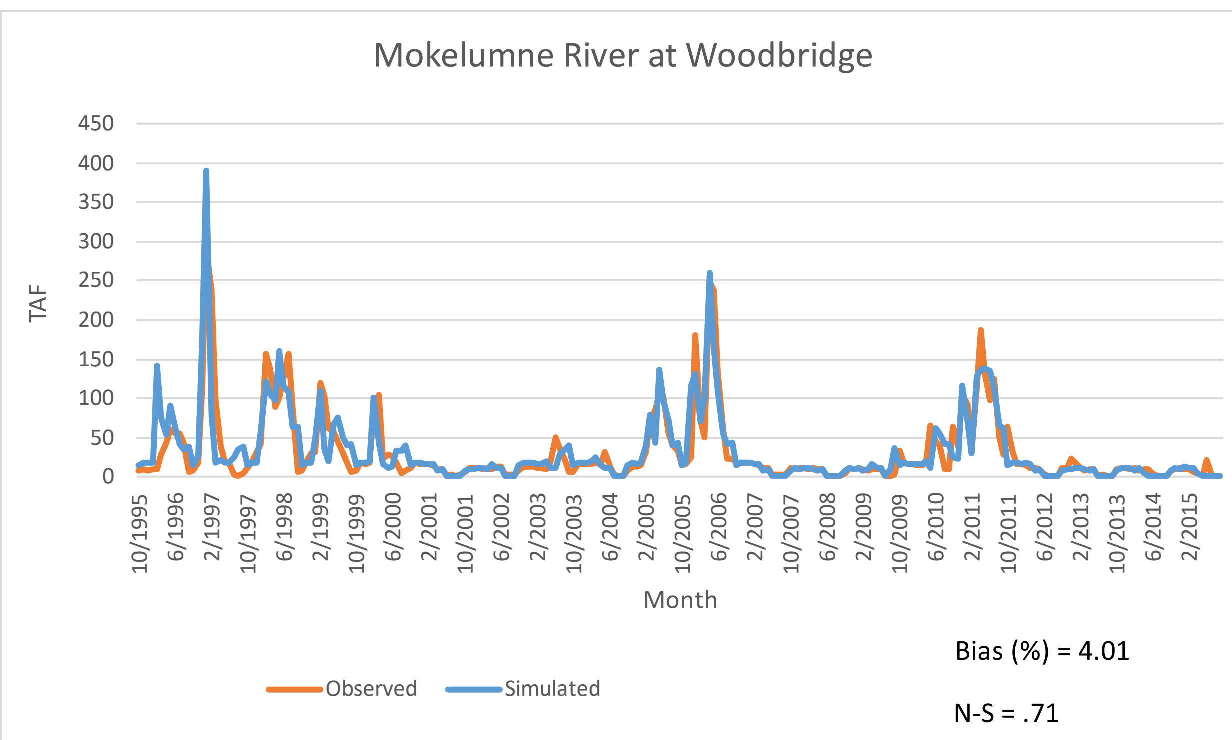


Figure A.8.6a. Mokelumne River at Woodbridge, Monthly 1996 to 2015

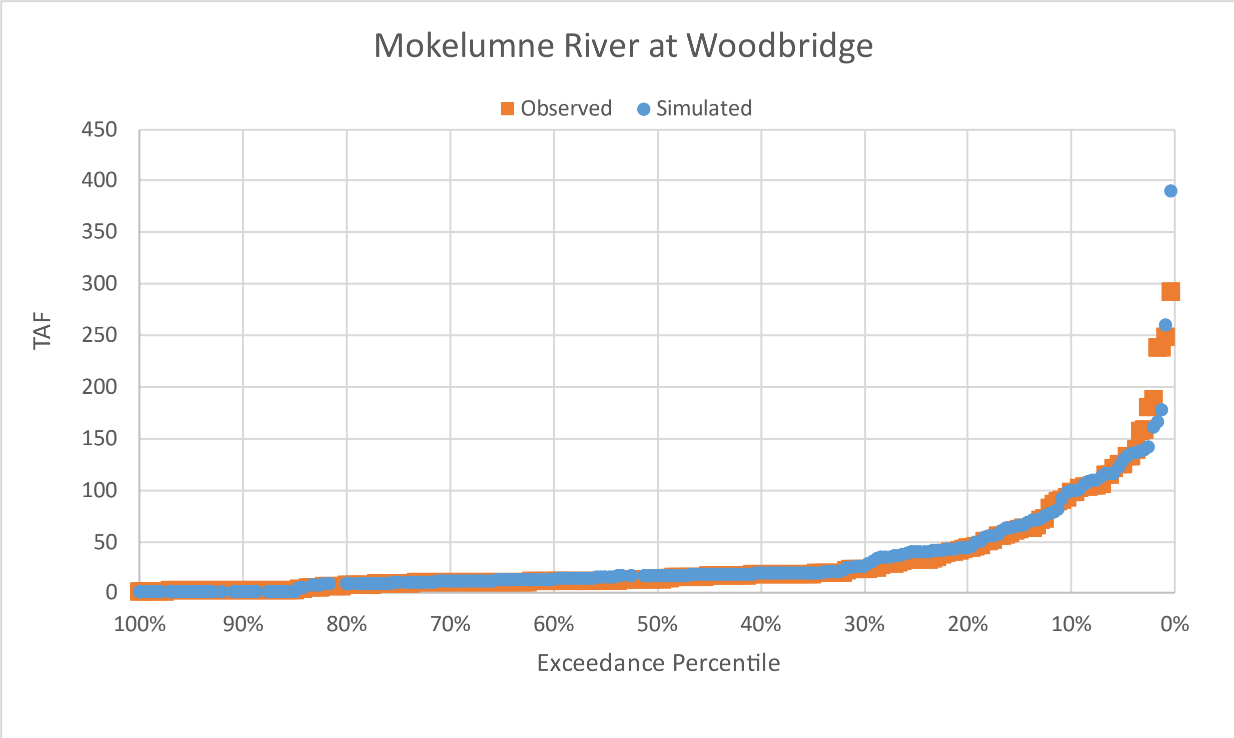


Figure A.8.6b. Mokelumne River at Woodbridge, Exceedance

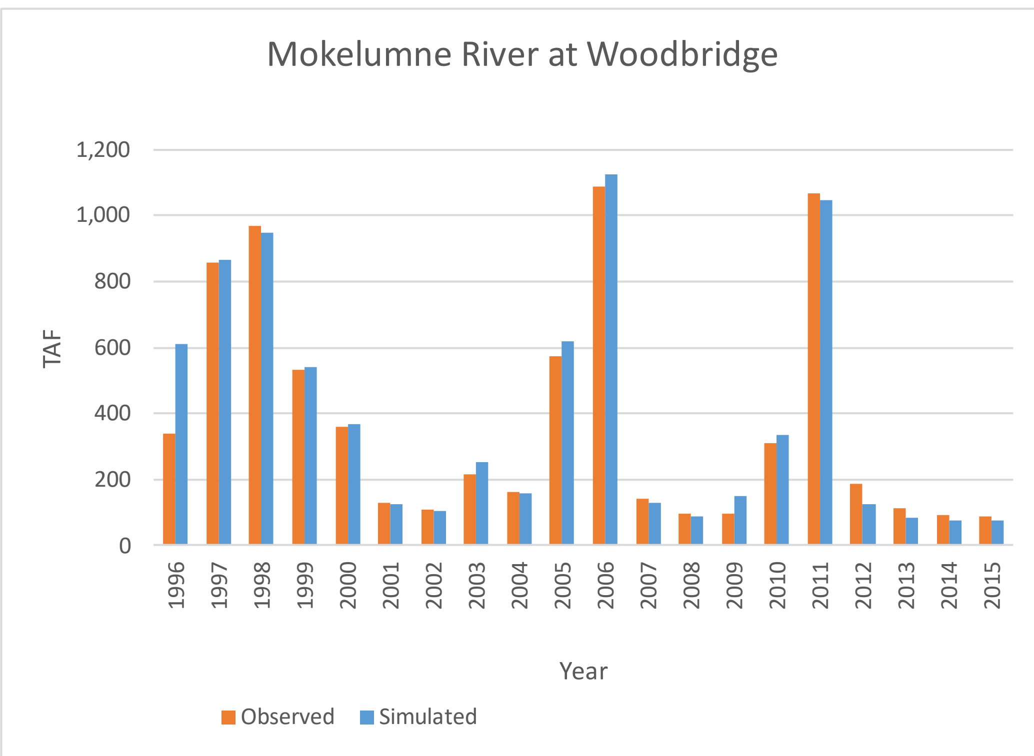


Figure A.8.6c. Mokelumne River at Woodbridge, Annual 1996 to 2015

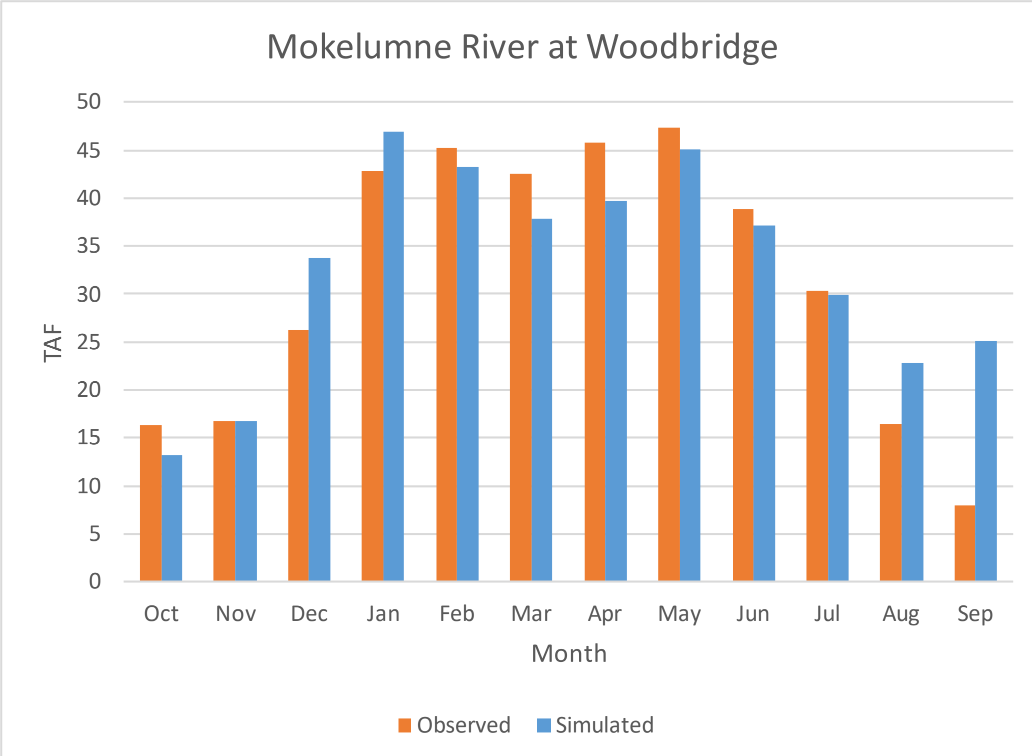


Figure A.8.6d. Mokelumne River at Woodbridge, Average Monthly

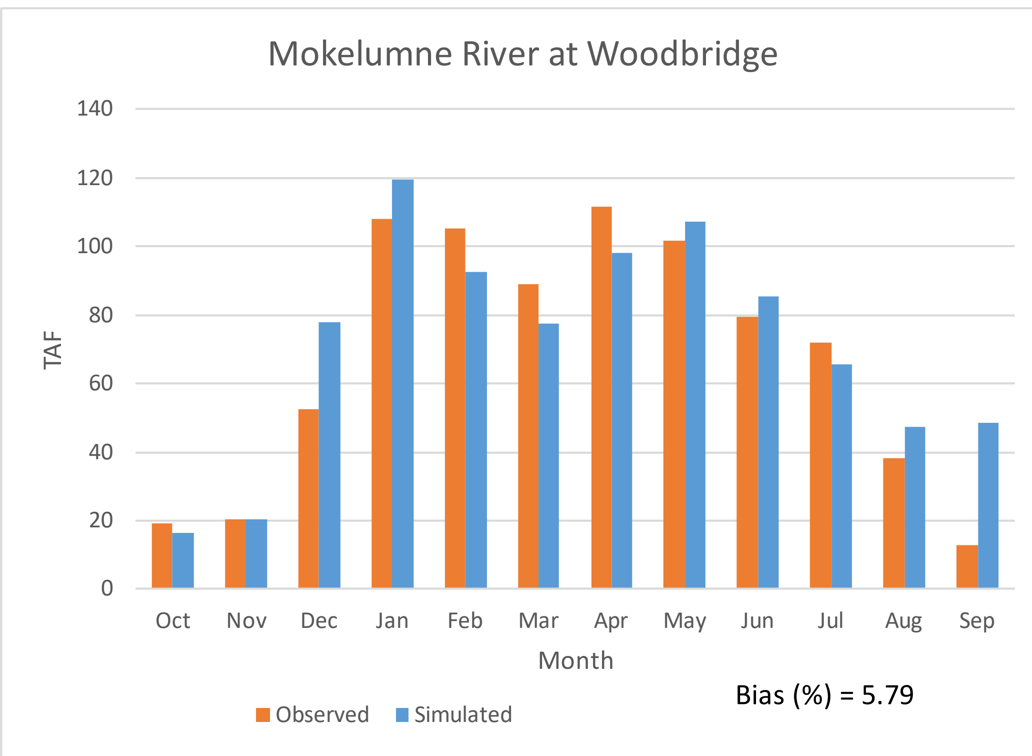


Figure A.8.6e. Mokelumne River at Woodbridge, Average Monthly (Wet)

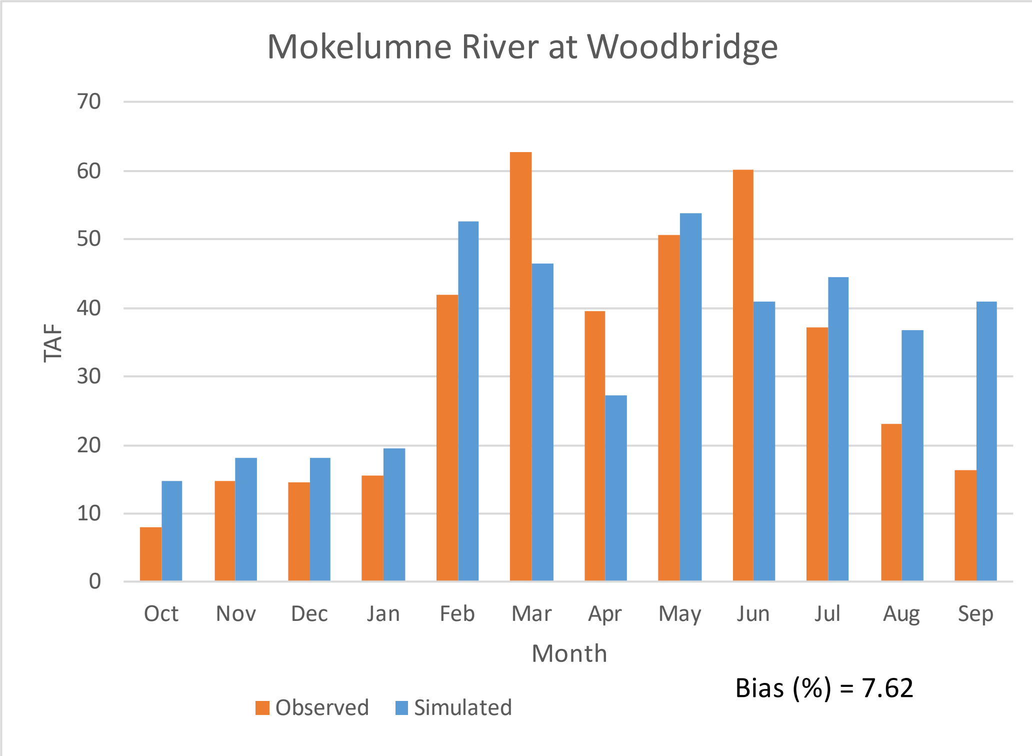


Figure A.8.6f. Mokelumne River at Woodbridge, Average Monthly (Above Normal)

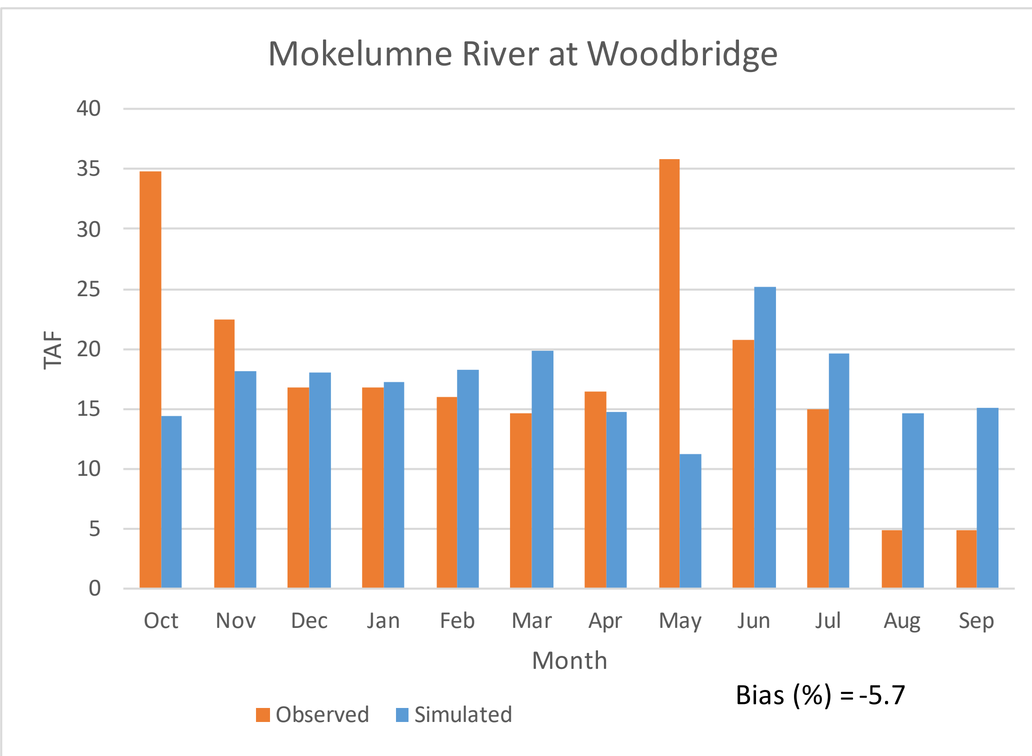


Figure A.8.6g. Mokelumne River at Woodbridge, Average Monthly (Below Normal)

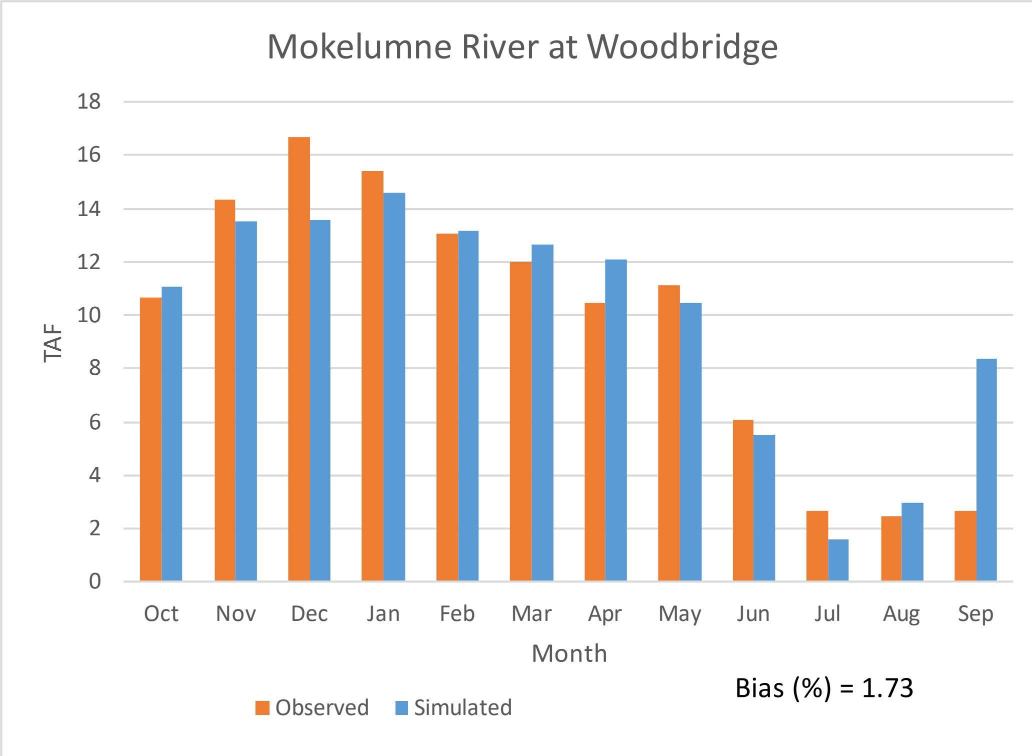


Figure A.8.6h. Mokelumne River at Woodbridge, Average Monthly (Dry)

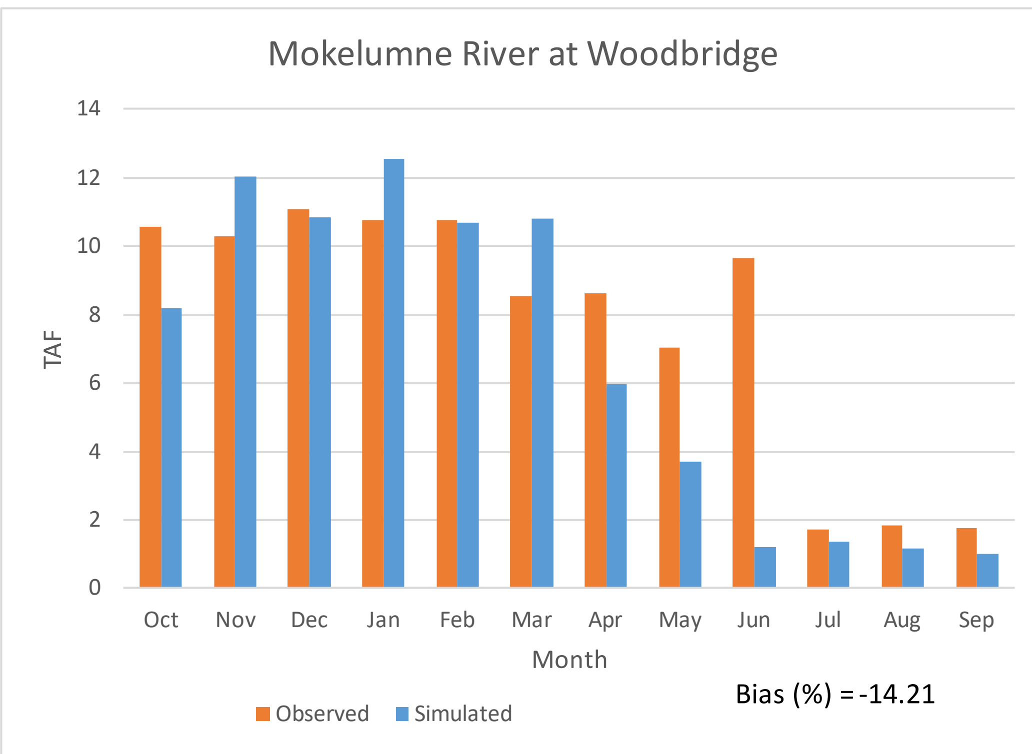


Figure A.8.6i. Mokelumne River at Woodbridge, Average Monthly (Critical)

A.8.7 Calaveras River below New Hogan Dam

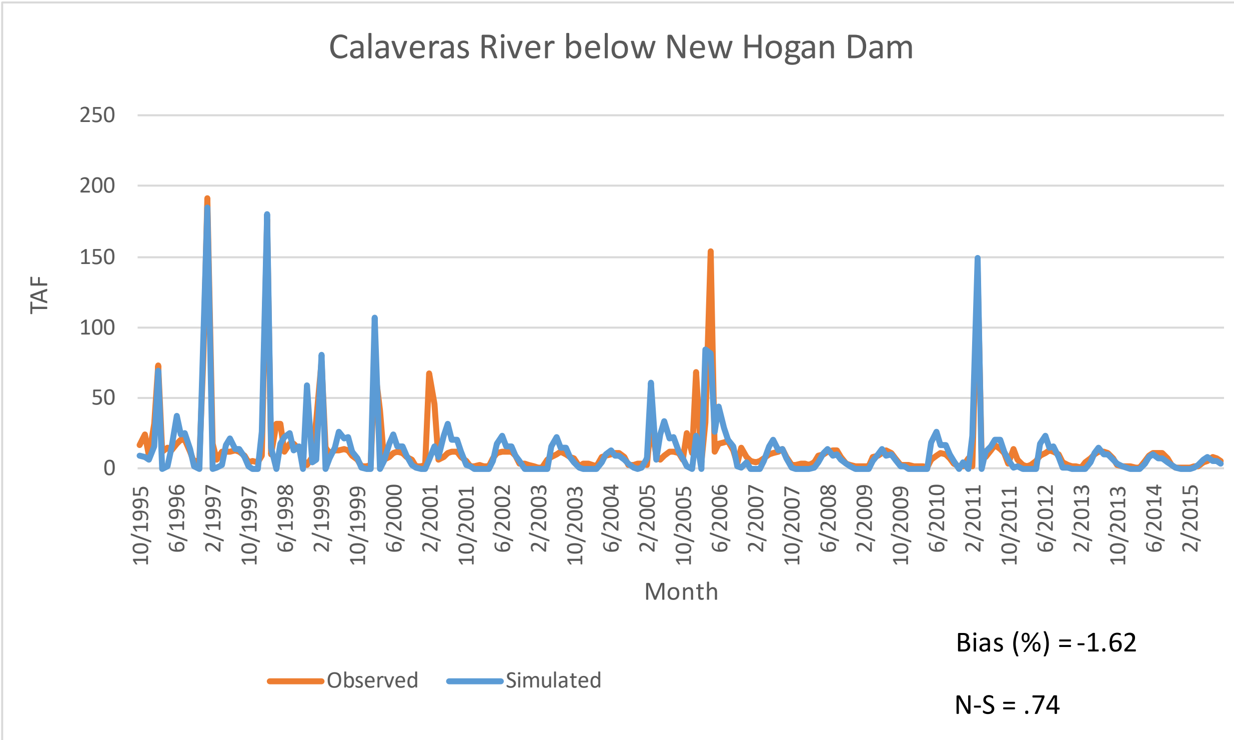


Figure A.8.7a. Calaveras River Below New Hogan Dam, Monthly 1996 to 2015

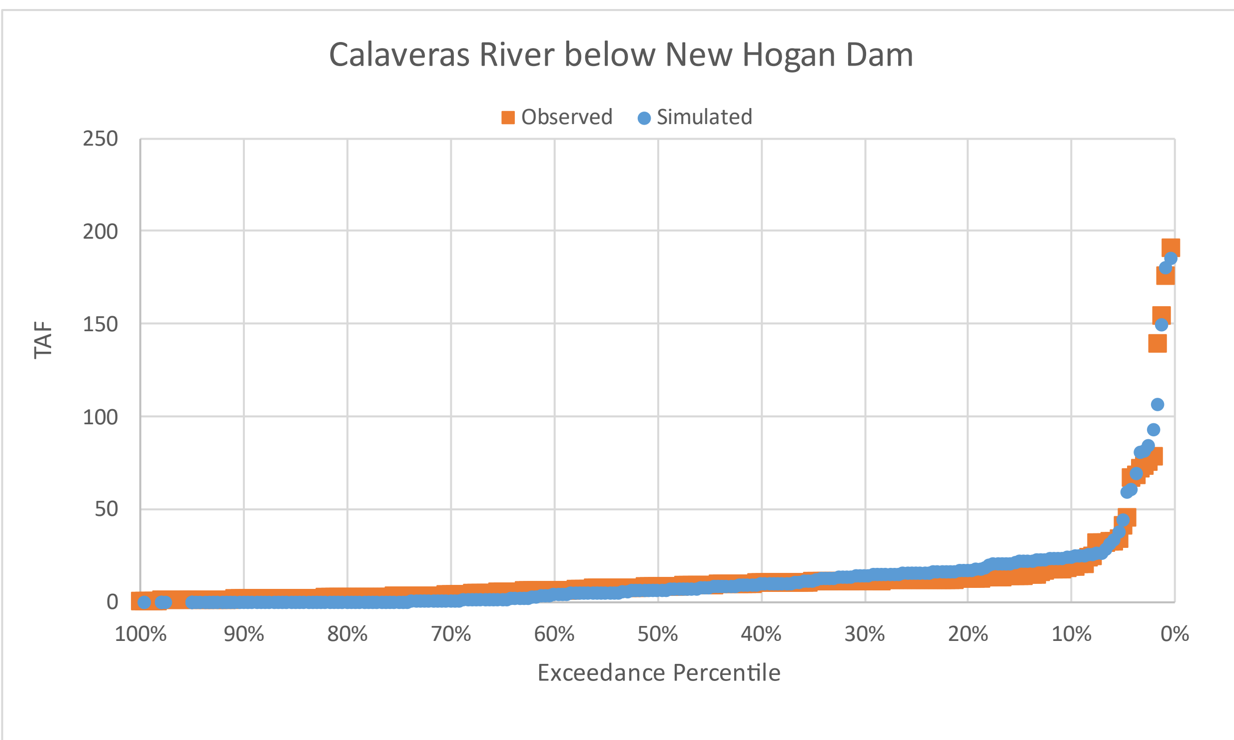


Figure A.8.7b. Calaveras River Below New Hogan Dam, Exceedance

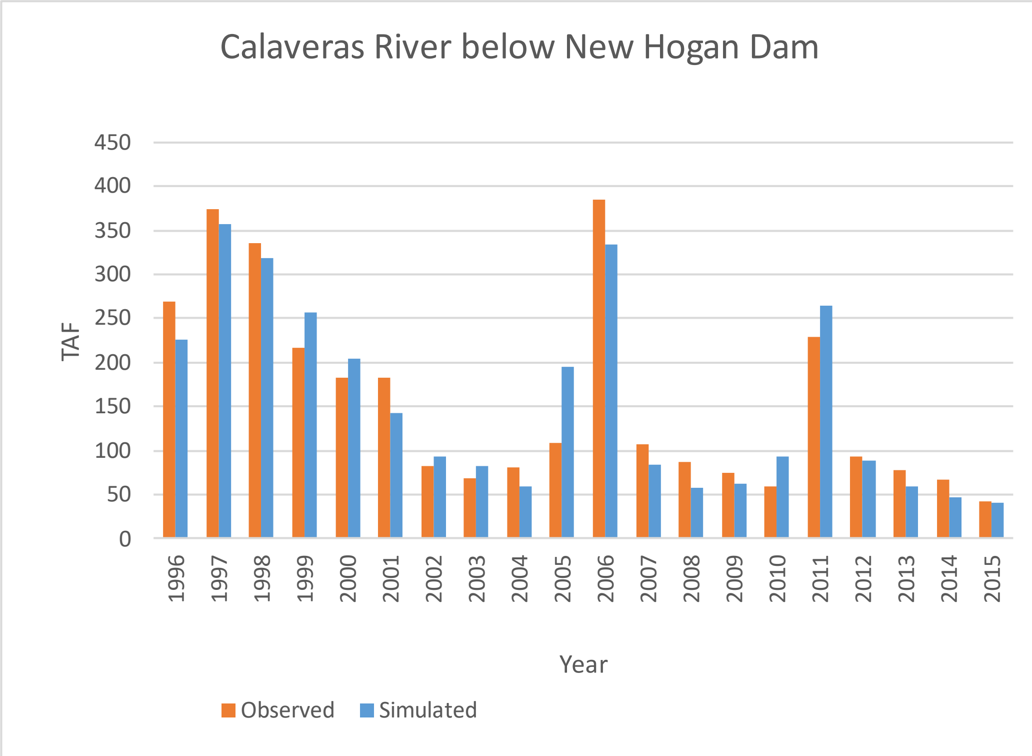


Figure A.8.7c. Calaveras River Below New Hogan Dam, Annual 1996 to 2015

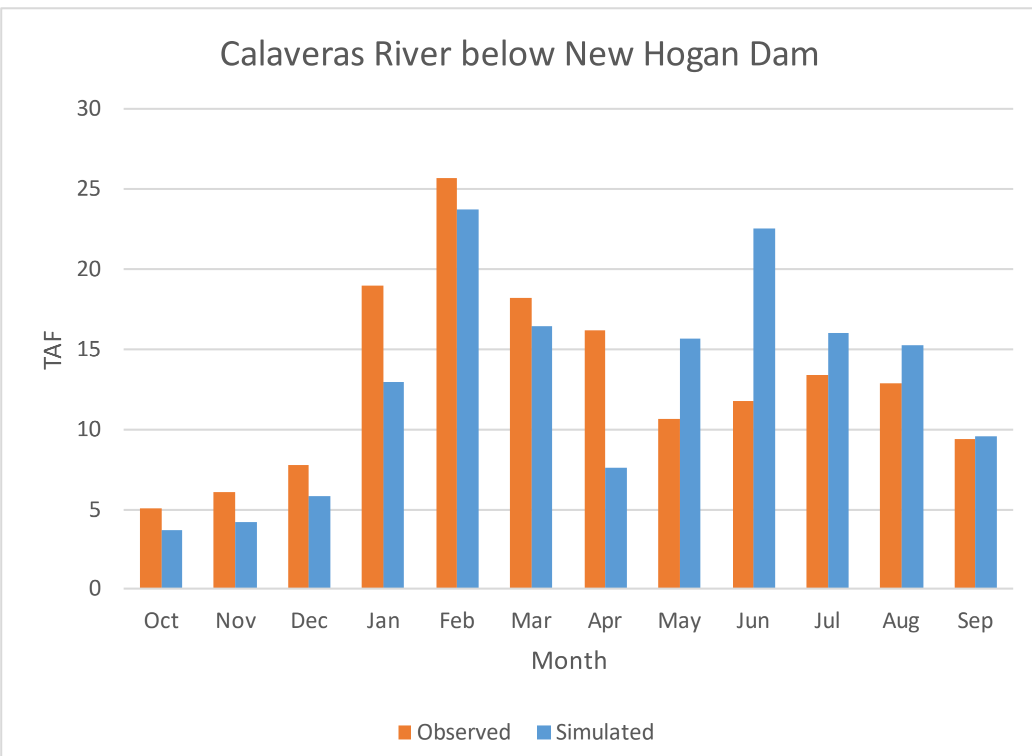


Figure A.8.7d. Calaveras River Below New Hogan Dam, Average Monthly

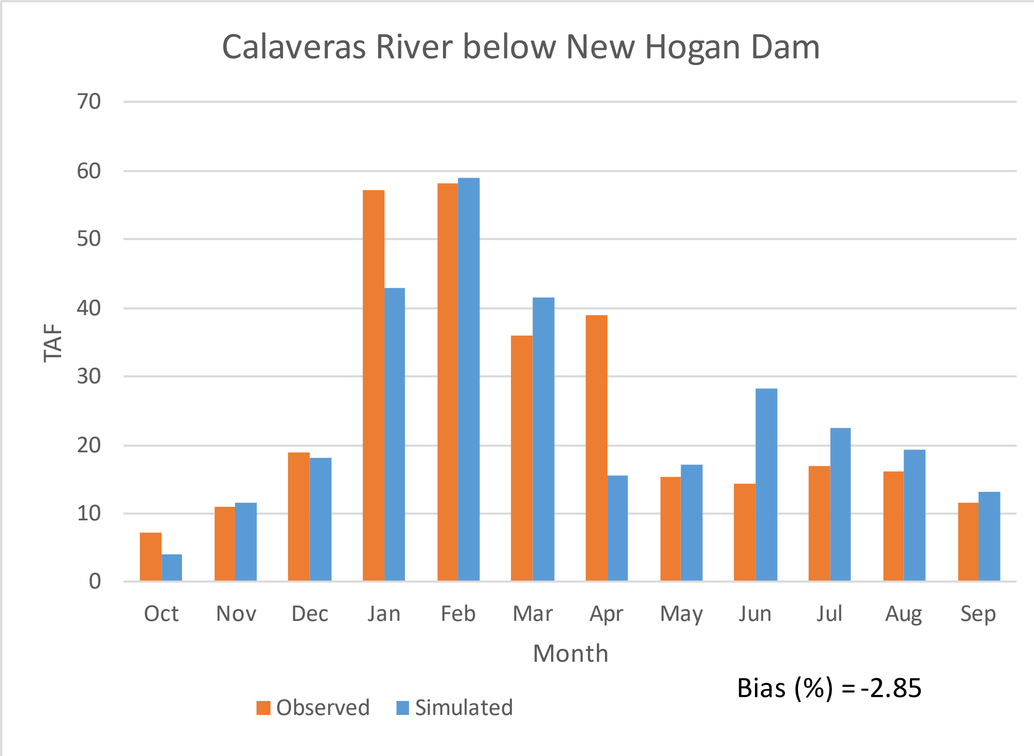


Figure A.8.7e. Calaveras River Below New Hogan Dam, Average Monthly (Wet)

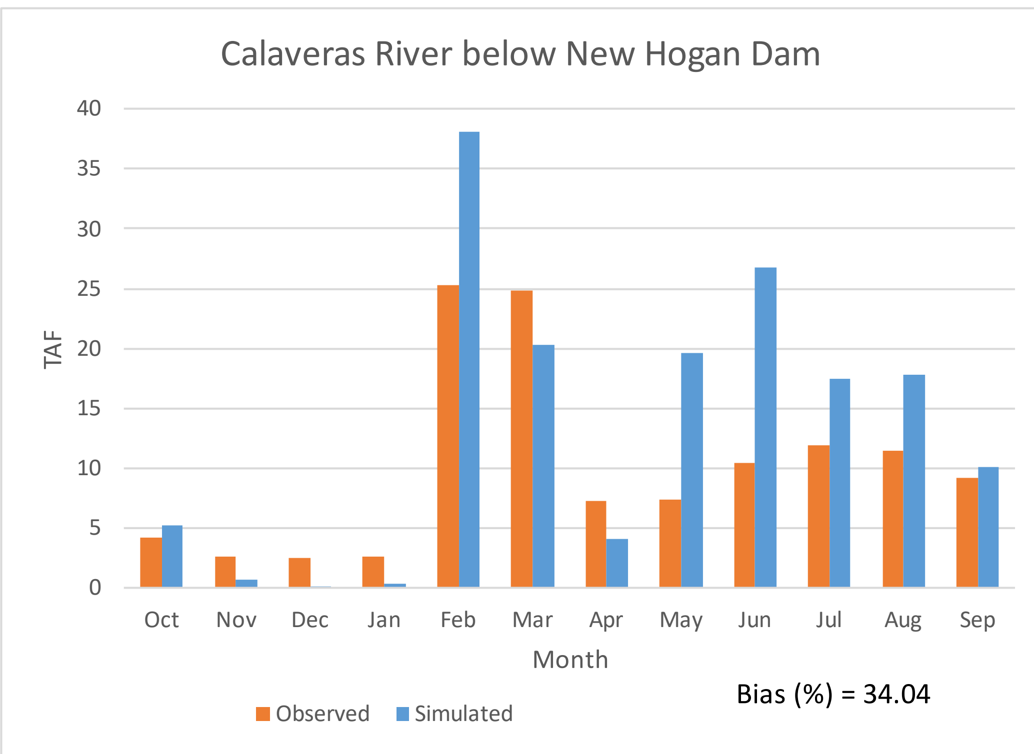


Figure A.8.7f. Calaveras River Below New Hogan Dam, Average Monthly (Above Normal)

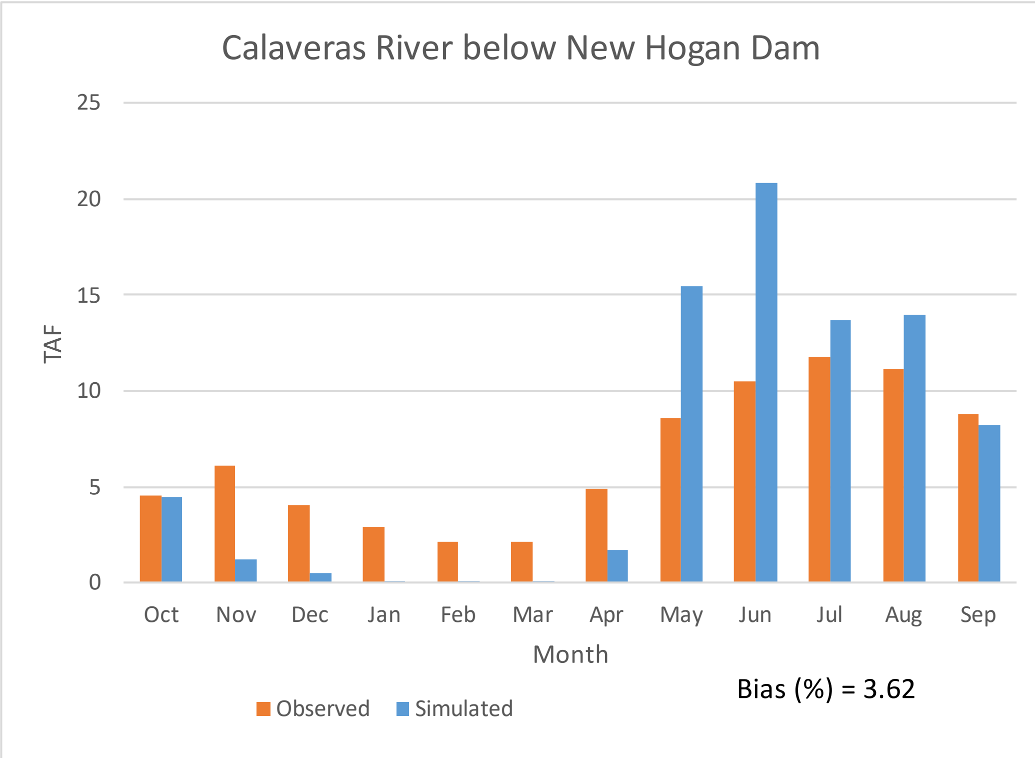


Figure A.8.7g. Calaveras River Below New Hogan Dam, Average Monthly (Below Normal)

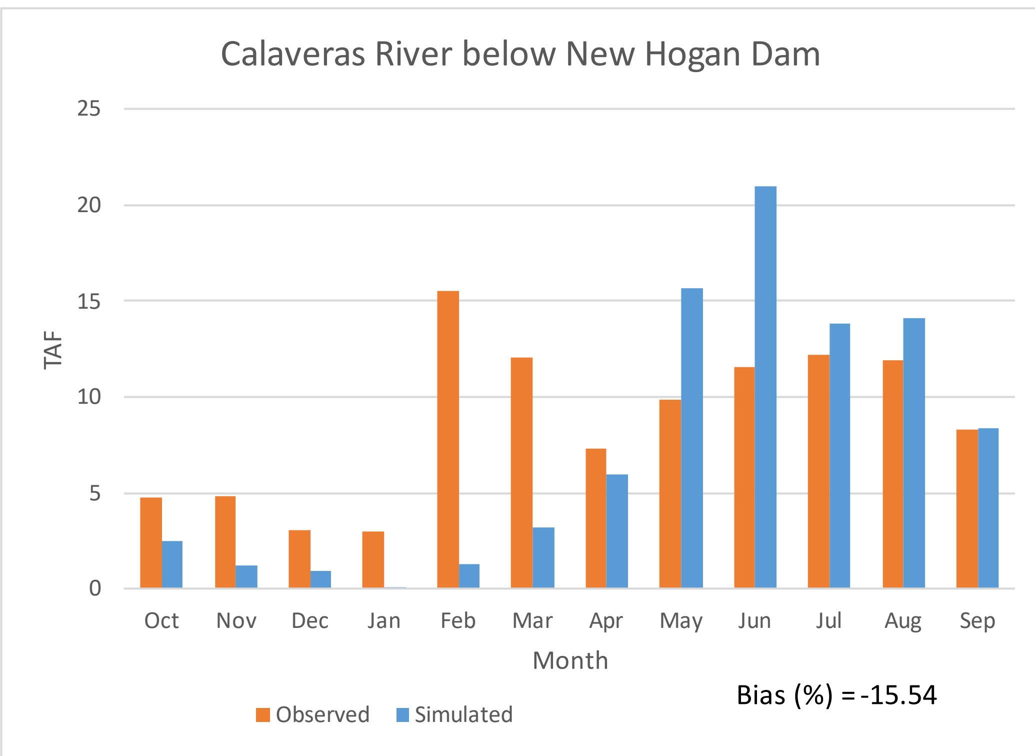


Figure A.8.7h. Calaveras River Below New Hogan Dam, Average Monthly (Dry)

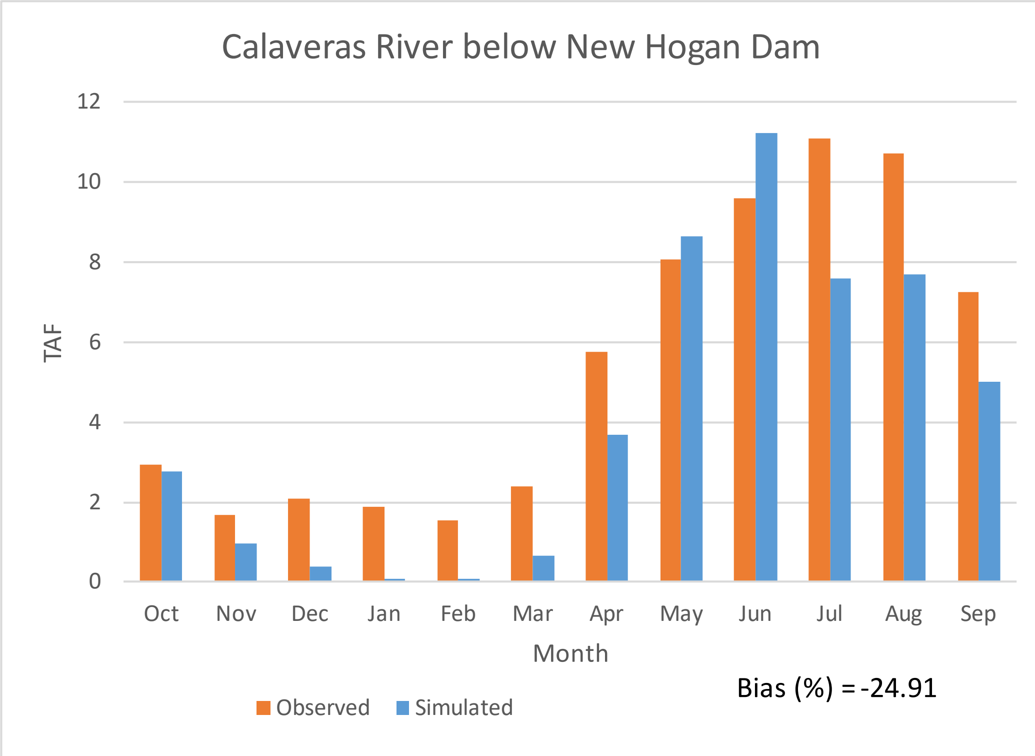


Figure A.8.7i. Calaveras River Below New Hogan Dam, Average Monthly (Critical)

A.8.8 Stony Creek at Black Butte Dam

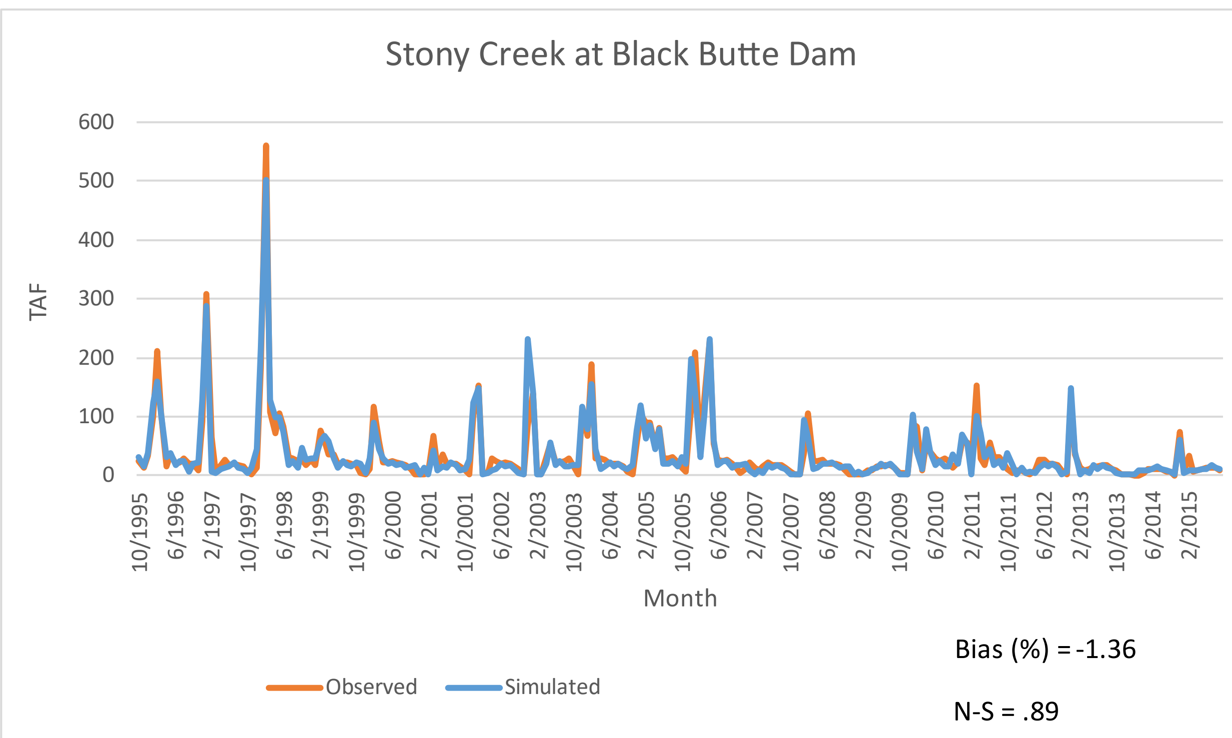


Figure A.8.8a. Stony Creek at Black Butte Dam, Monthly 1996 to 2015

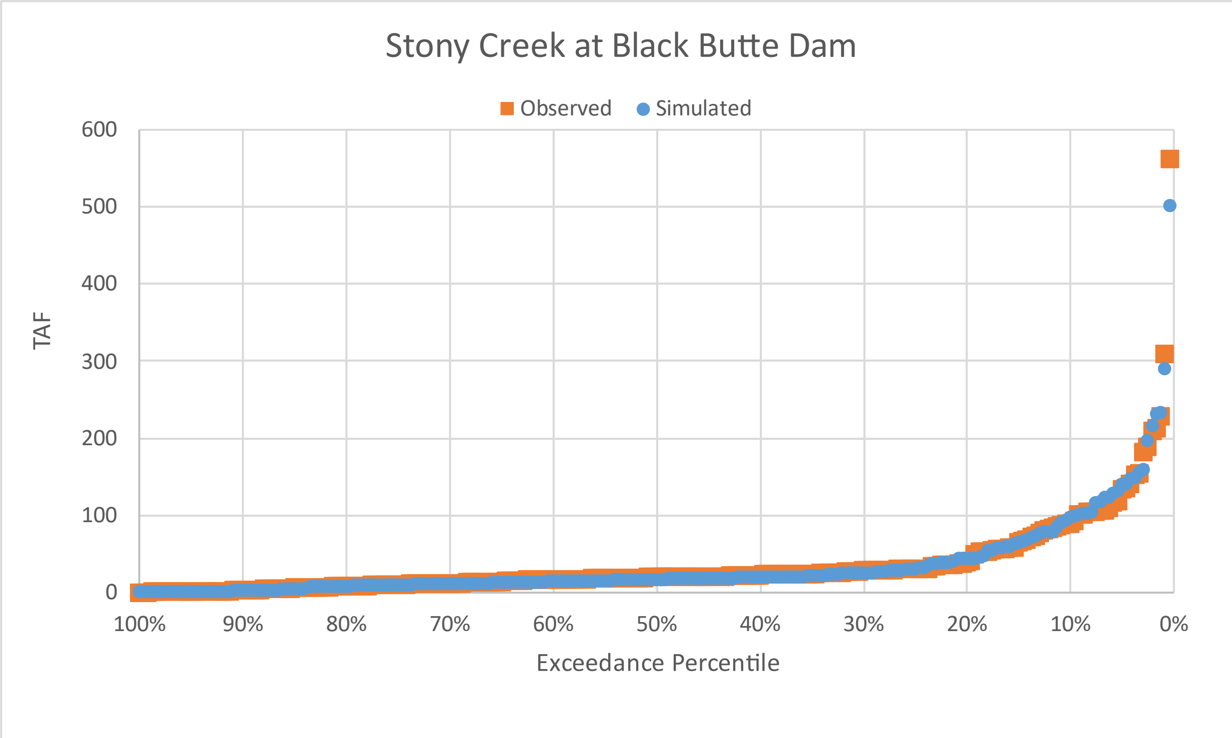


Figure A.8.8b. Stony Creek at Black Butte Dam, Exceedance

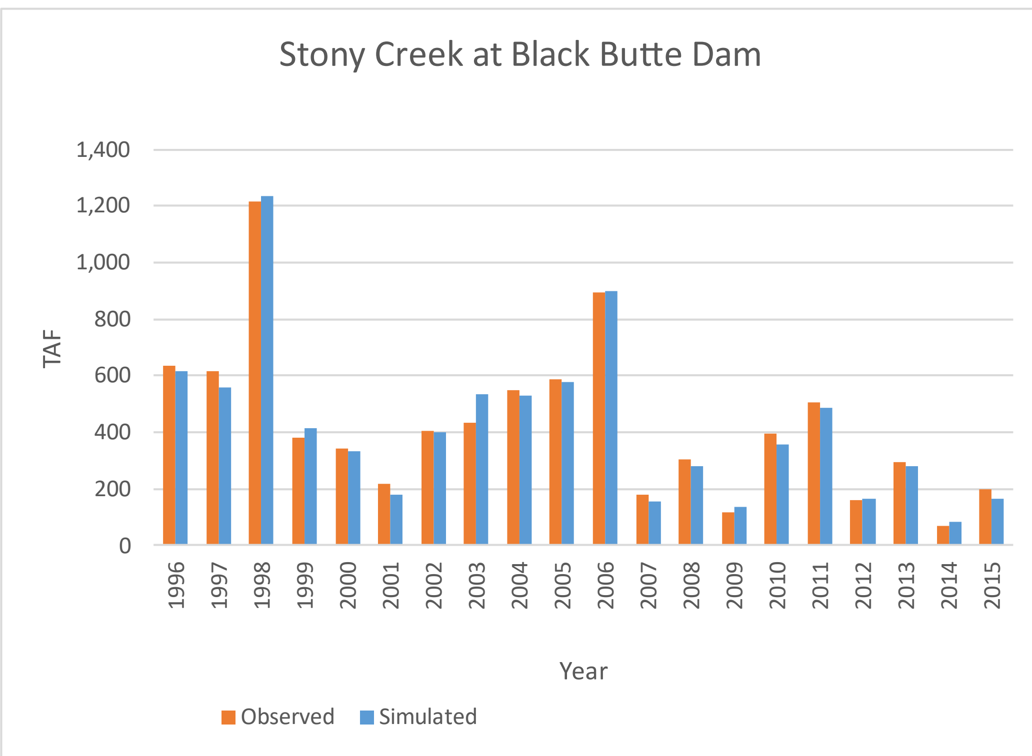


Figure A.8.8c. Stony Creek at Black Butte Dam, Annual 1996 to 2015

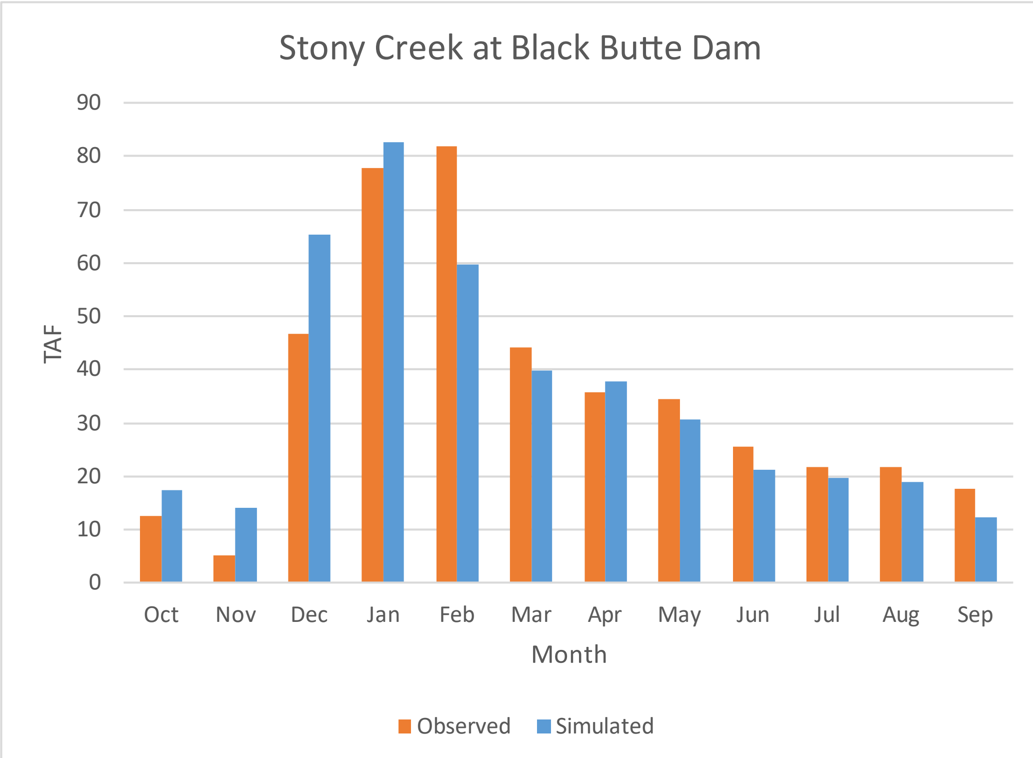


Figure A.8.8d. Stony Creek at Black Butte Dam, Average Monthly

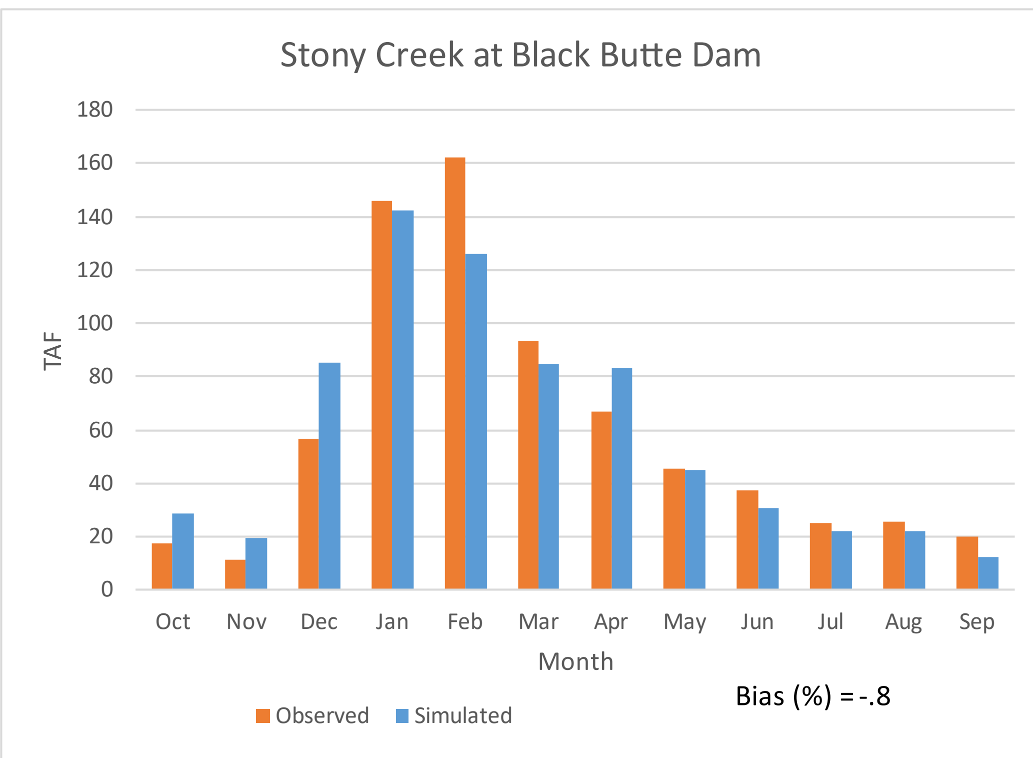


Figure A.8.8e. Stony Creek at Black Butte Dam, Average Monthly (Wet)

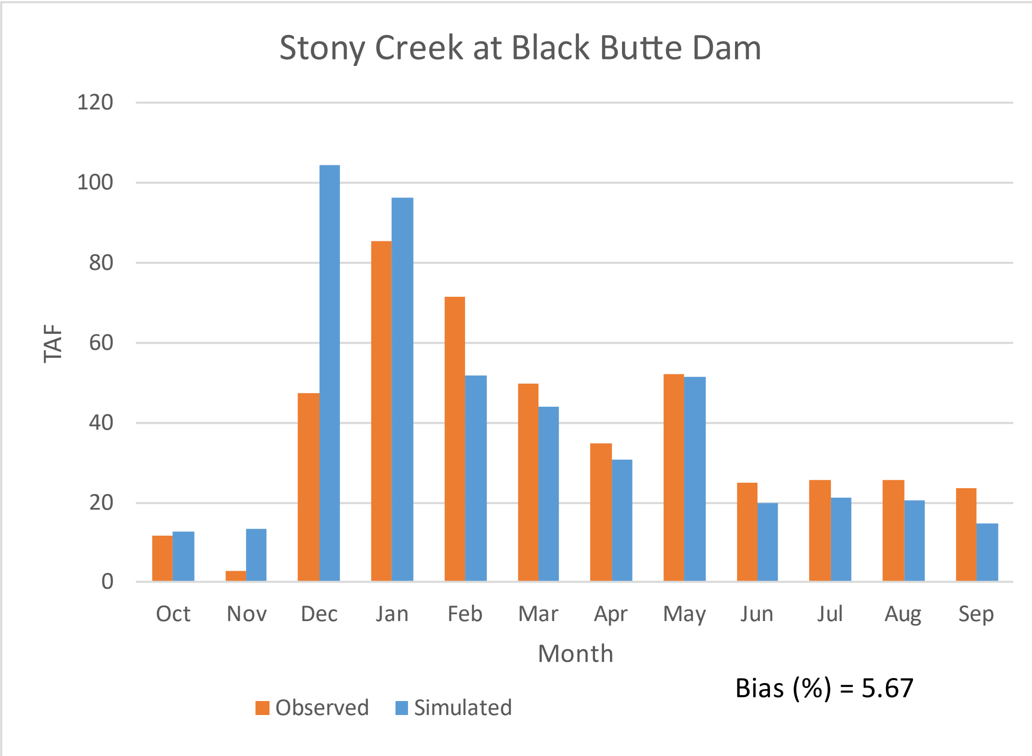


Figure A.8.8f. Stony Creek at Black Butte Dam, Average Monthly (Above Normal)

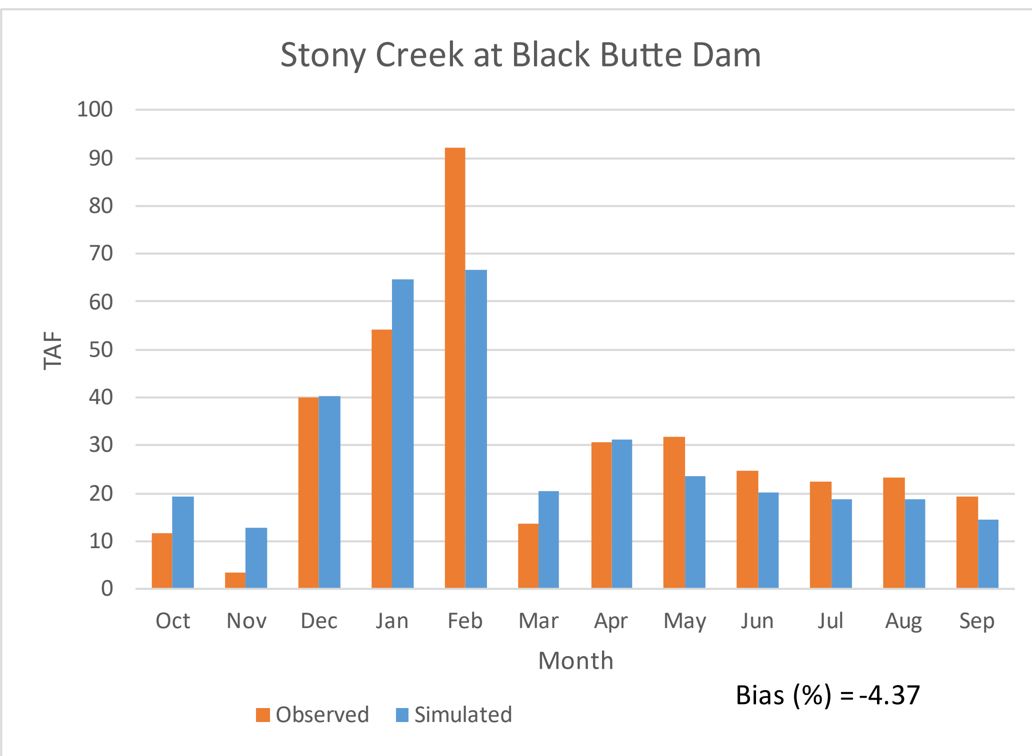


Figure A.8.8g. Stony Creek at Black Butte Dam, Average Monthly (Below Normal)

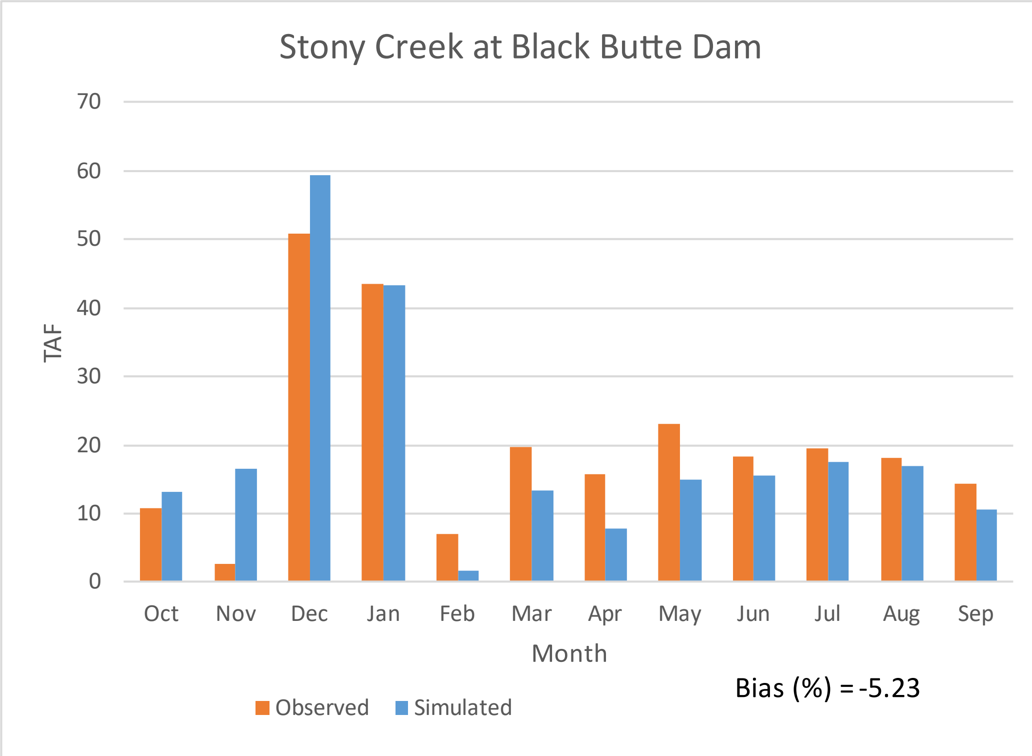


Figure A.8.8h. Stony Creek at Black Butte Dam, Average Monthly (Dry)

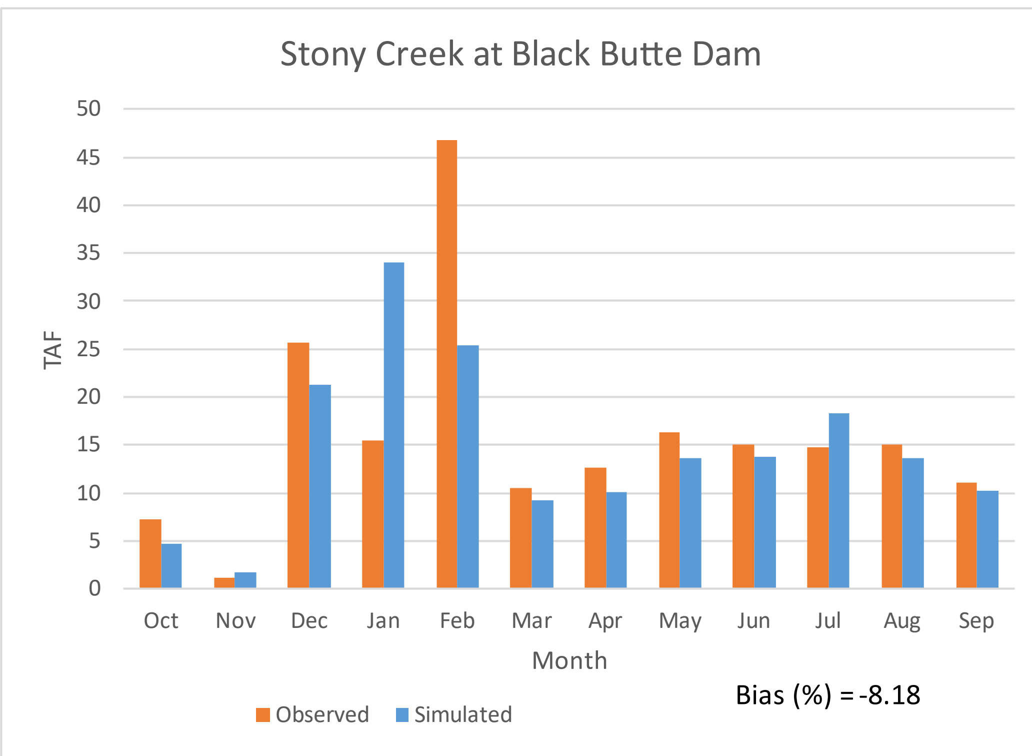


Figure A.8.8i. Stony Creek at Black Butte Dam, Average Monthly (Critical)

A.8.9 Cache Creek at Yolo

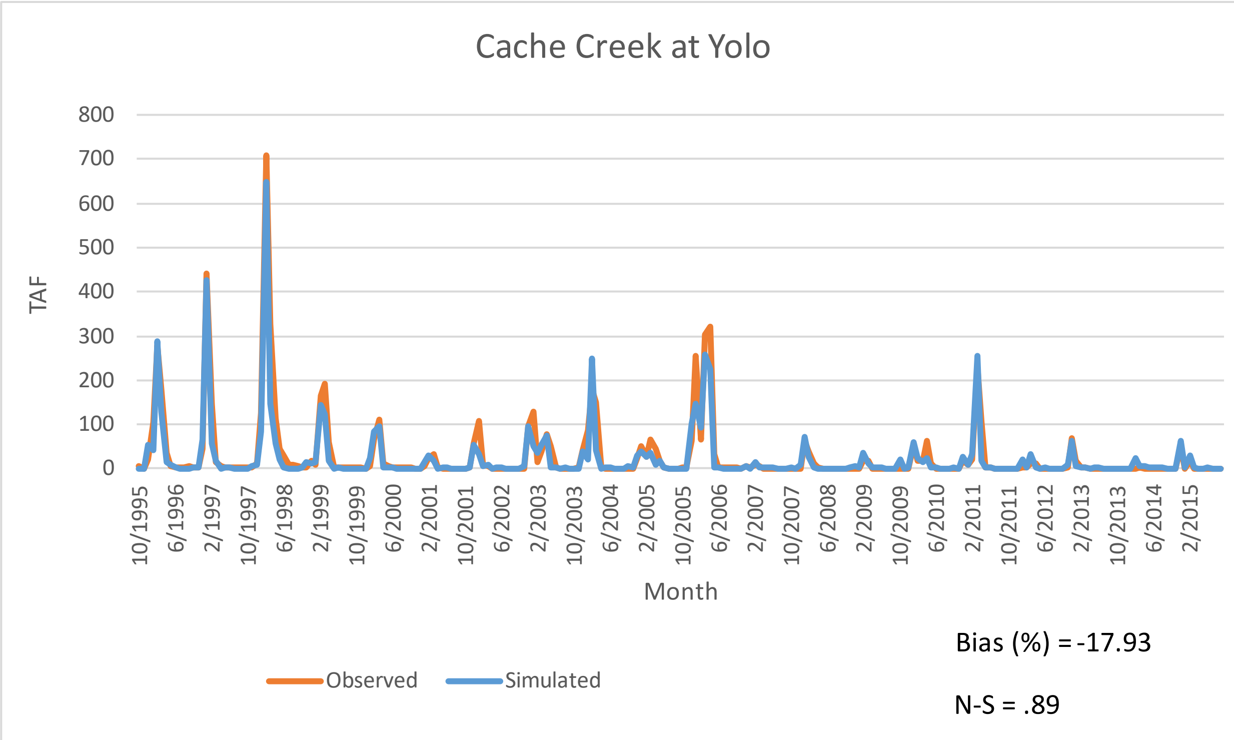


Figure A.8.9a. Cache Creek at Yolo, Monthly 1996 to 2015

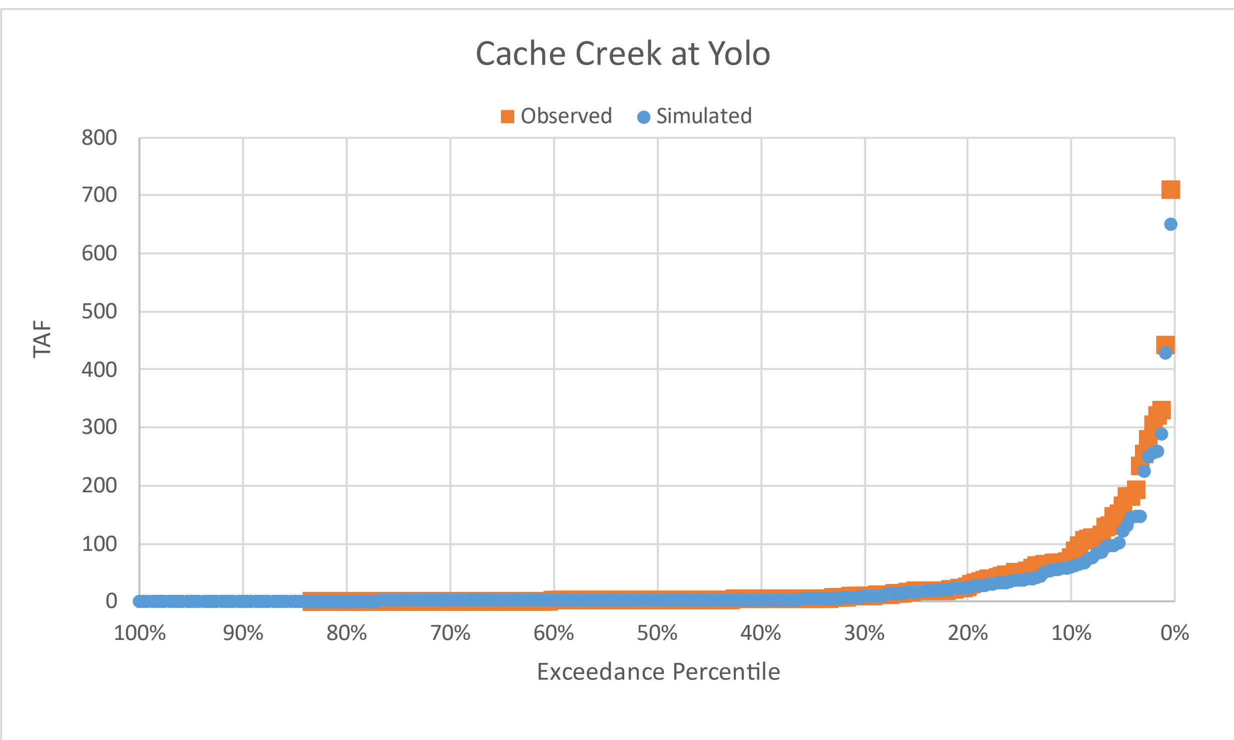


Figure A.8.9b. Cache Creek at Yolo, Exceedance

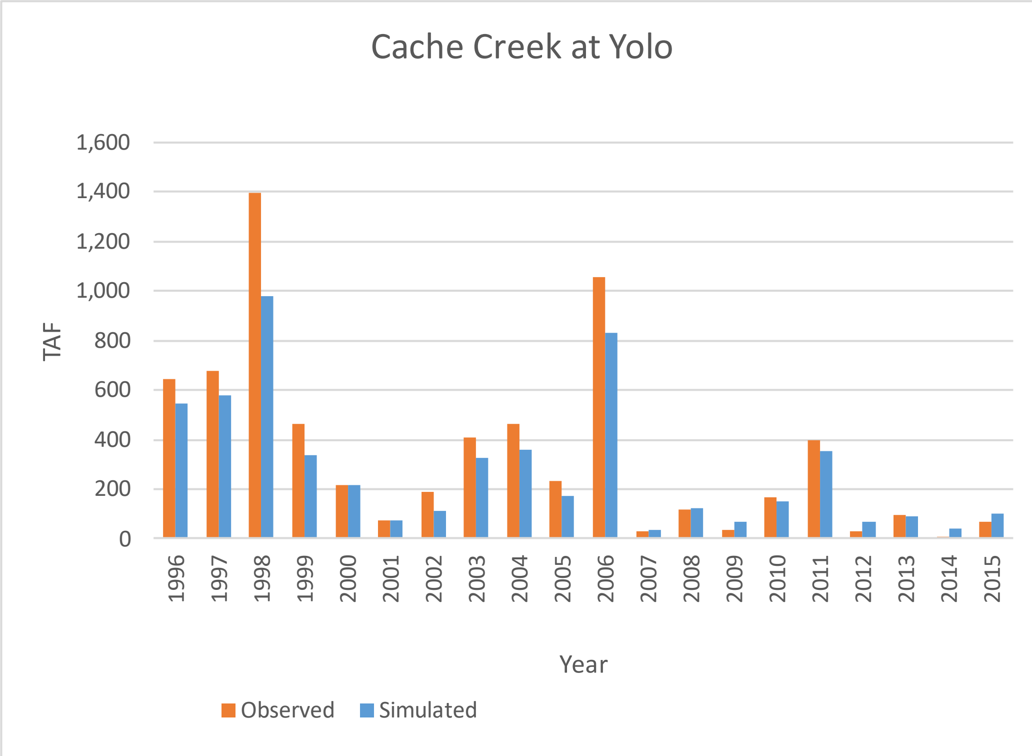


Figure A.8.9c. Cache Creek at Yolo, Annual 1996 to 2015

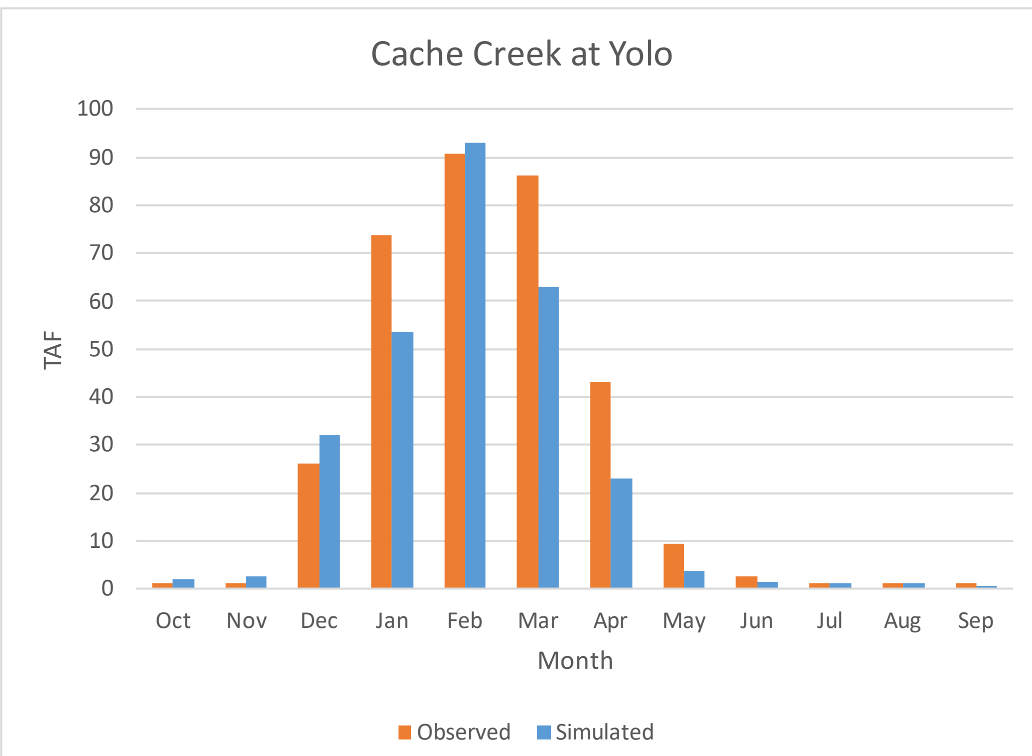


Figure A.8.9d. Cache Creek at Yolo, Average Monthly

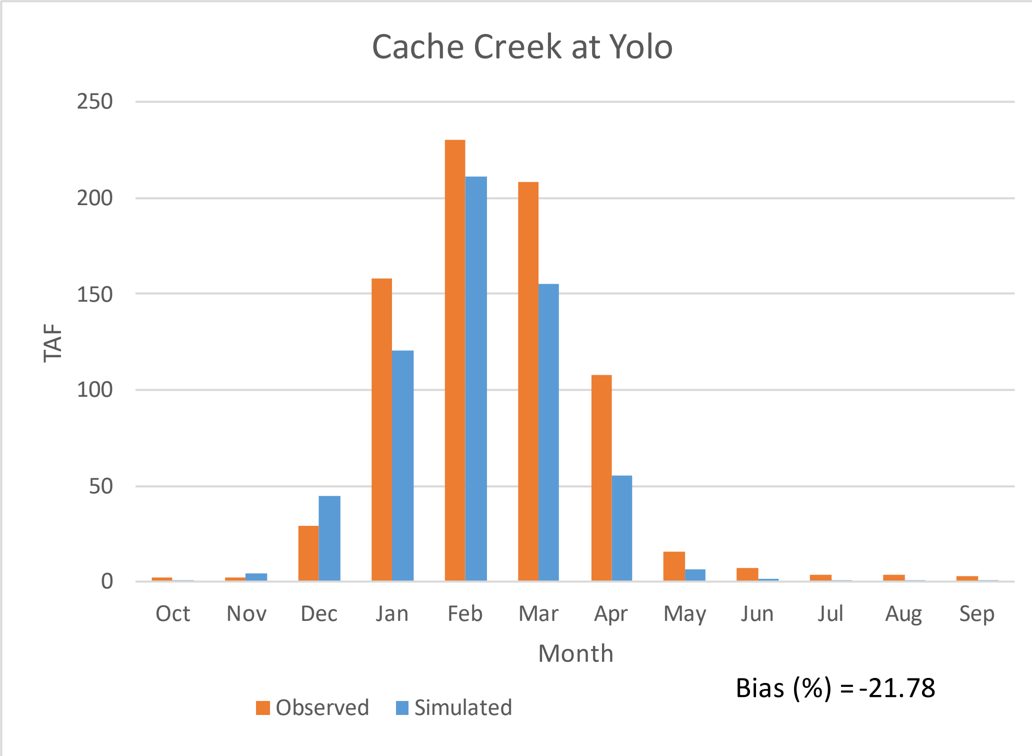


Figure A.8.9e. Cache Creek at Yolo, Average Monthly (Wet)

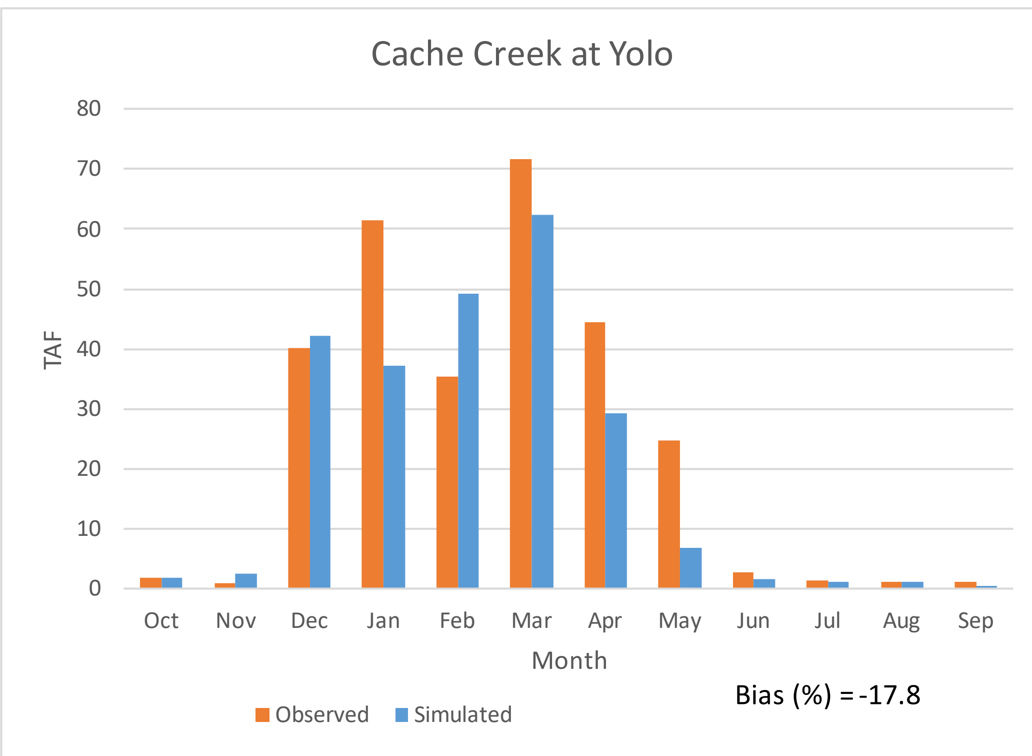


Figure A.8.9f. Cache Creek at Yolo, Average Monthly (Above Normal)

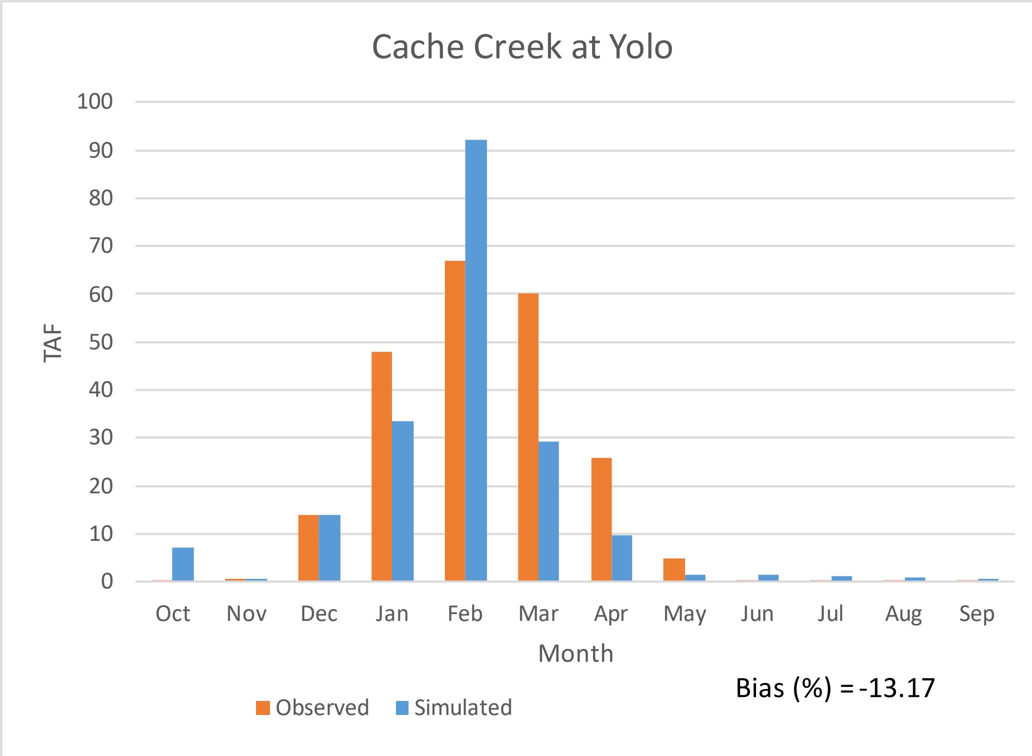


Figure A.8.9g. Cache Creek at Yolo, Average Monthly (Below Normal)

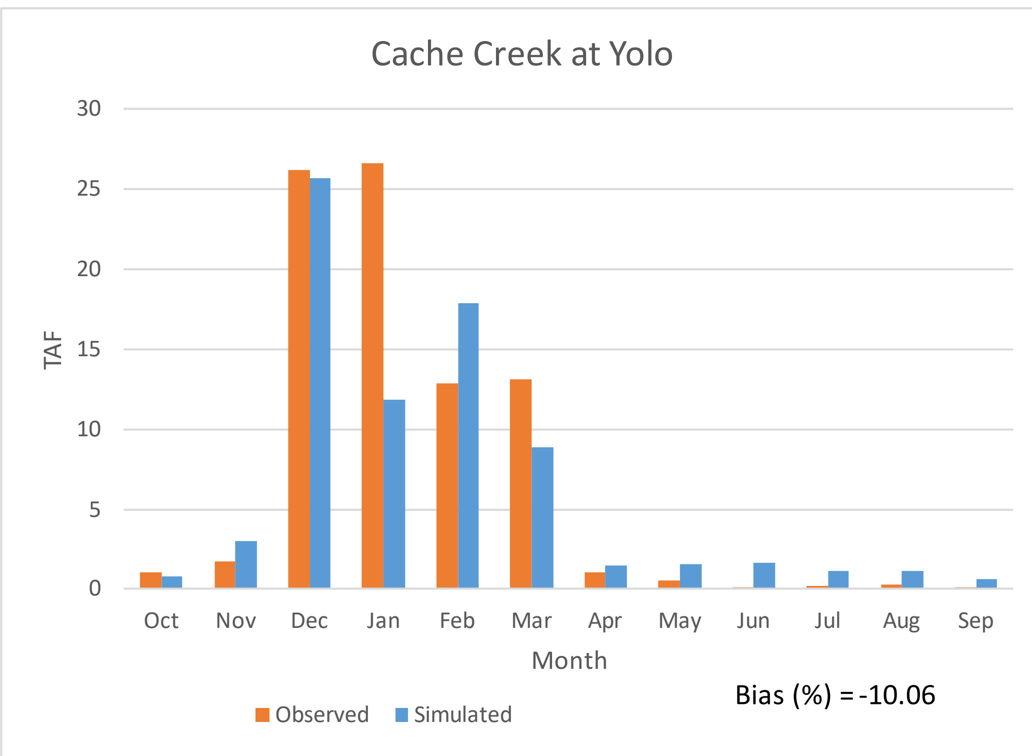


Figure A.8.9h. Cache Creek at Yolo, Average Monthly (Dry)

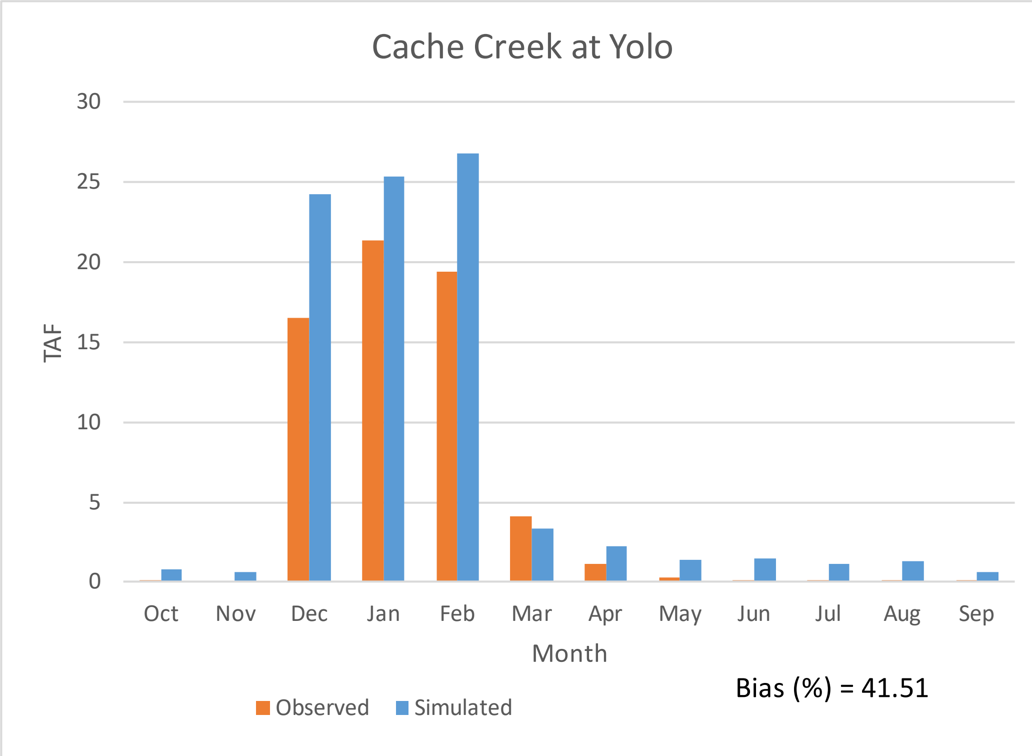


Figure A.8.9i. Cache Creek at Yolo, Average Monthly (Critical)

A.8.10 Cosumnes at Michigan Bar

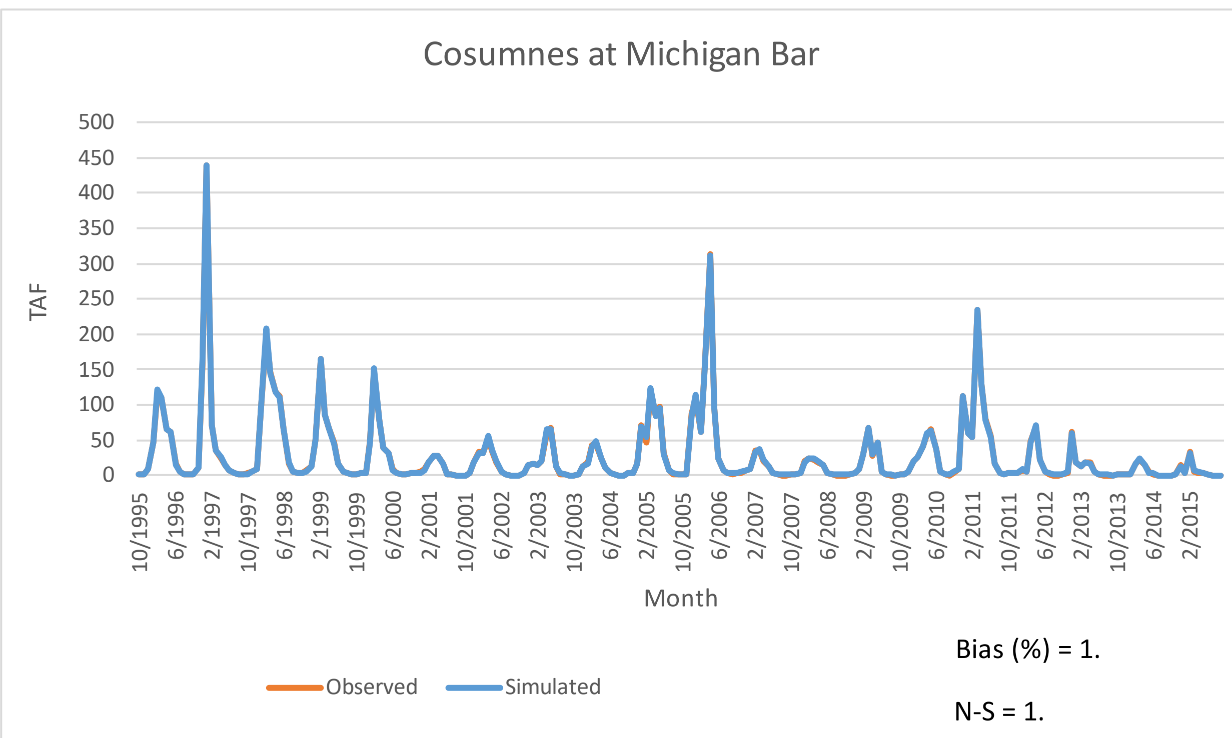


Figure A.8.10a. Cosumnes at Michigan Bar, Monthly 1996 to 2015

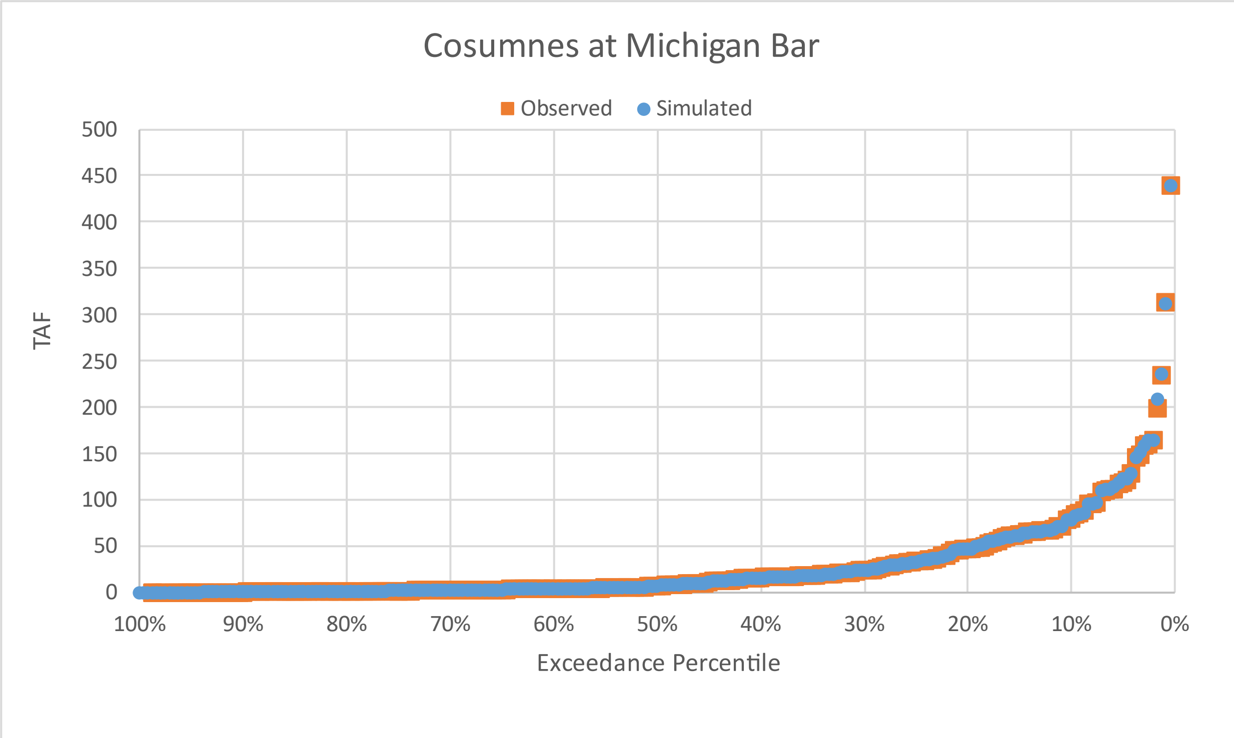


Figure A.8.10b. Cosumnes at Michigan Bar, Exceedance

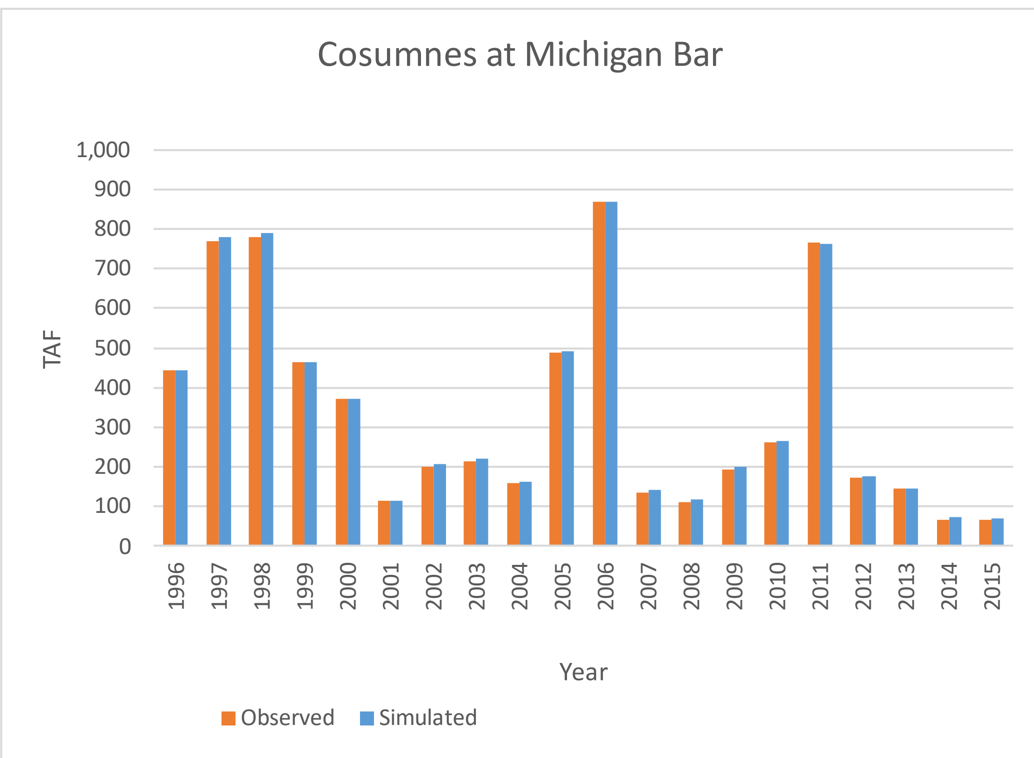


Figure A.8.10c. Cosumnes at Michigan Bar, Annual 1996 to 2015

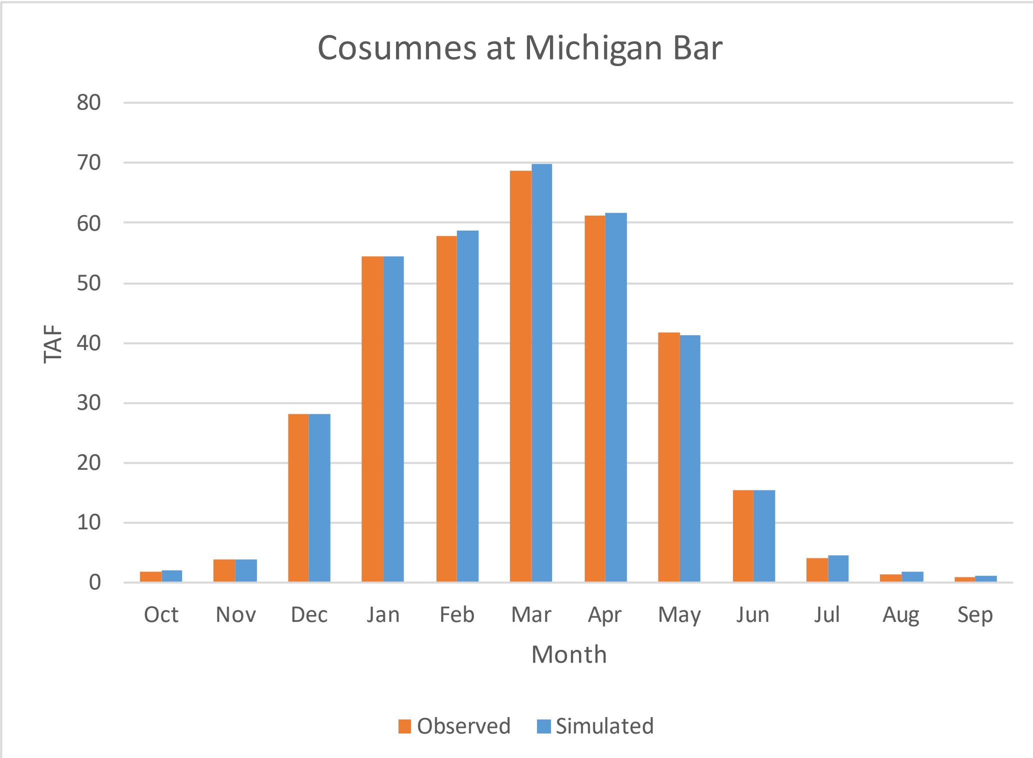


Figure A.8.10d. Cosumnes at Michigan Bar, Average Monthly

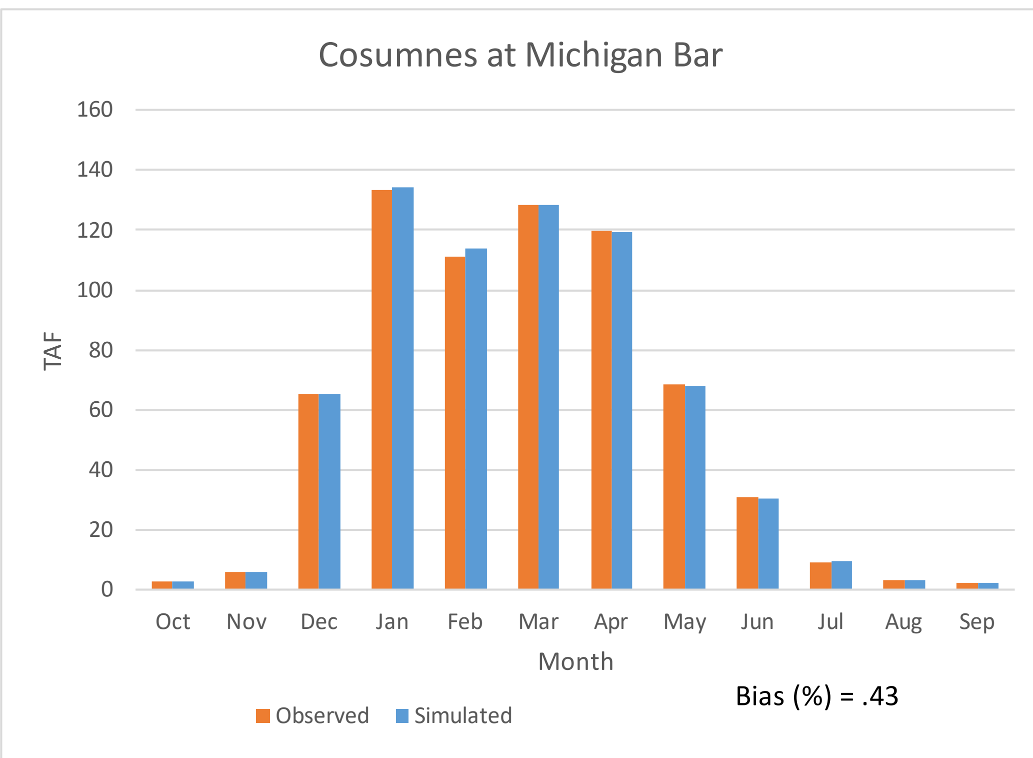


Figure A.8.10e. Cosumnes at Michigan Bar, Average Monthly (Wet)

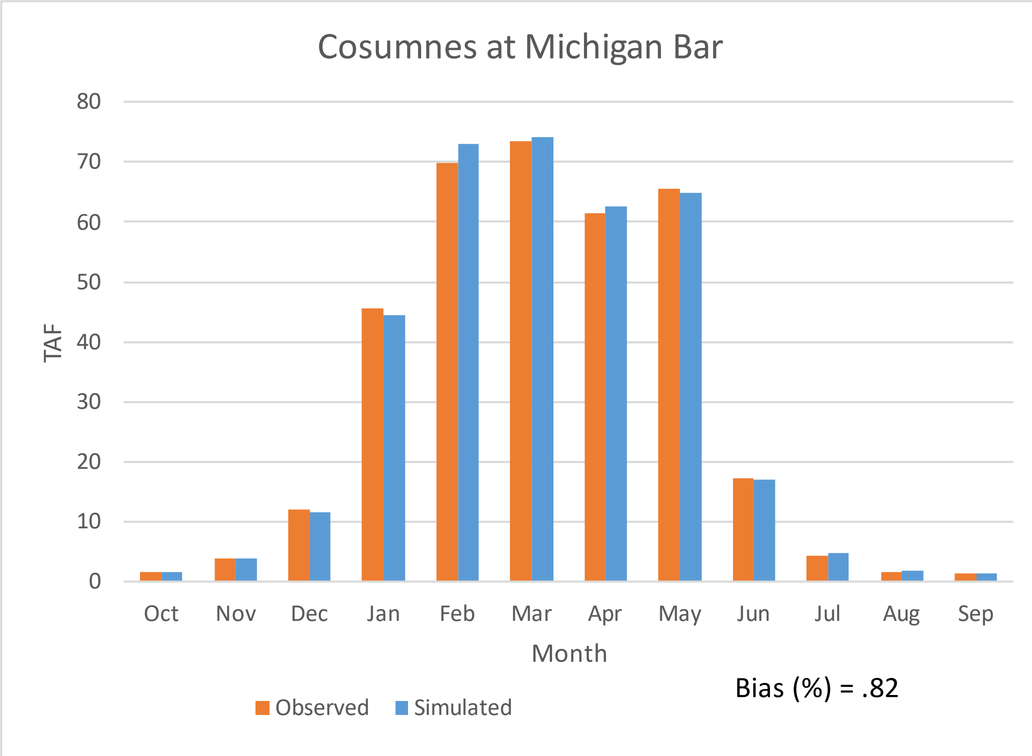


Figure A.8.10f. Cosumnes at Michigan Bar, Average Monthly (Above Normal)

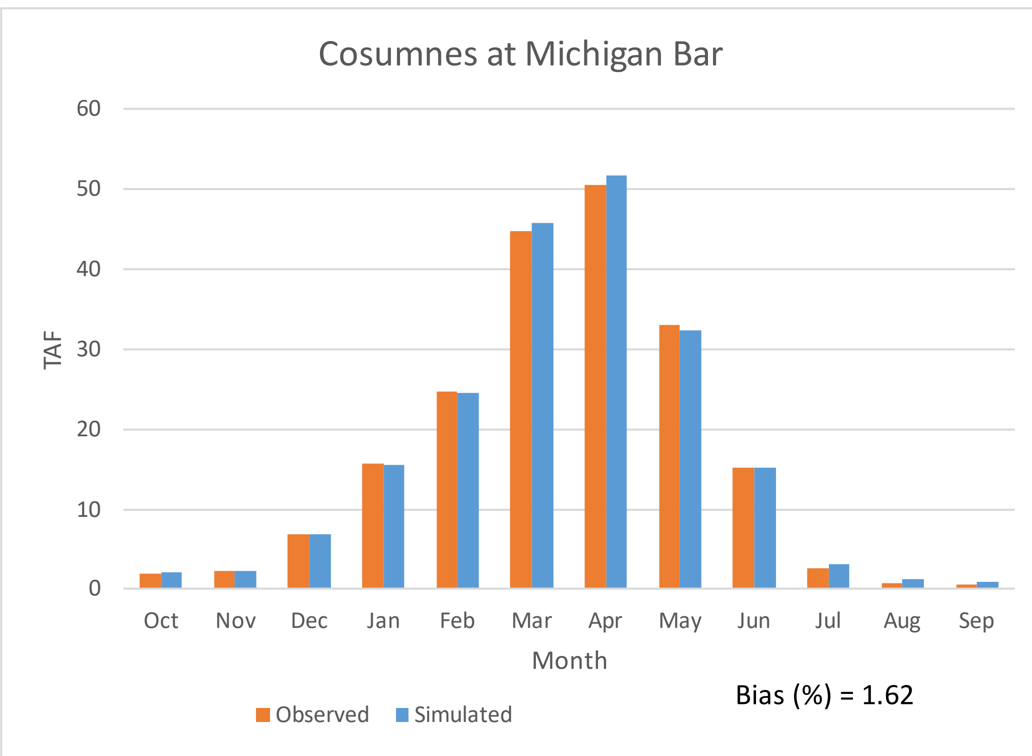


Figure A.8.10g. Cosumnes at Michigan Bar, Average Monthly (Below Normal)

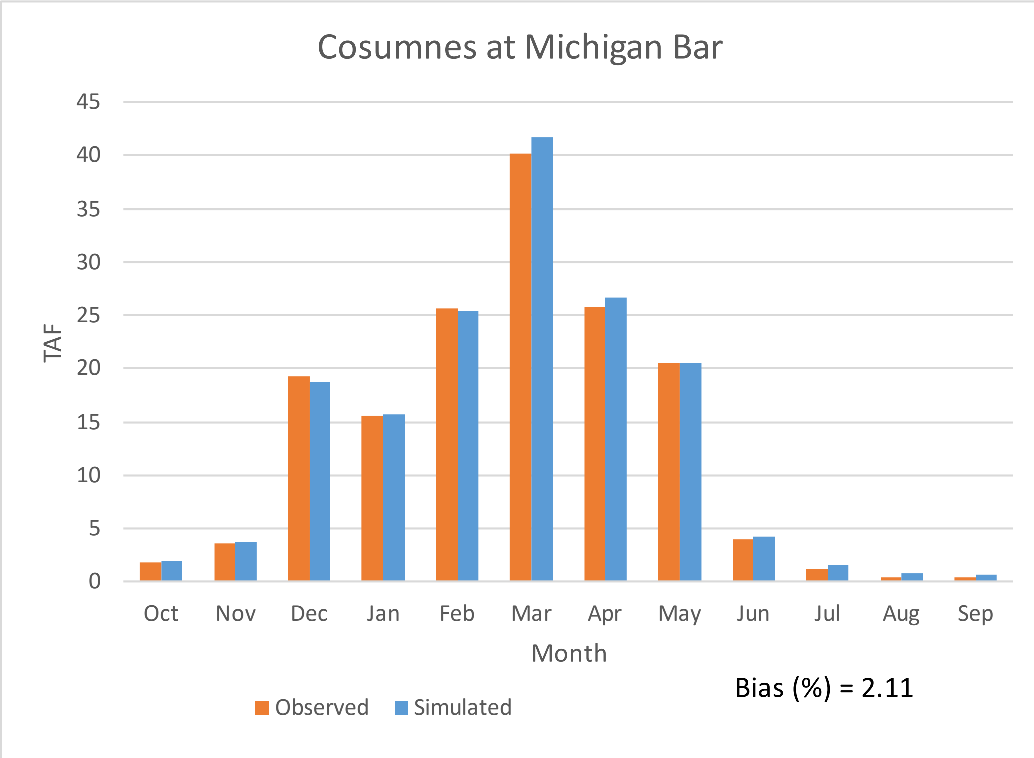


Figure A.8.10h. Cosumnes at Michigan Bar, Average Monthly (Dry)

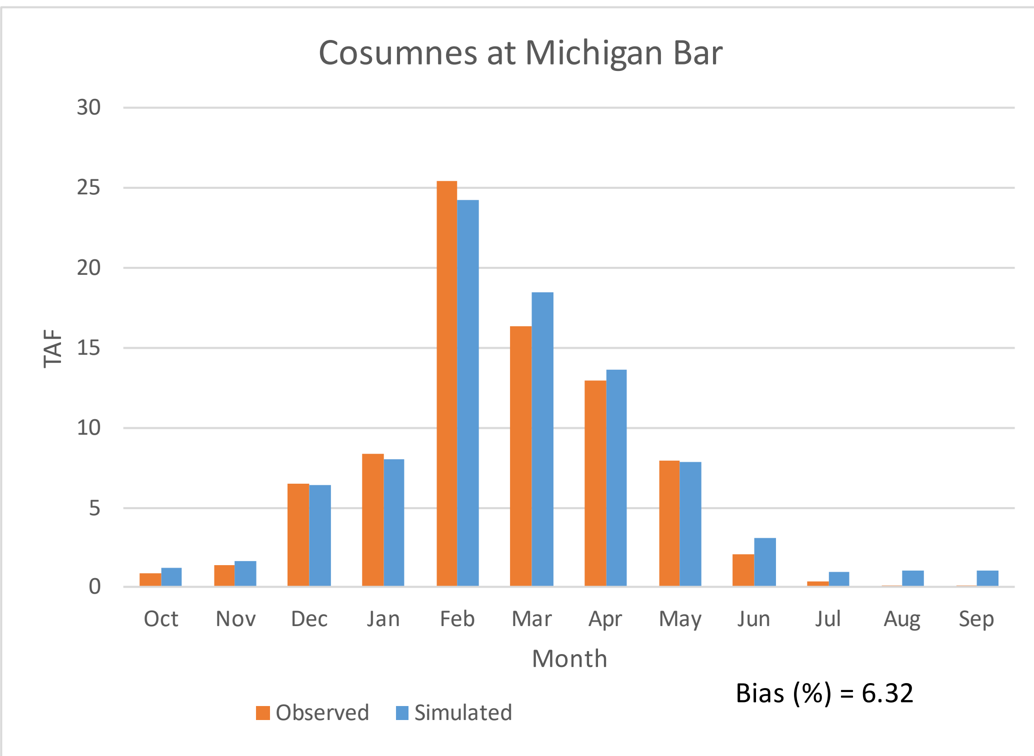


Figure A.8.10i. Cosumnes at Michigan Bar, Average Monthly (Critical)

A.8.11 Folsom Lake Inflow

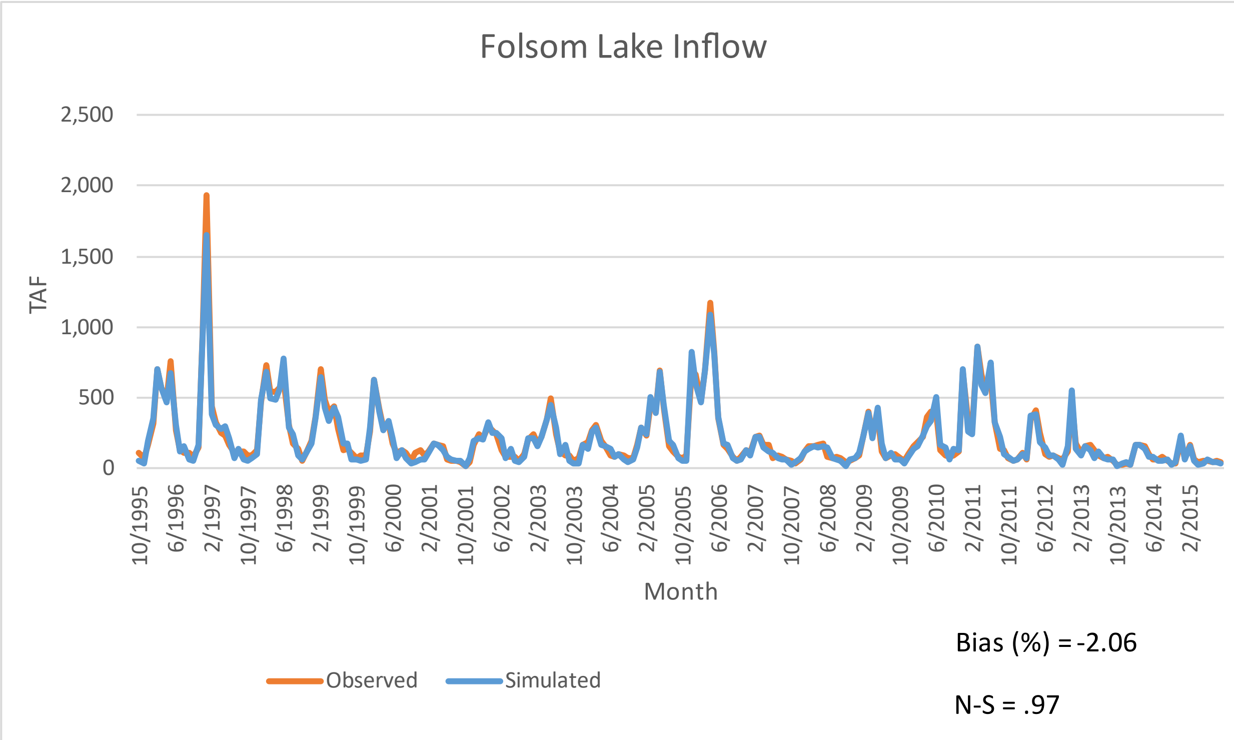


Figure A.8.11a. Folsom Lake Inflow, Monthly 1996 to 2015

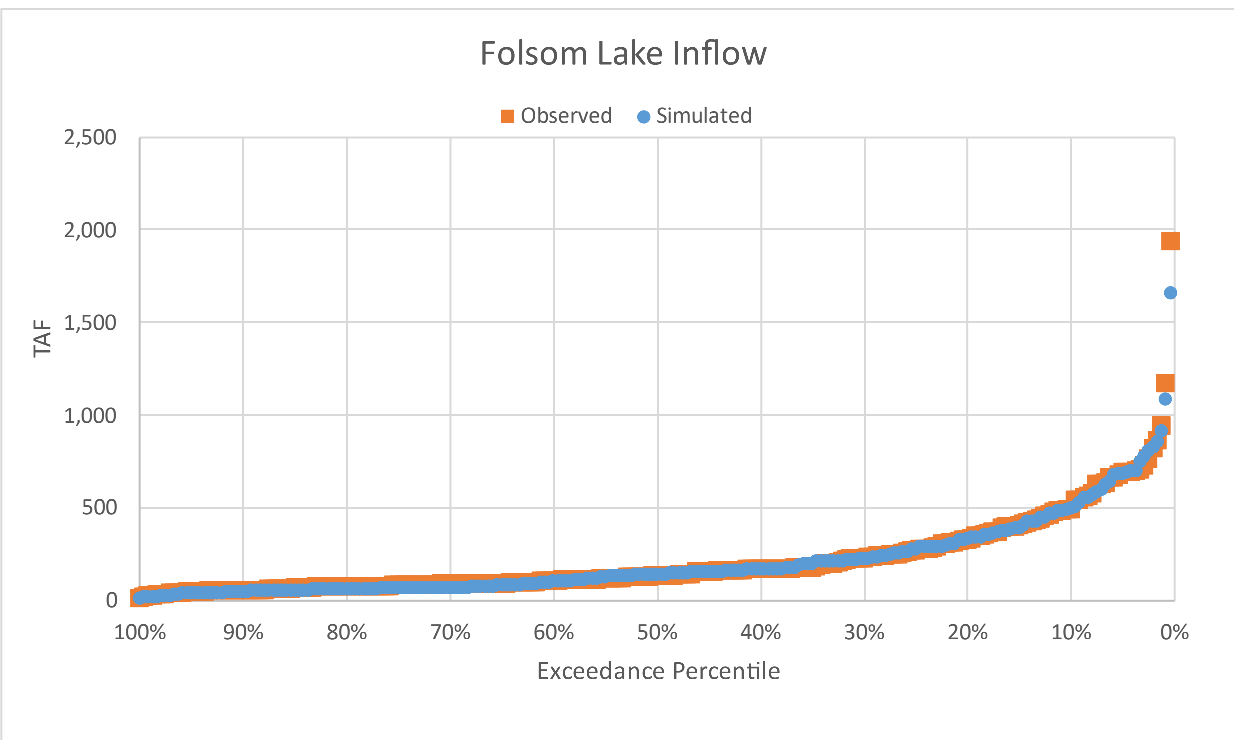


Figure A.8.11b. Folsom Lake Inflow, Exceedance

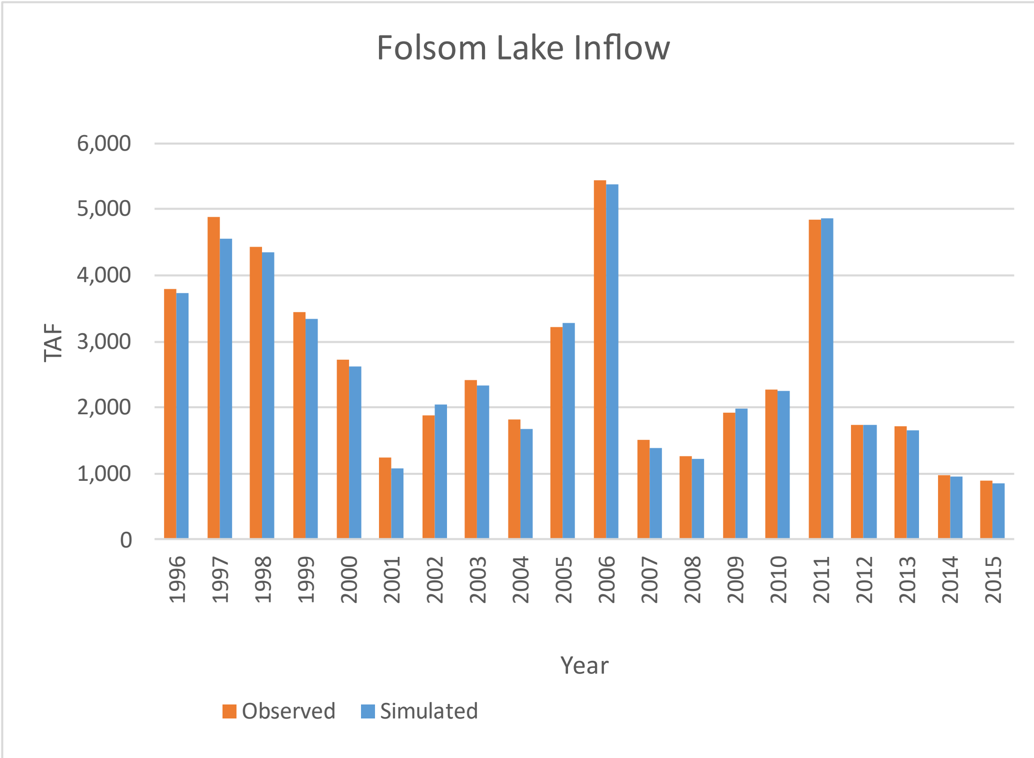


Figure A.8.11c. Folsom Lake Inflow, Annual 1996 to 2015

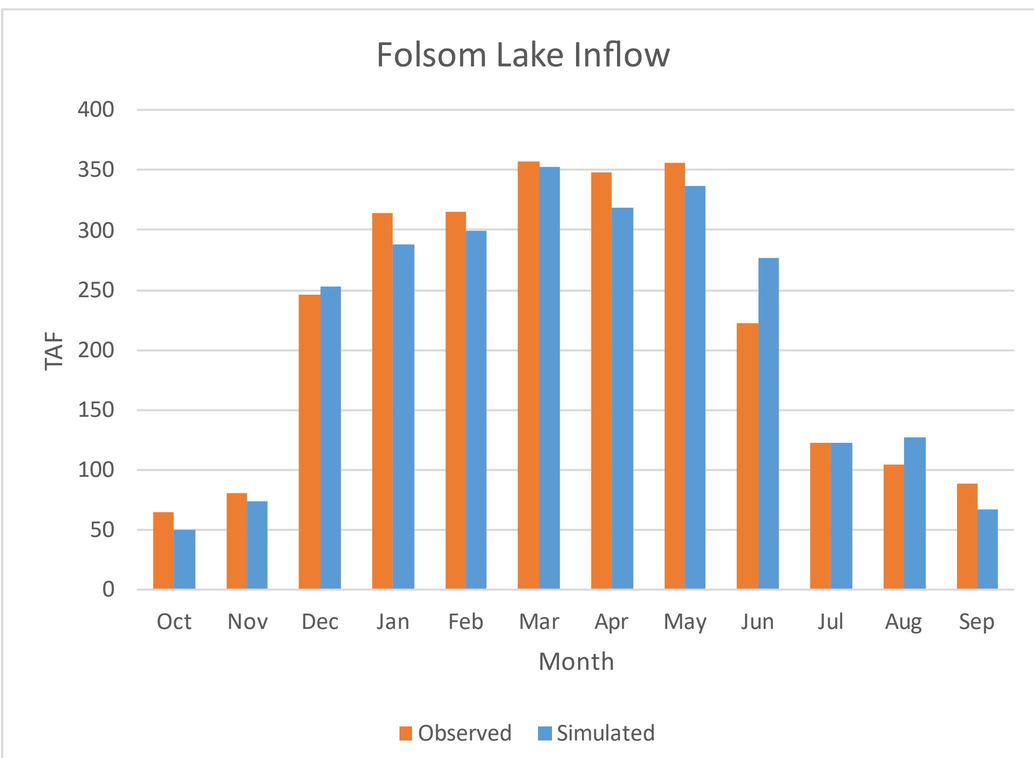


Figure A.8.11d. Folsom Lake Inflow, Average Monthly

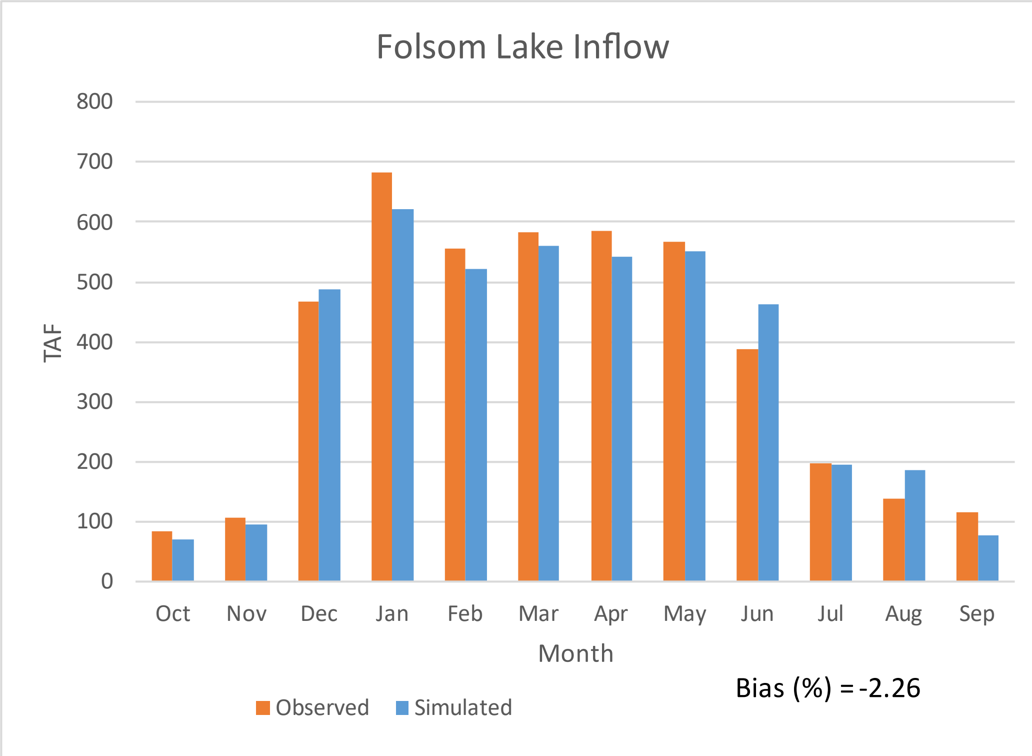


Figure A.8.11e. Folsom Lake Inflow, Average Monthly (Wet)

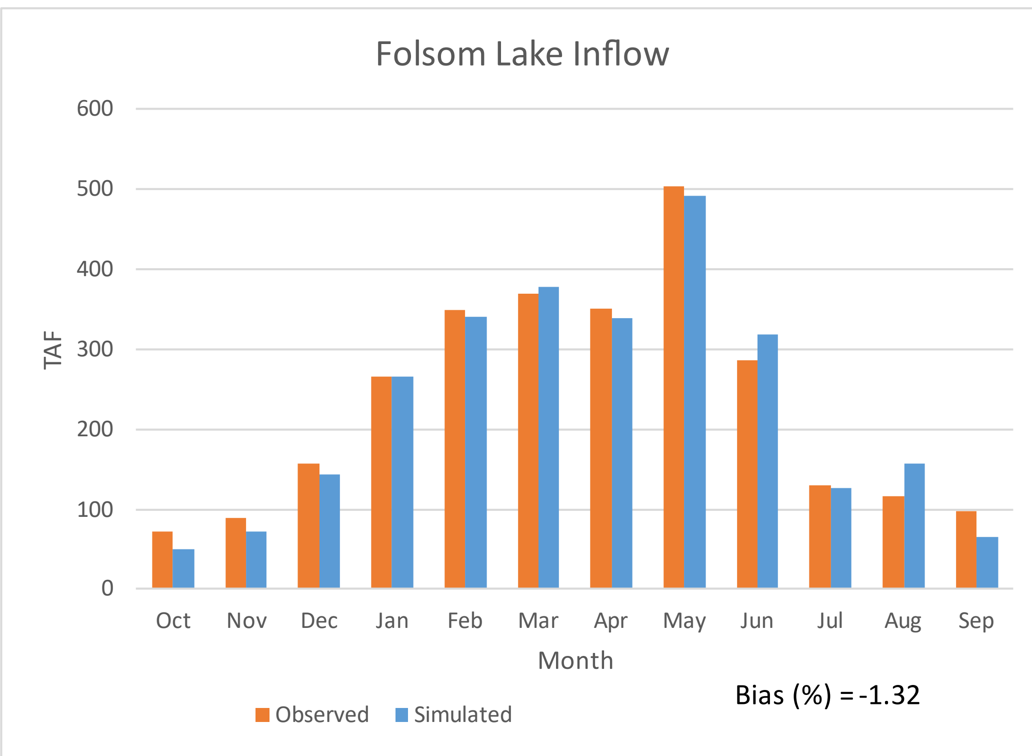


Figure A.8.11f. Folsom Lake Inflow, Average Monthly (Above Normal)

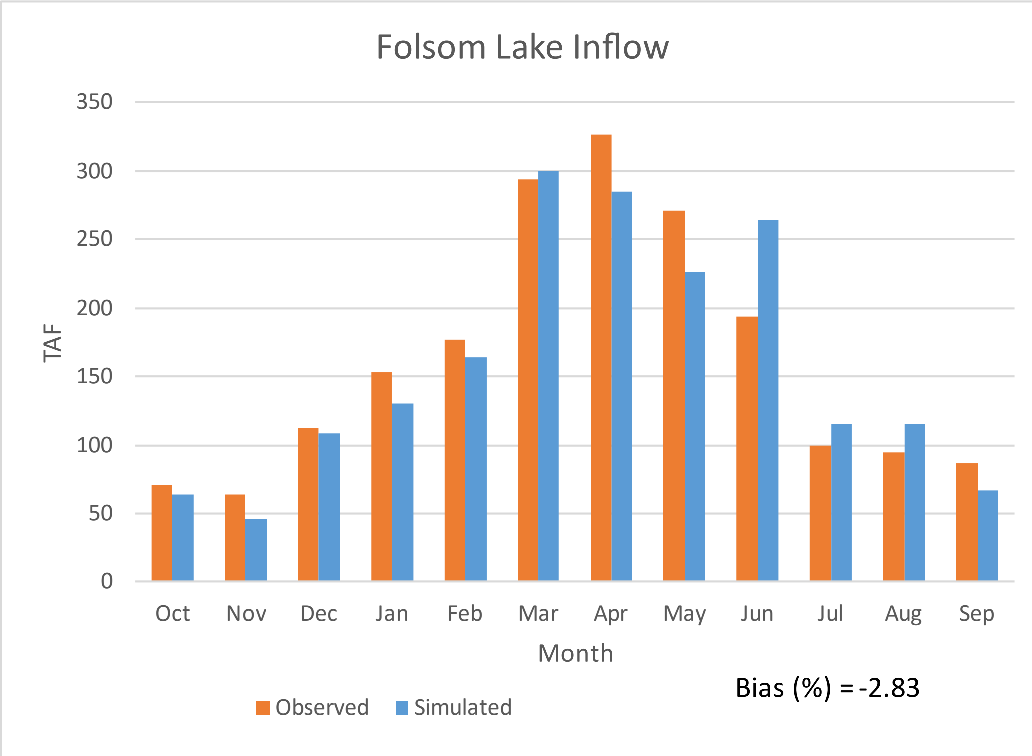


Figure A.8.11g. Folsom Lake Inflow, Average Monthly (Below Normal)

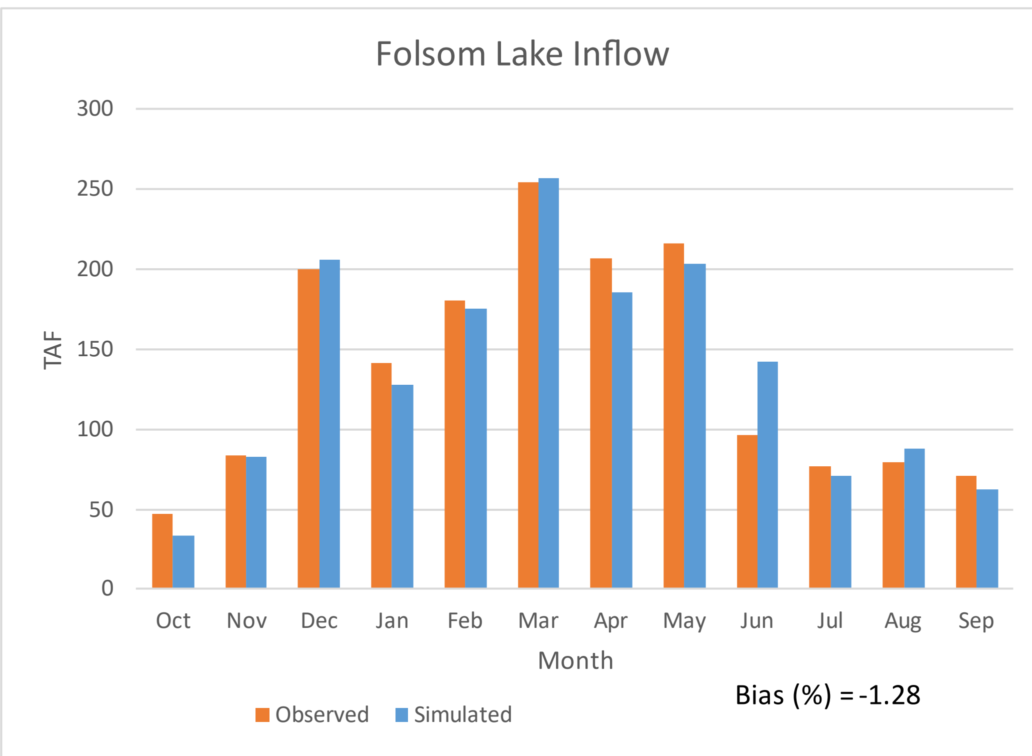


Figure A.8.11h. Folsom Lake Inflow, Average Monthly (Dry)

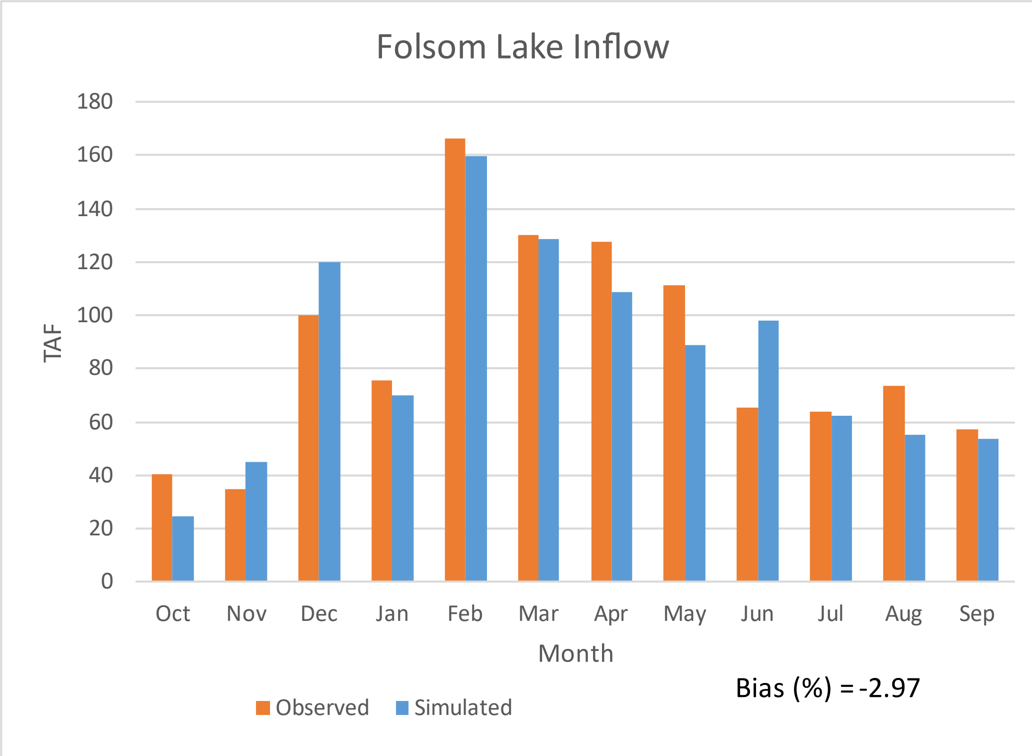


Figure A.8.11i. Folsom Lake Inflow, Average Monthly (Critical)

A.8.12 Lake Oroville Inflow

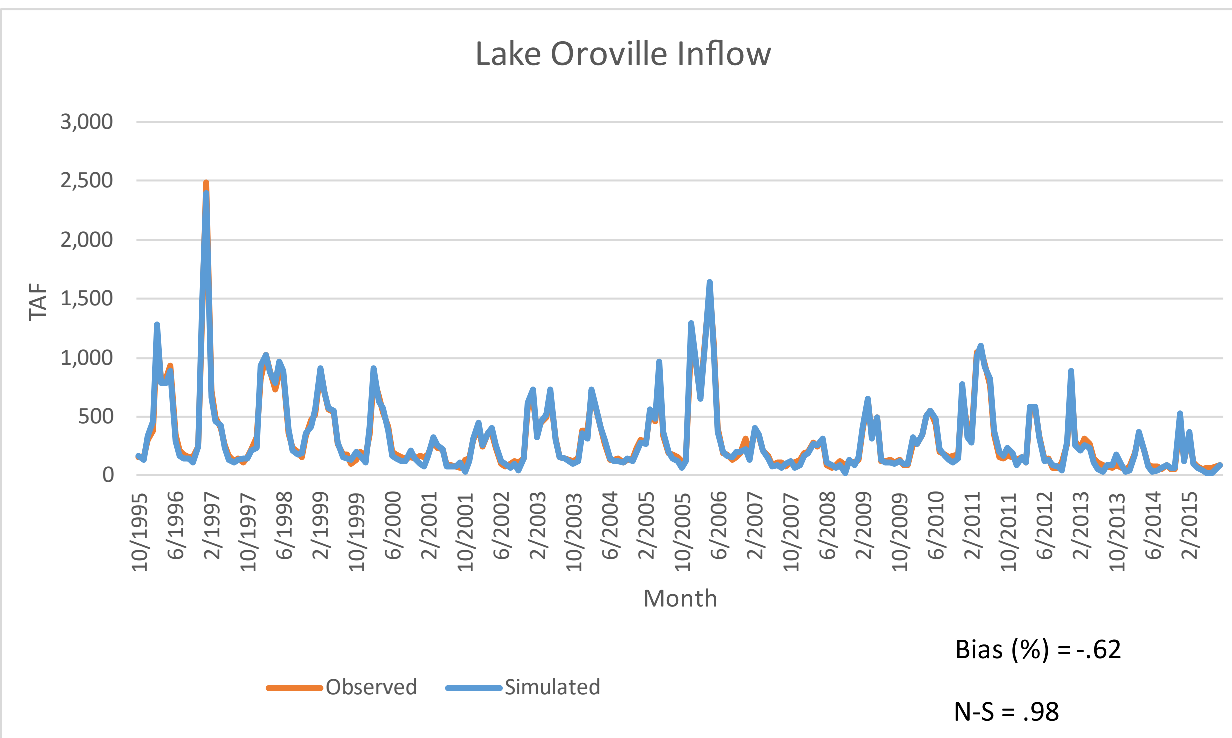


Figure A.8.12a. Lake Oroville Inflow, Monthly 1996 to 2015

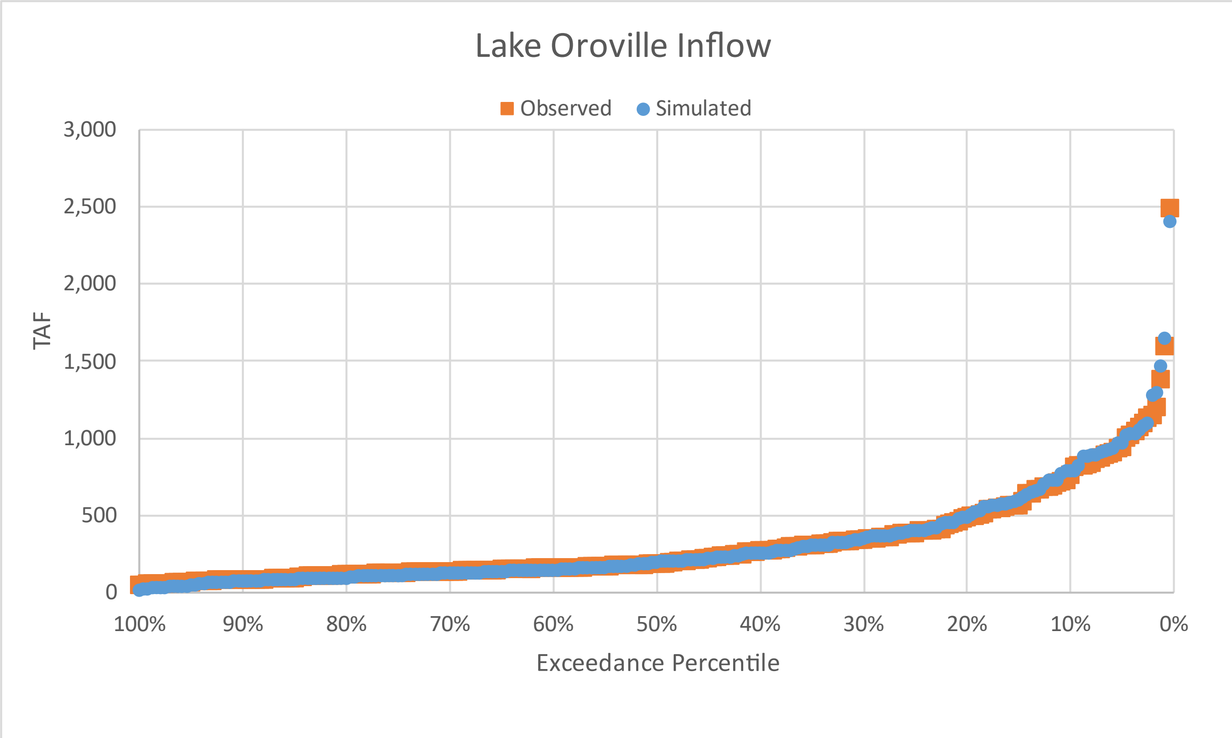


Figure A.8.12b. Lake Oroville Inflow, Exceedance

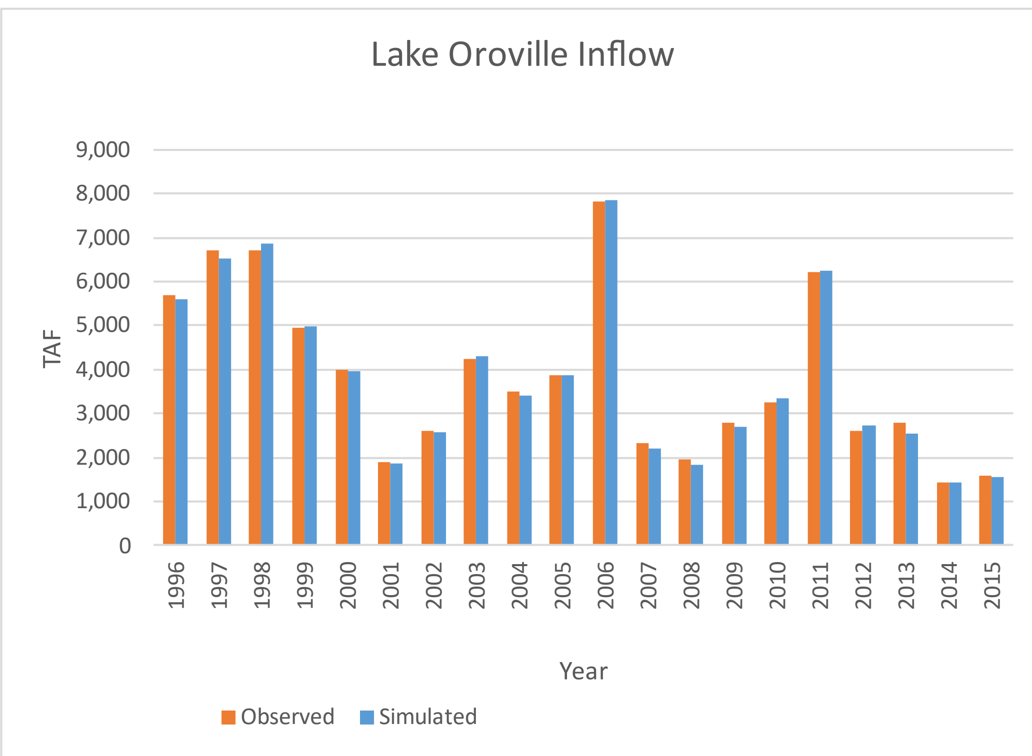


Figure A.8.12c. Lake Oroville Inflow, Annual 1996 to 2015

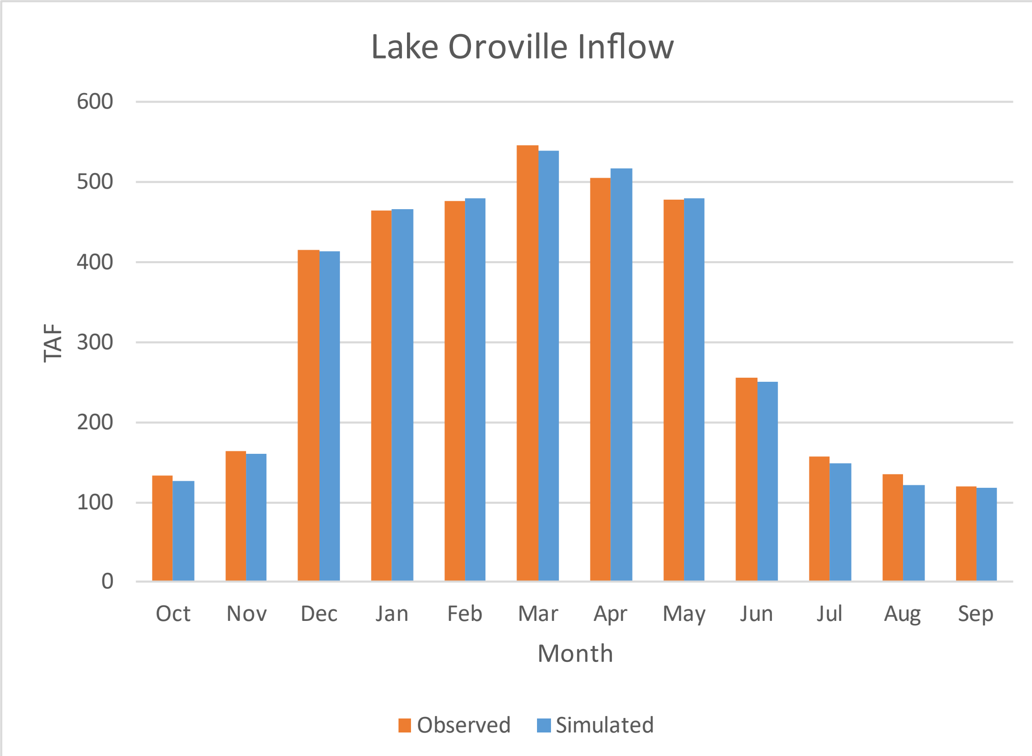


Figure A.8.12d. Lake Oroville Inflow, Average Monthly

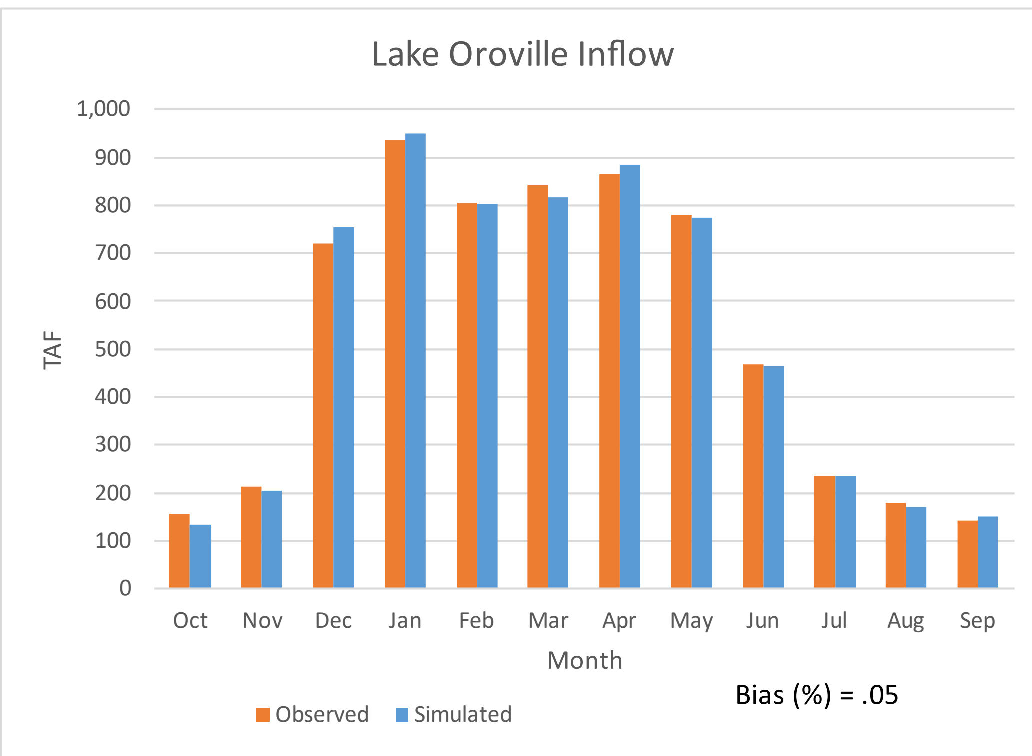


Figure A.8.12e. Lake Oroville Inflow, Average Monthly (Wet)

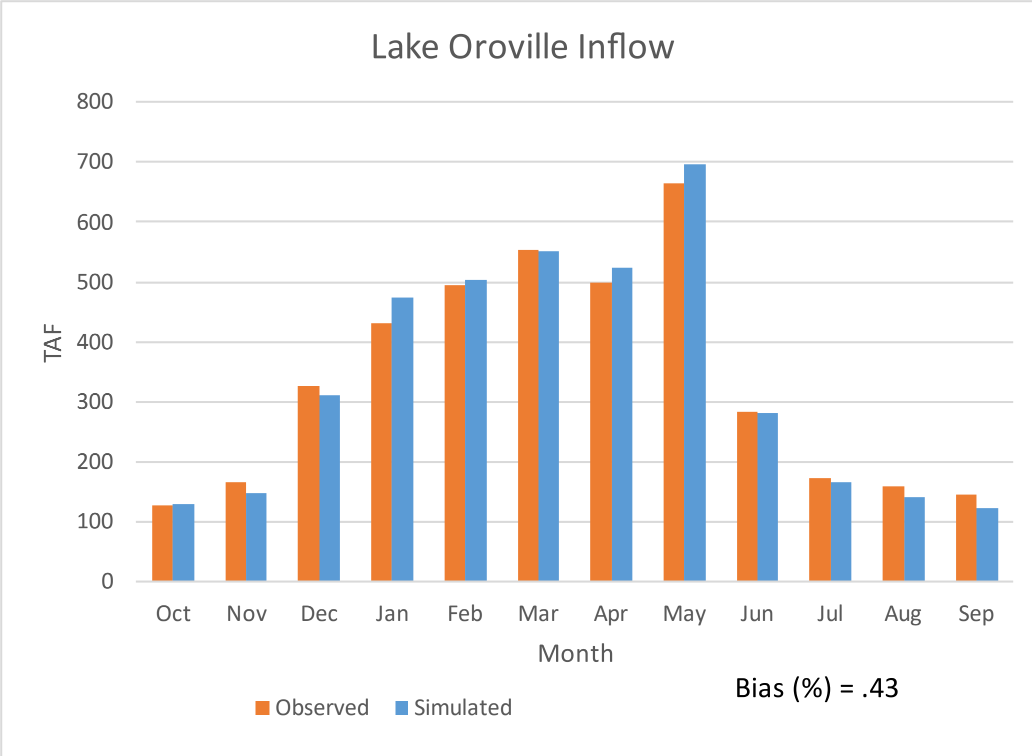


Figure A.8.12f. Lake Oroville Inflow, Average Monthly (Above Normal)

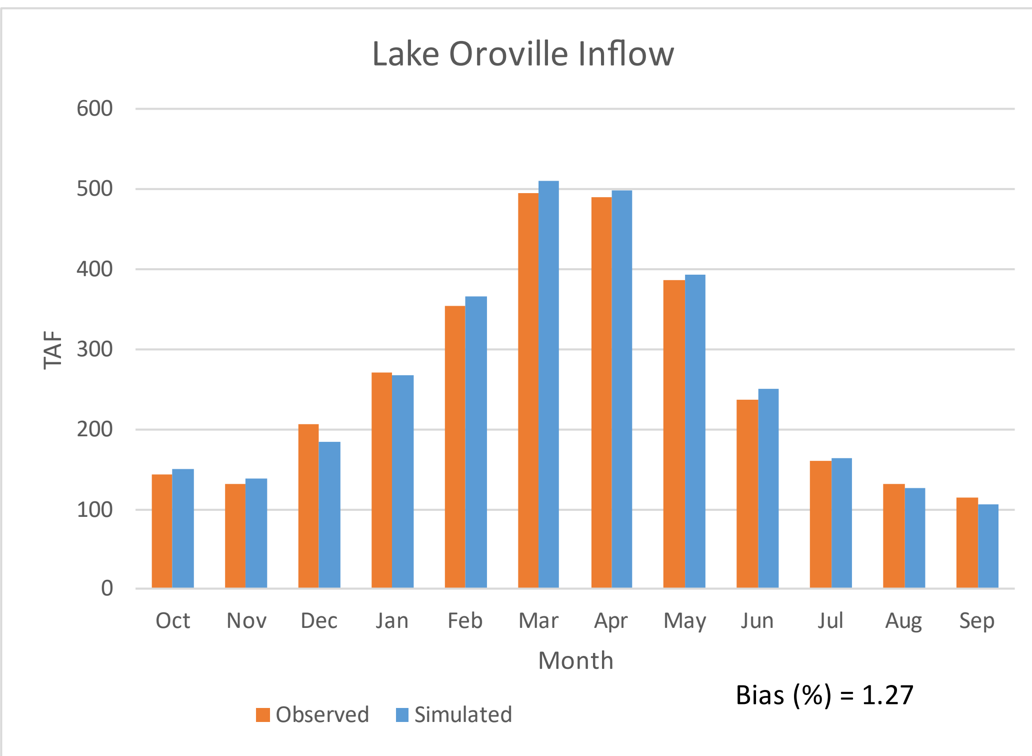


Figure A.8.12g. Lake Oroville Inflow, Average Monthly (Below Normal)

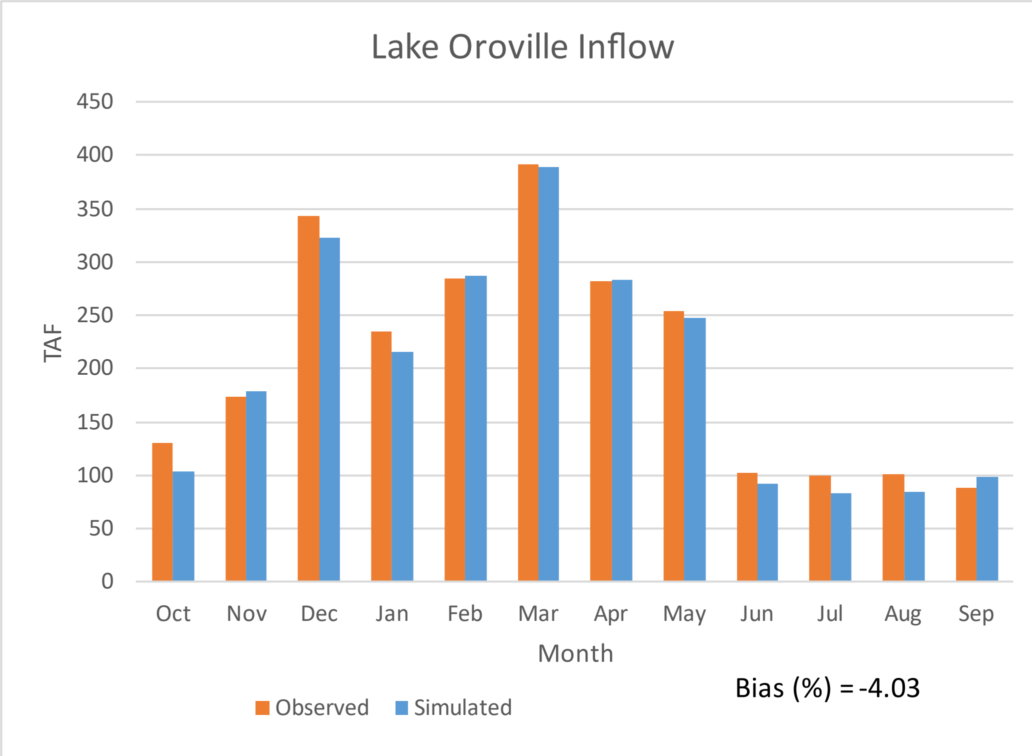


Figure A.8.12h. Lake Oroville Inflow, Average Monthly (Dry)

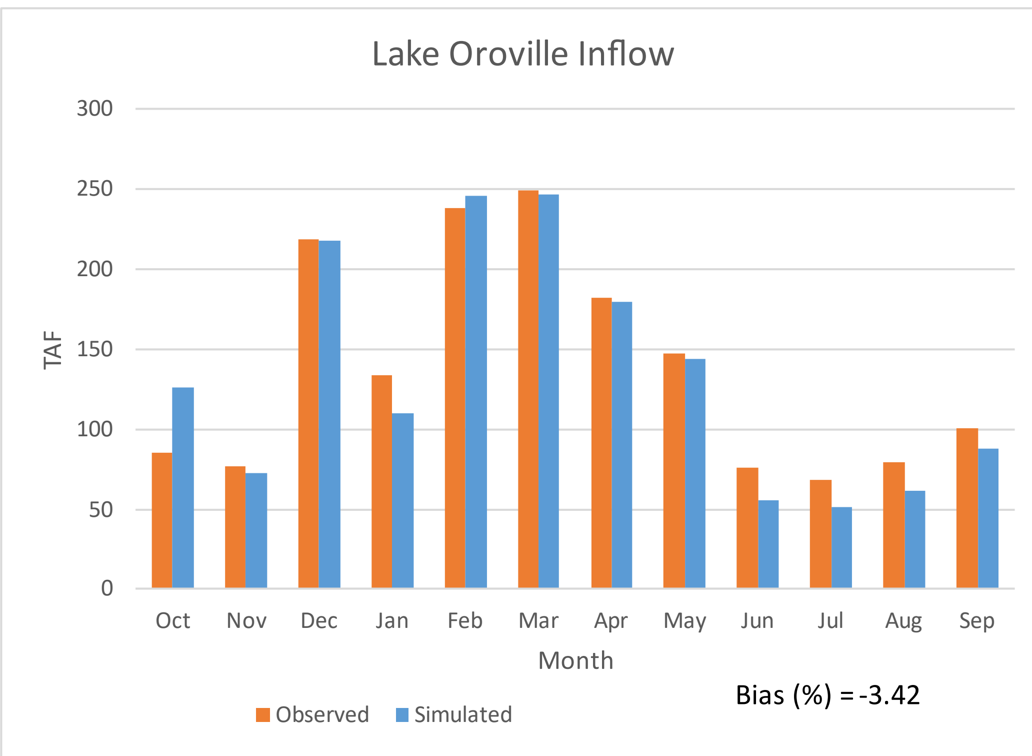


Figure A.8.12i. Lake Oroville Inflow, Average Monthly (Critical)

A.9 Non-Project Reservoir Storage Validation

The following section present simulated storage results for reservoirs located in the Sacramento and San Joaquin River Hydrologic Regions that are owned by Reclamation or local water agencies and are operated for a mix of flood control, hydropower, local water supply, and recreational uses. These reservoirs include the following (with the owner/operating agency shown in parenthesis):

1. Indian Valley Reservoir (Yolo County FC&WCD)
2. Clear Lake (Yolo County FC&WCD)
3. Lake Berryessa (Reclamation - Solano Project)
4. New Bullards Bar Reservoir (Yuba County WA)
5. Camp Far West Reservoir (South Sutter WD)
6. Camanche Reservoir (East Bay MUD)
7. New Hogan Reservoir (USACE/Stockton East WD)
8. East Park, Stony Gorge, and Black Butte reservoirs (Reclamation – Orland Project and CVP)
9. Butt Valley Reservoir, Bucks Lake, Mountain Meadows Reservoir and Lake Almanor (PG&E)
10. Jackson Meadows Reservoir and Bowman Lake (Nevada ID)
11. Lake Fordyce and Lake Spaulding (PG&E)
12. French Meadows and Ice House Reservoirs (Yuba County WA)
13. Ice House, Loon Lake, and Union Valley (SMUD)

Results are presented for water years 1996-2015 in the form of: (1) time series of monthly storage, (2) monthly storage exceedence, (3) time series of carryover (end-of-September) storage, and (4) average monthly storage. Subsequently, charts of average monthly storage are presented by water year type (Sacramento Valley 40-30-30 index). All charts compare simulated storage to historical storage.

A.9.1 Indian Valley Storage

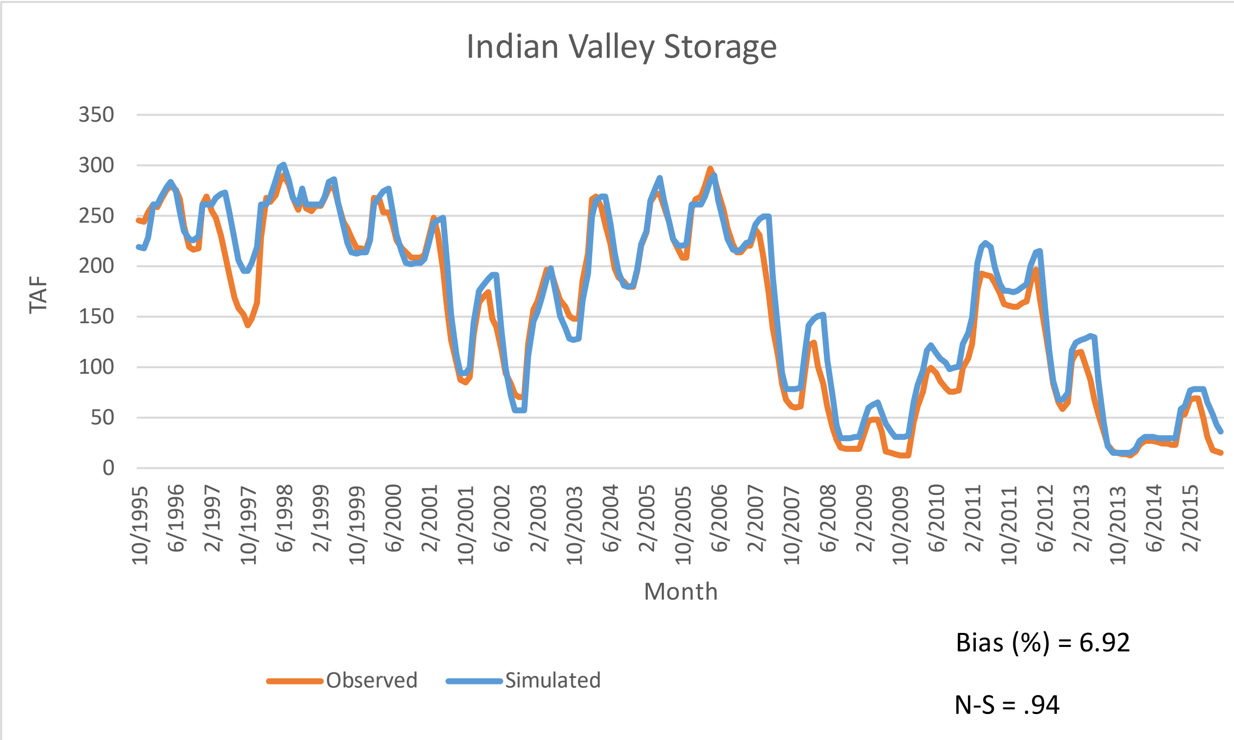


Figure A.9.1a. Indian Valley Storage, Monthly 1996 to 2015

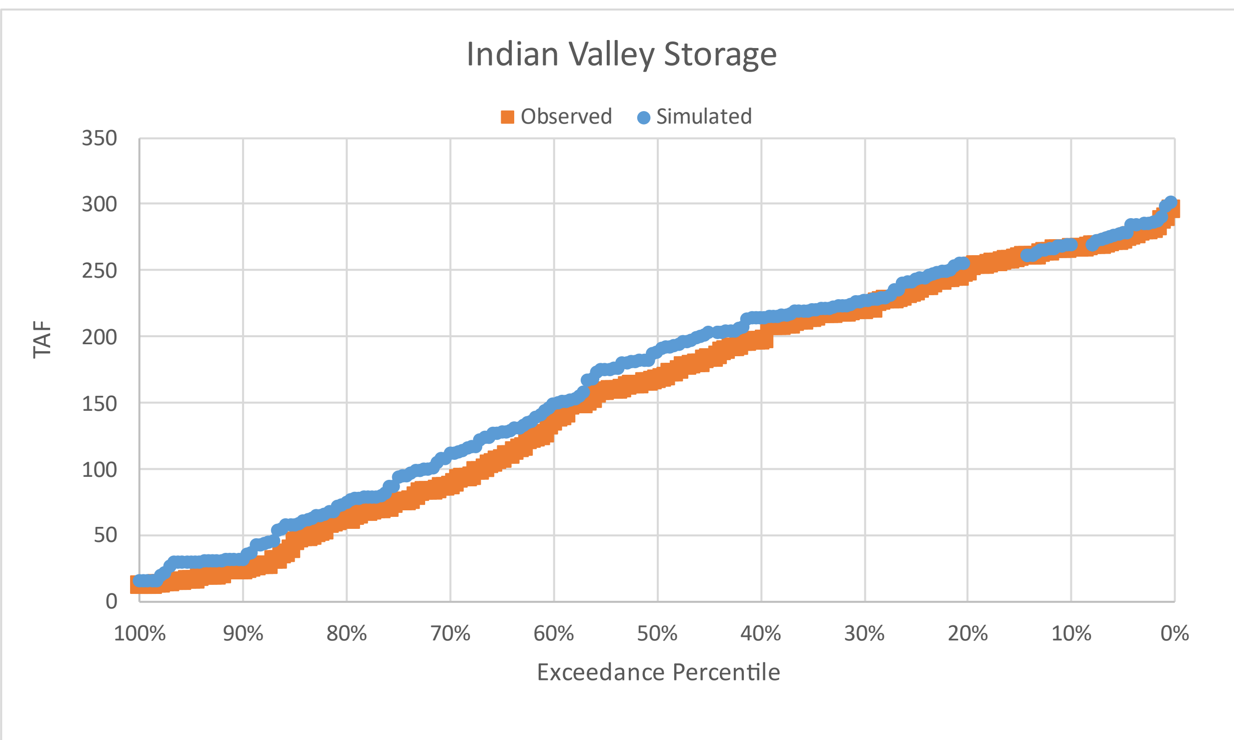


Figure A.9.1b. Indian Valley Storage, Exceedance

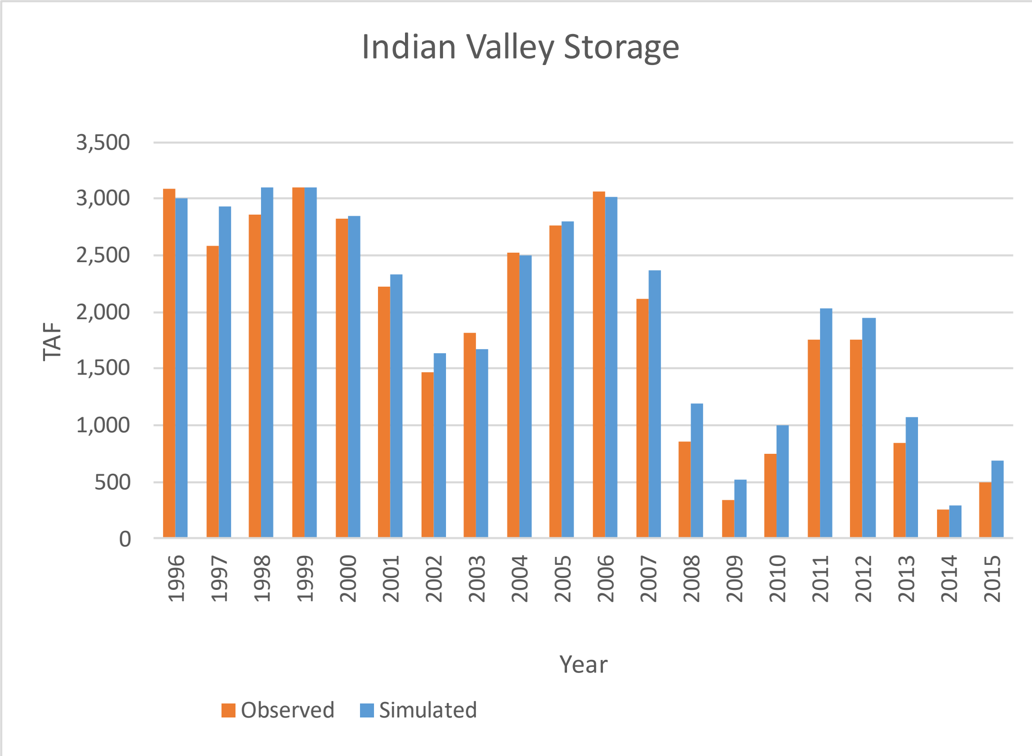


Figure A.9.1c. Indian Valley Storage, Annual 1996 to 2015

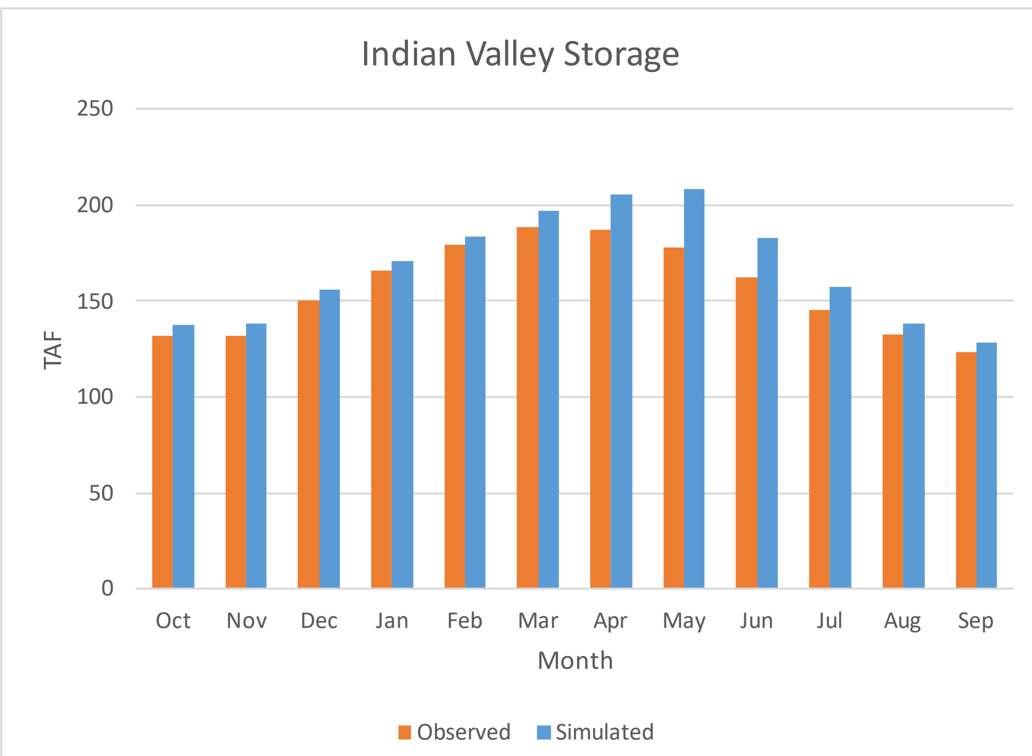


Figure A.9.1d. Indian Valley Storage, Average Monthly

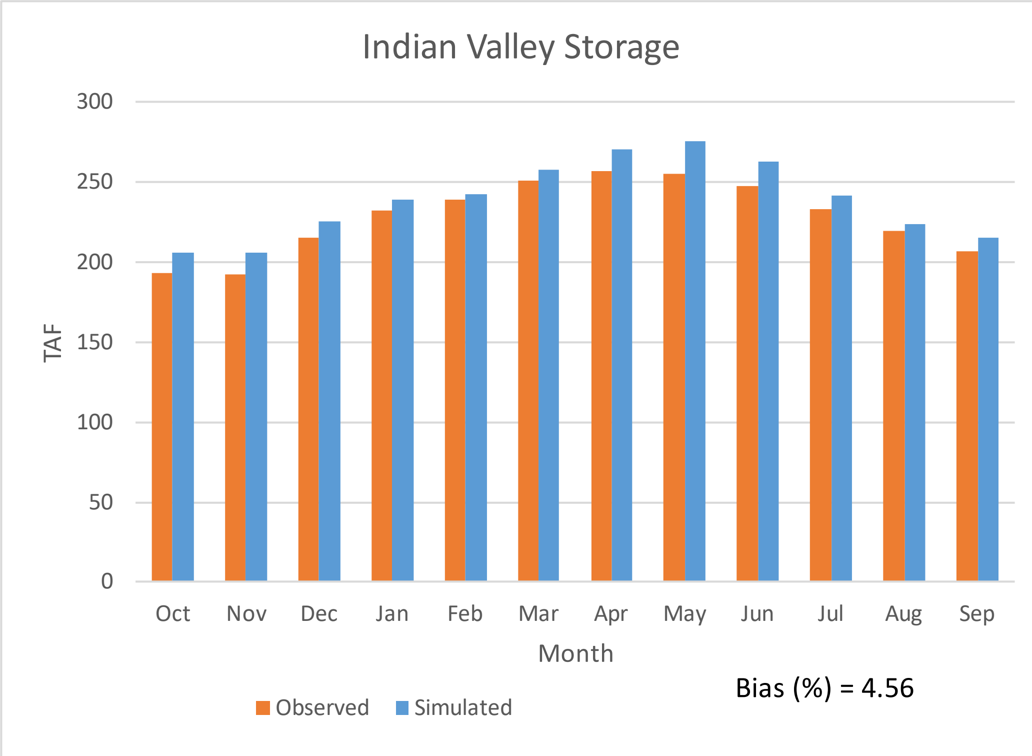


Figure A.9.1e. Indian Valley Storage, Average Monthly (Wet)

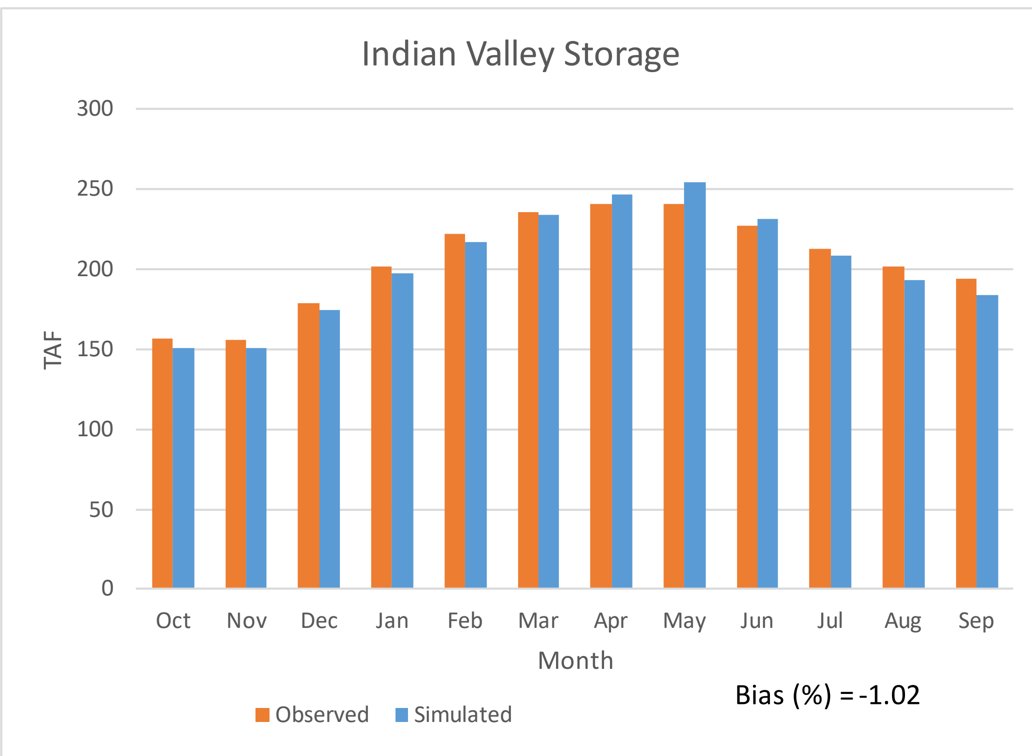


Figure A.9.1f. Indian Valley Storage, Average Monthly (Above Normal)

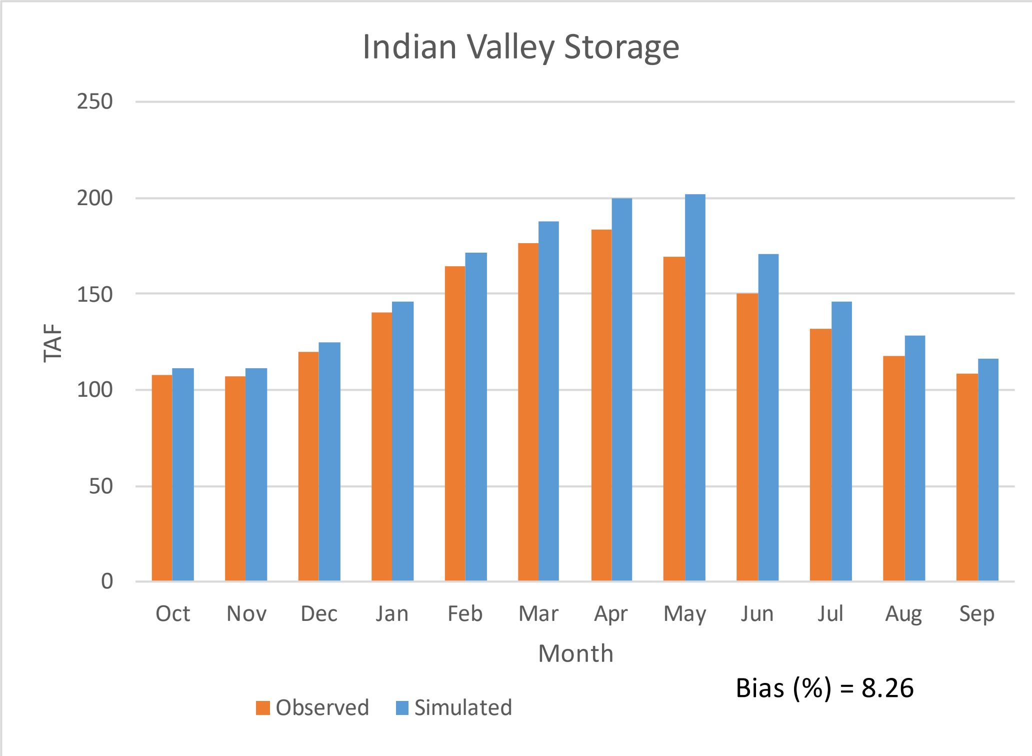


Figure A.9.1g. Indian Valley Storage, Average Monthly (Below Normal)

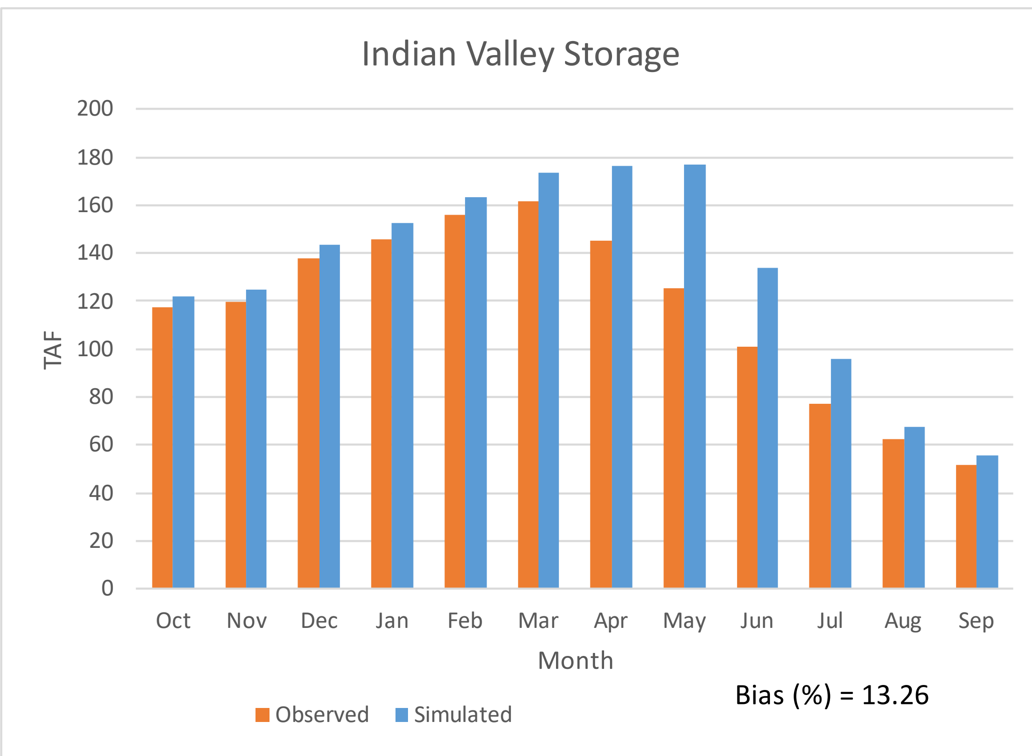


Figure A.9.1h. Indian Valley Storage, Average Monthly (Dry)

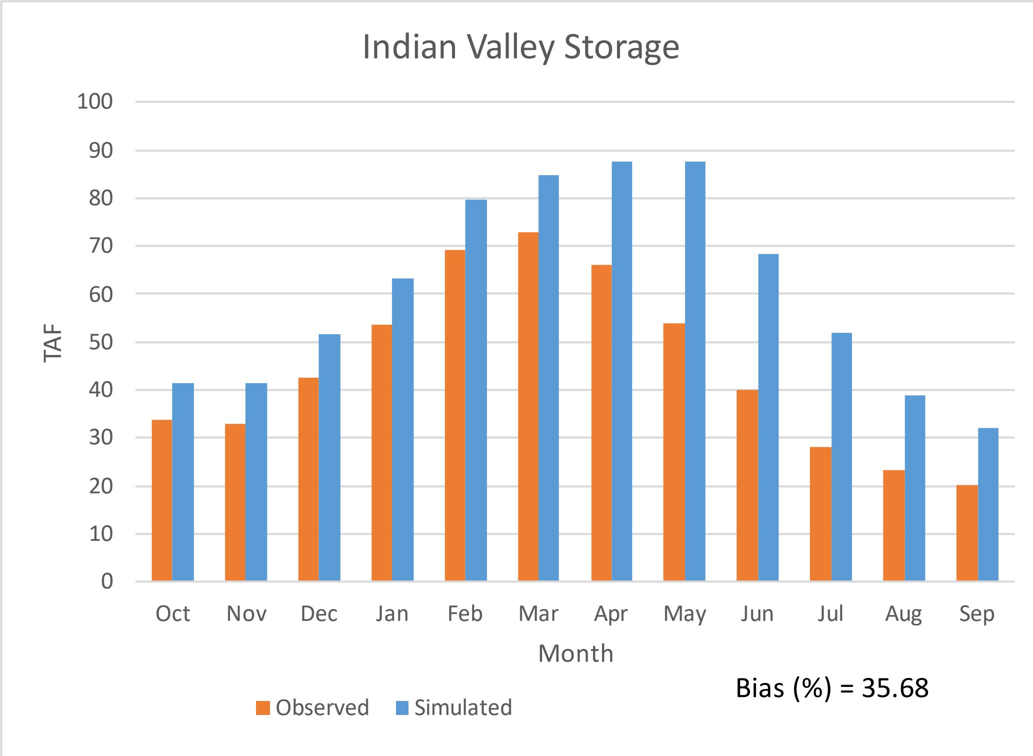


Figure A.9.1i. Indian Valley Storage, Average Monthly (Critical)

A.9.2 Clear Lake Storage

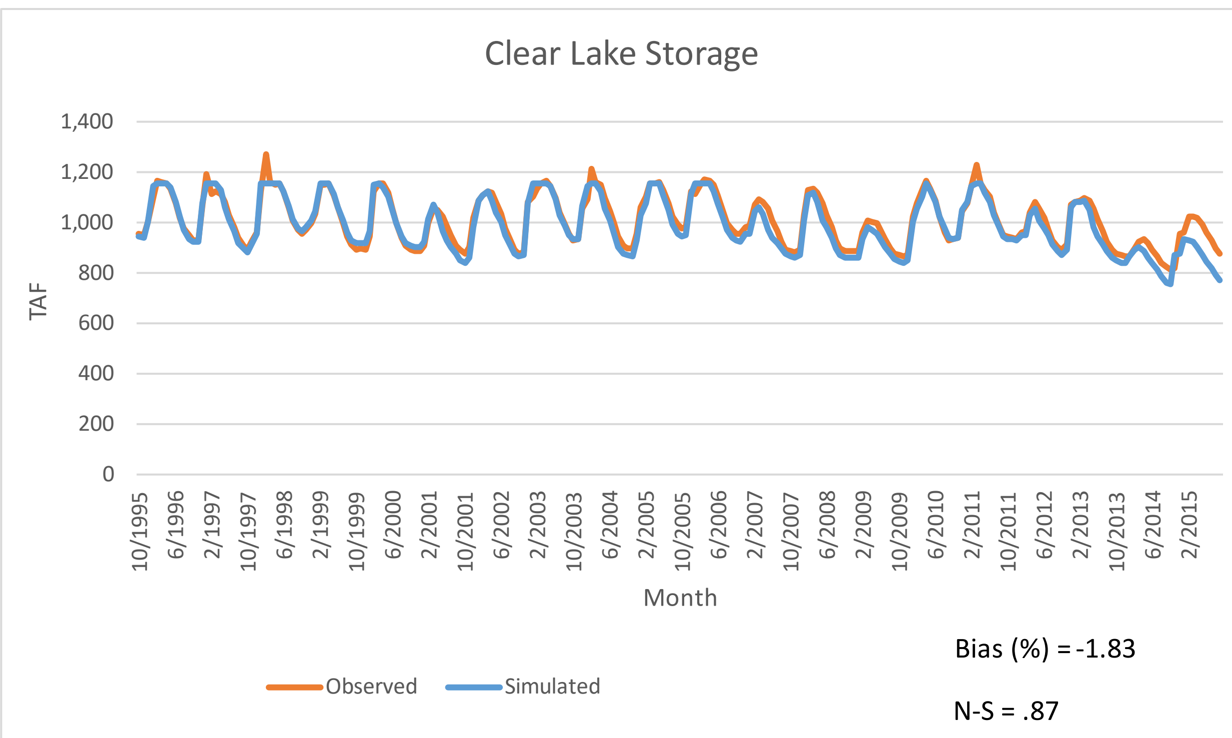


Figure A.9.2a. Clear Lake Storage, Monthly 1996 to 2015

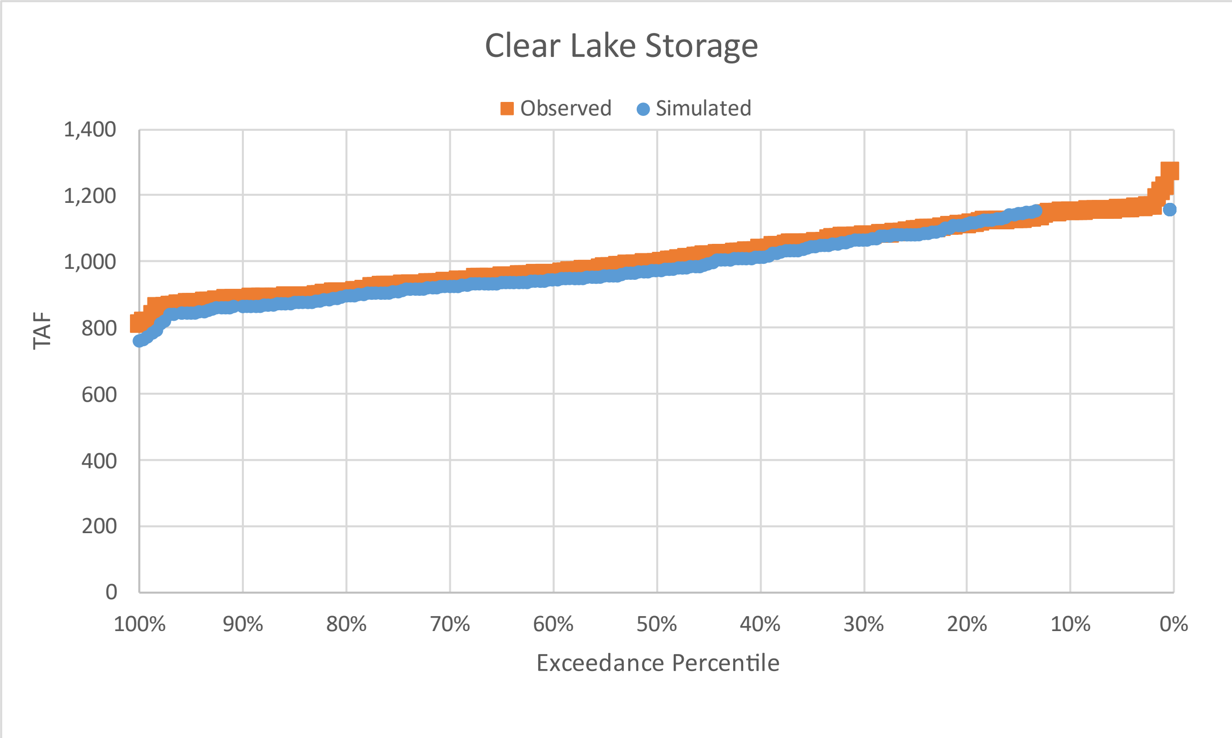


Figure A.9.2b. Clear Lake Storage, Exceedance

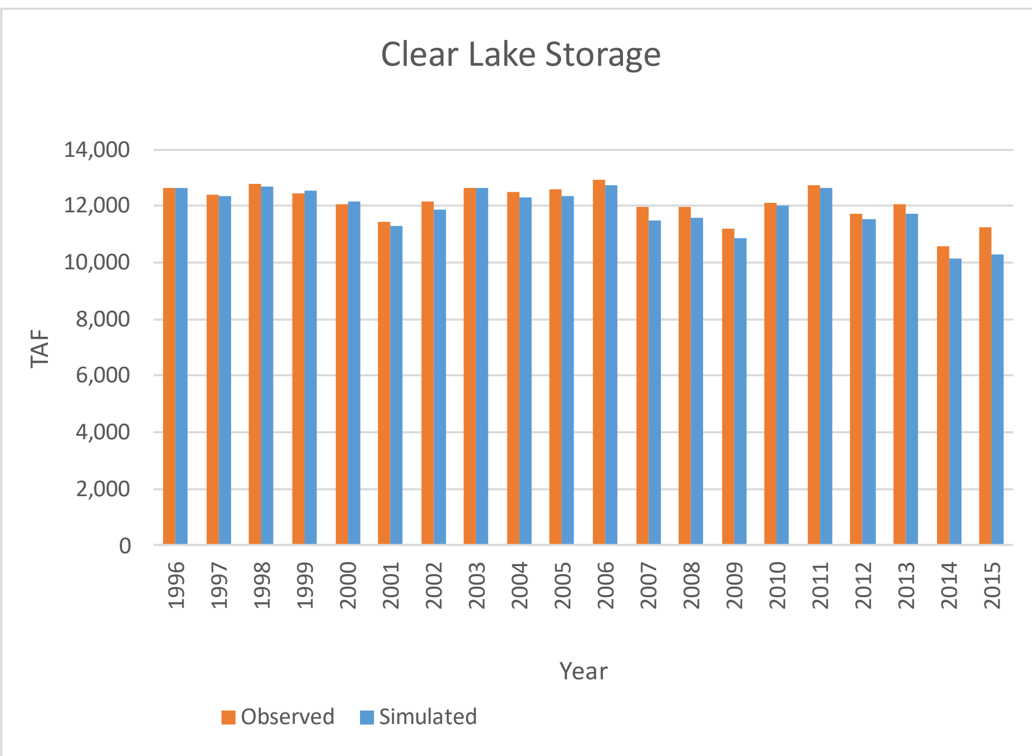


Figure A.9.2c. Clear Lake Storage, Annual 1996 to 2015

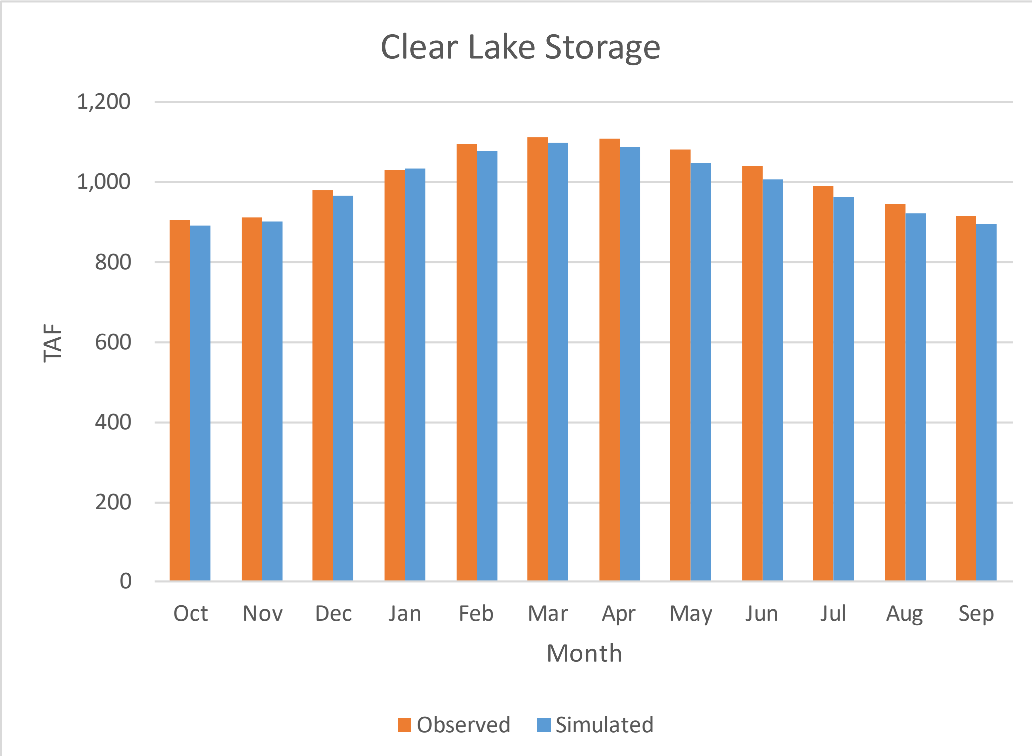


Figure A.9.2d. Clear Lake Storage, Average Monthly

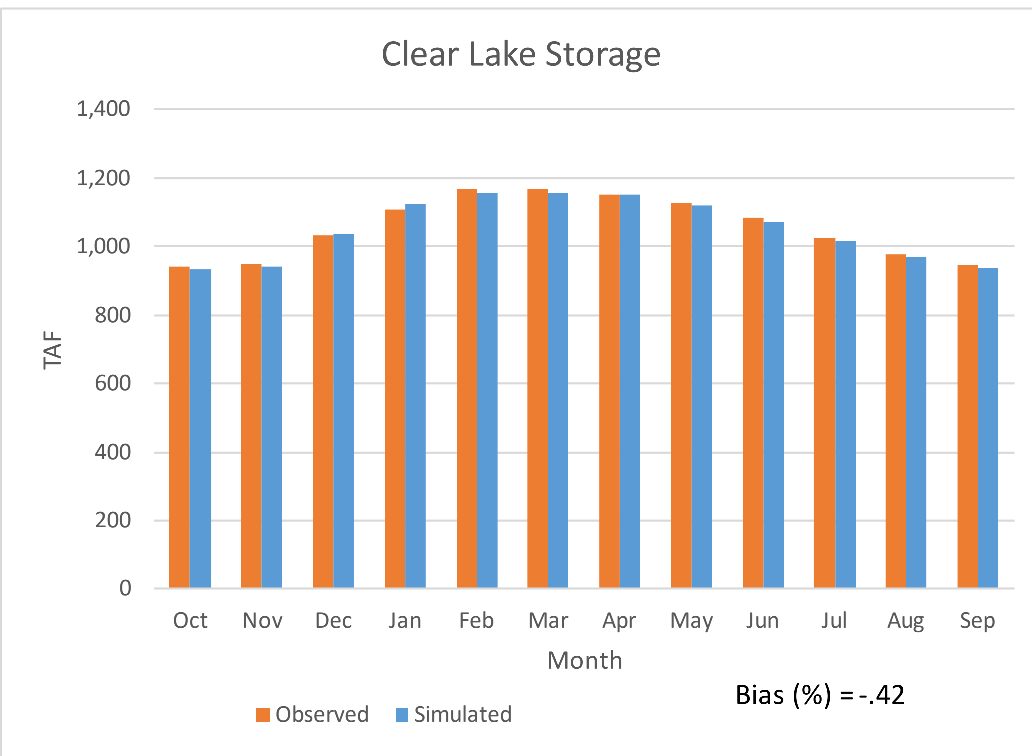


Figure A.9.2e. Clear Lake Storage, Average Monthly (Wet)

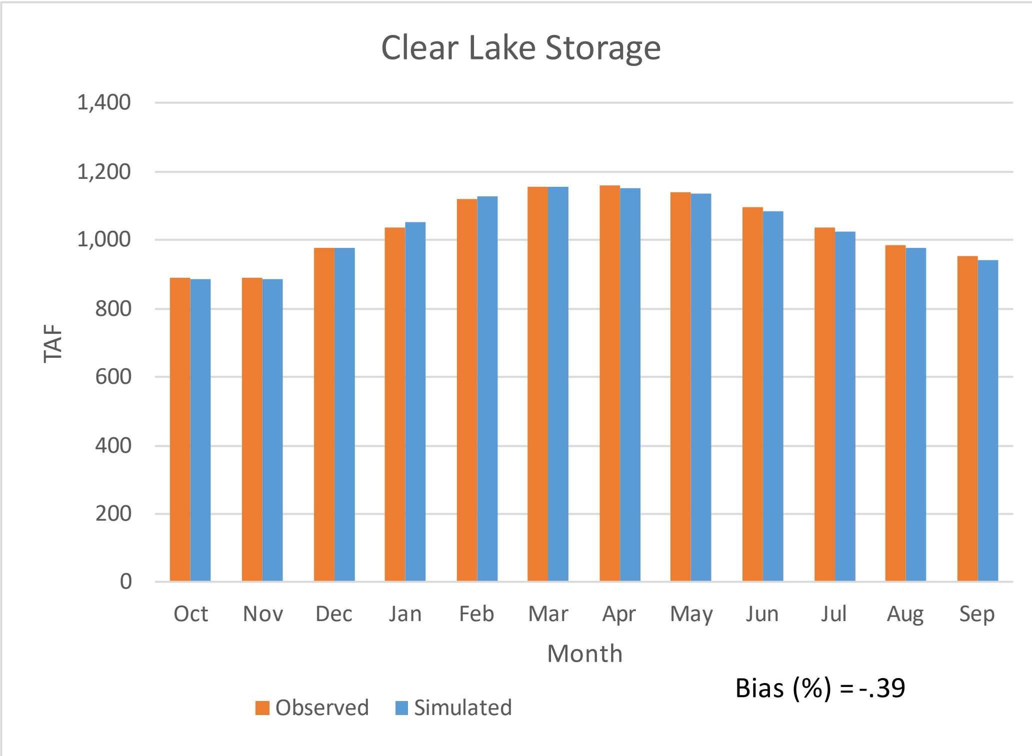


Figure A.9.2f. Clear Lake Storage, Average Monthly (Above Normal)

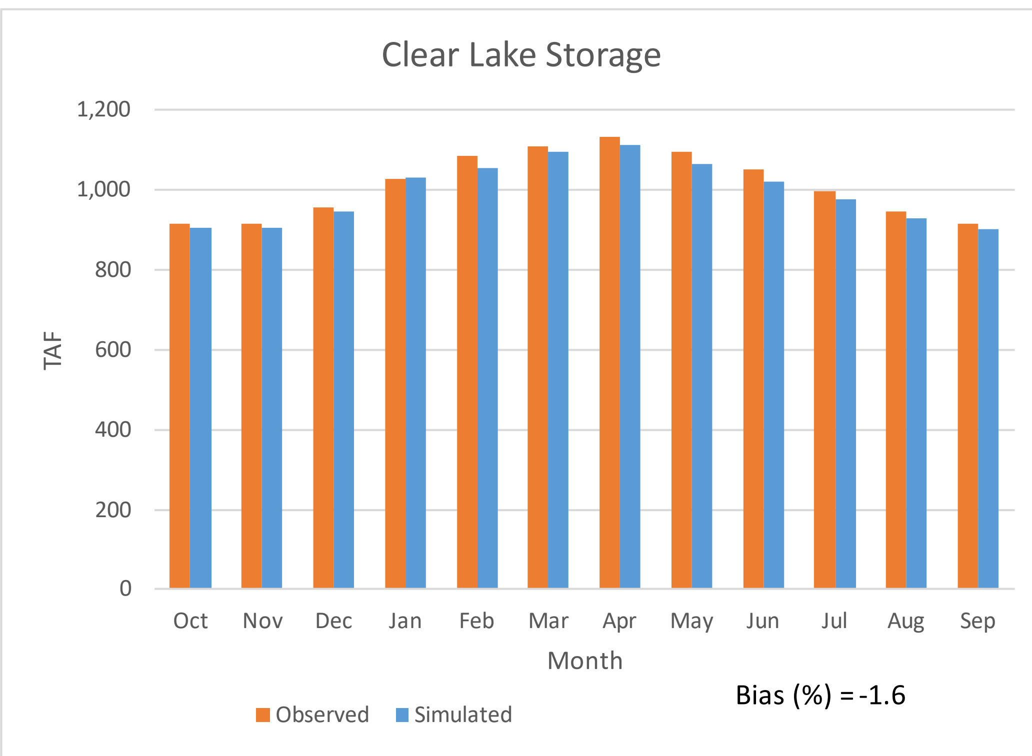


Figure A.9.2g. Clear Lake Storage, Average Monthly (Below Normal)

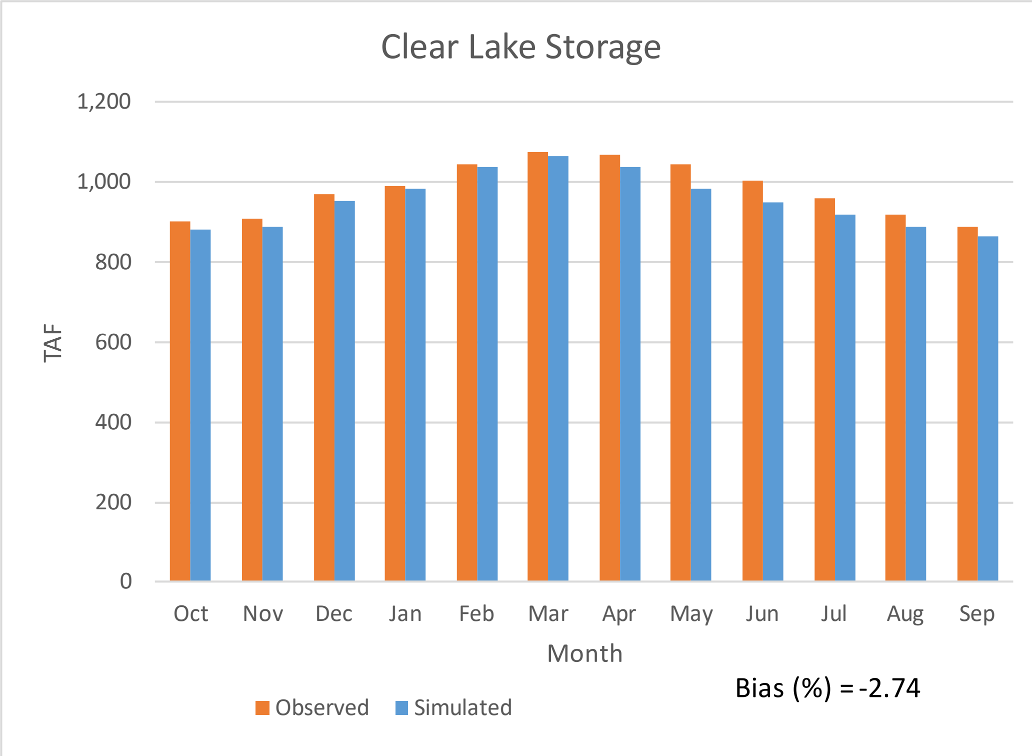


Figure A.9.2h. Clear Lake Storage, Average Monthly (Dry)

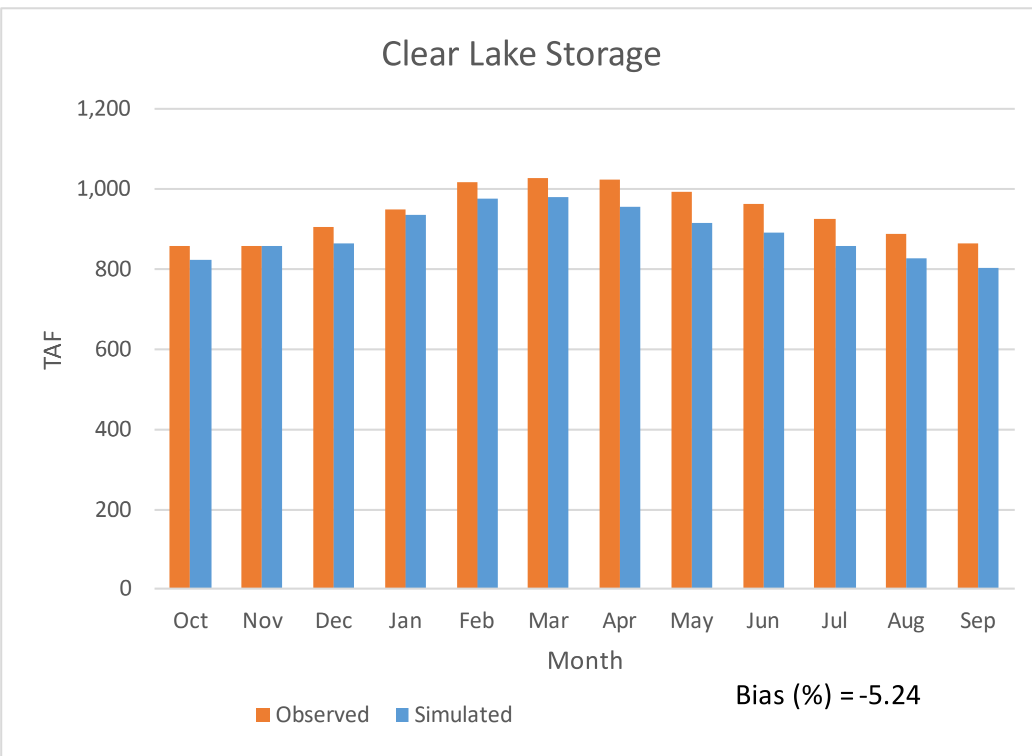


Figure A.9.2i. Clear Lake Storage, Average Monthly (Critical)

A.9.3 Lake Berryessa Storage

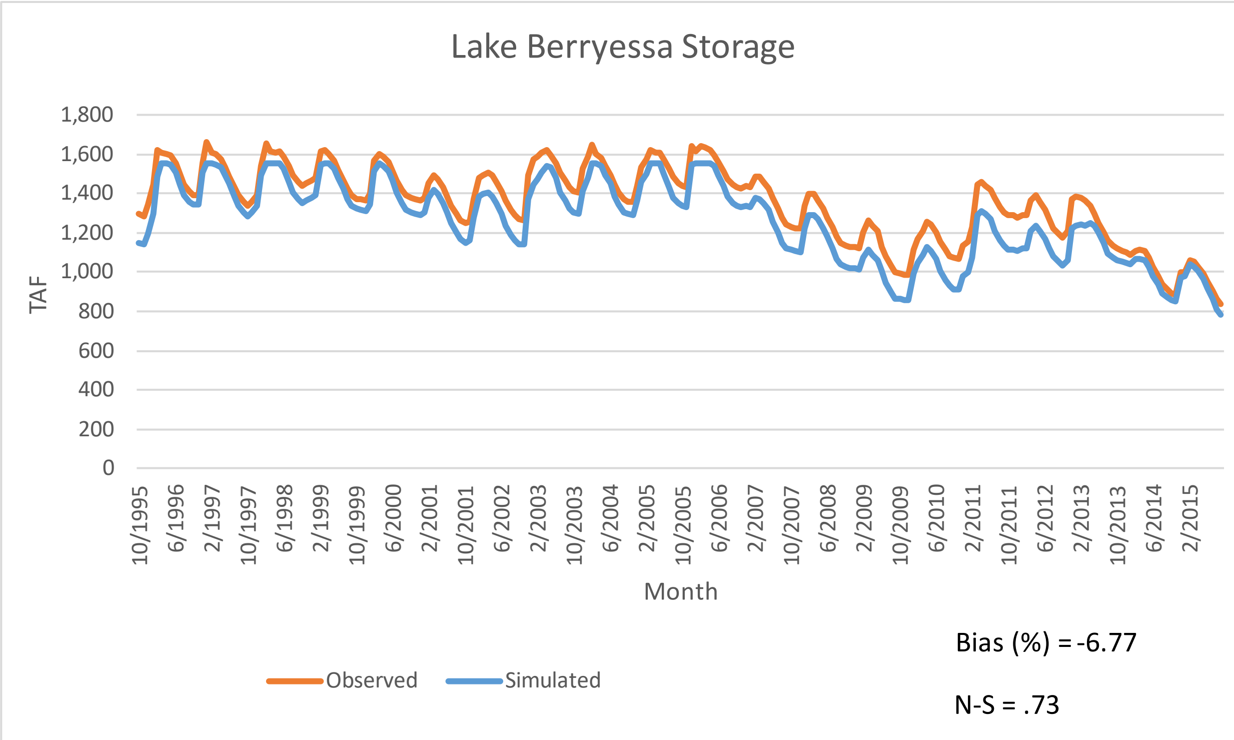


Figure A.9.3a. Lake Berryessa Storage, Monthly 1996 to 2015

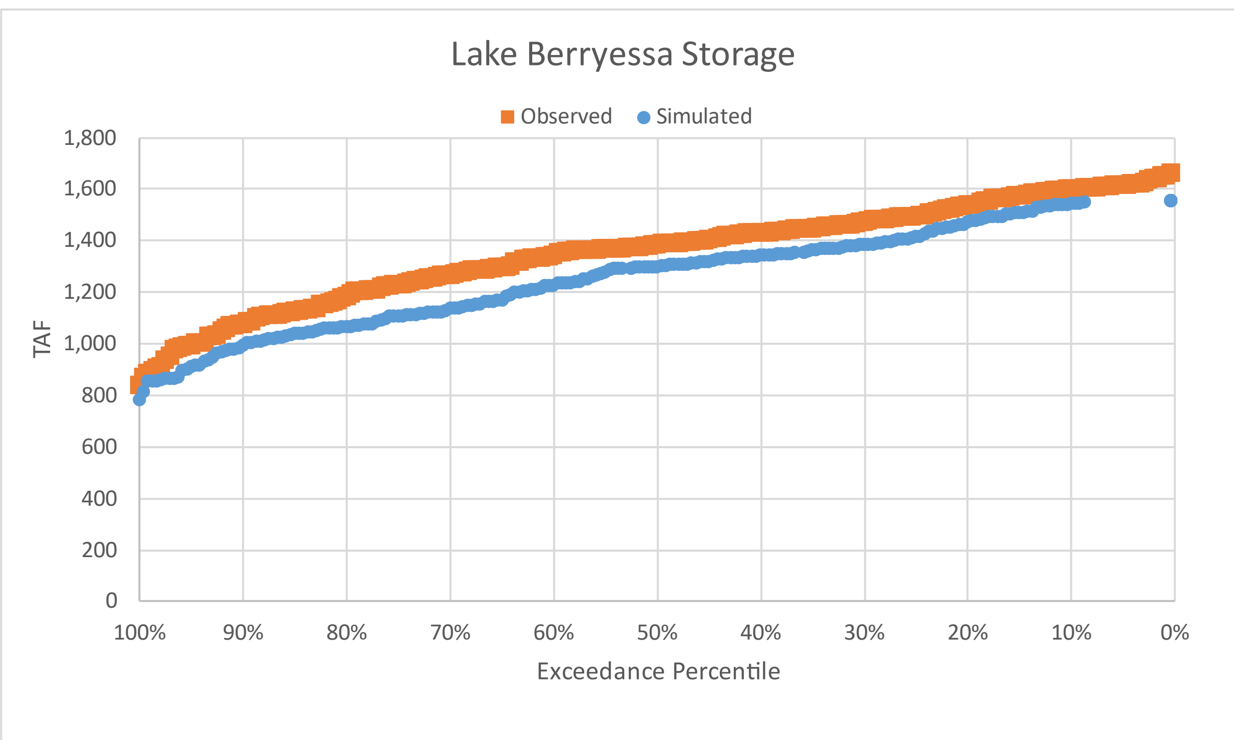


Figure A.9.3b. Lake Berryessa Storage, Exceedance

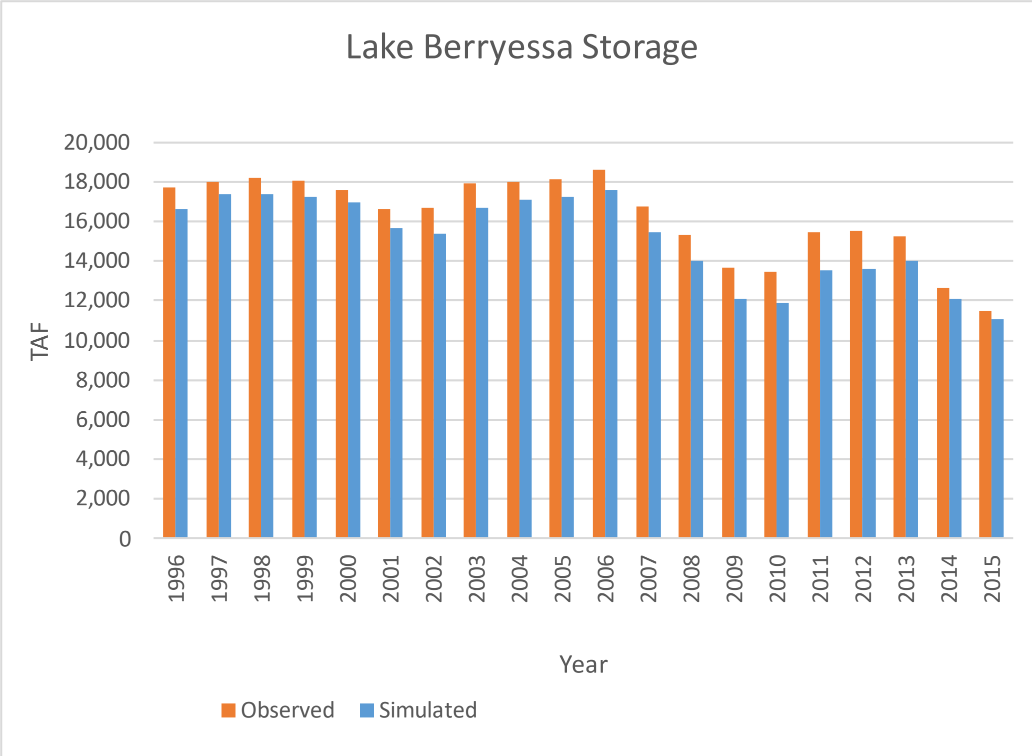


Figure A.9.3c. Lake Berryessa Storage, Annual 1996 to 2015

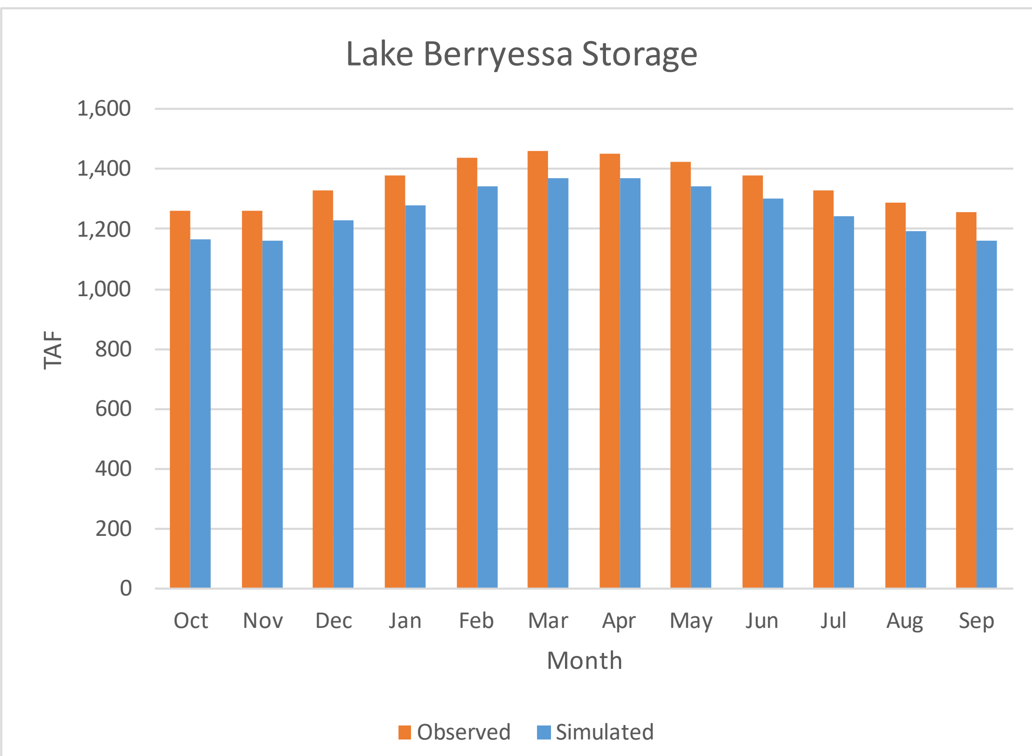


Figure A.9.3d. Lake Berryessa Storage, Average Monthly

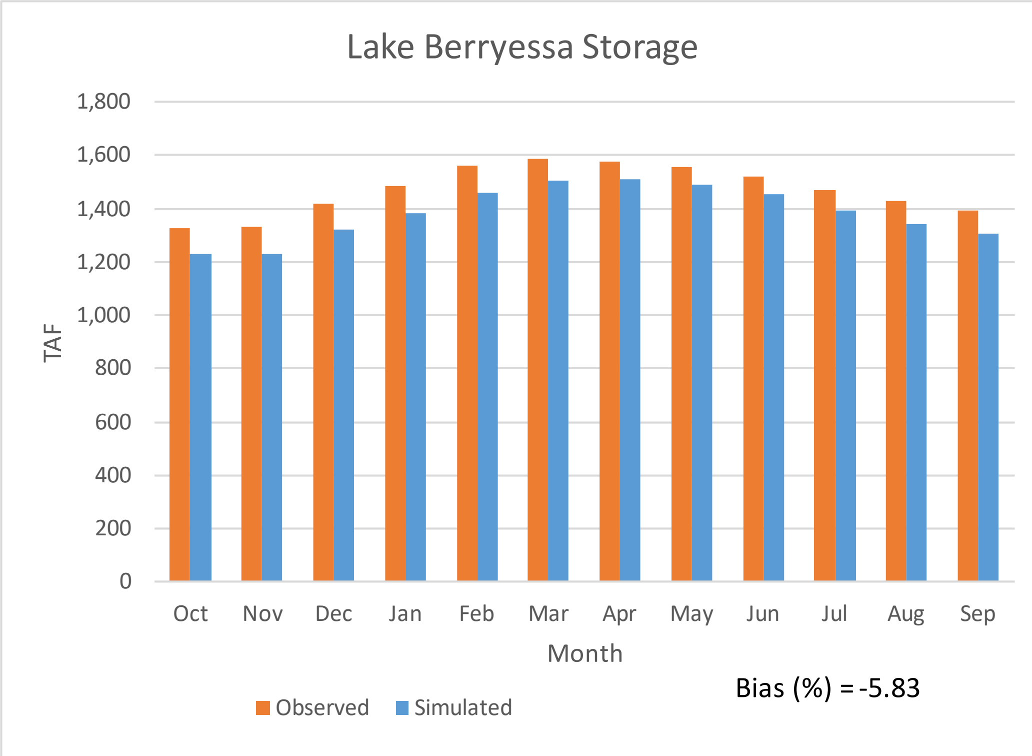


Figure A.9.3e. Lake Berryessa Storage, Average Monthly (Wet)

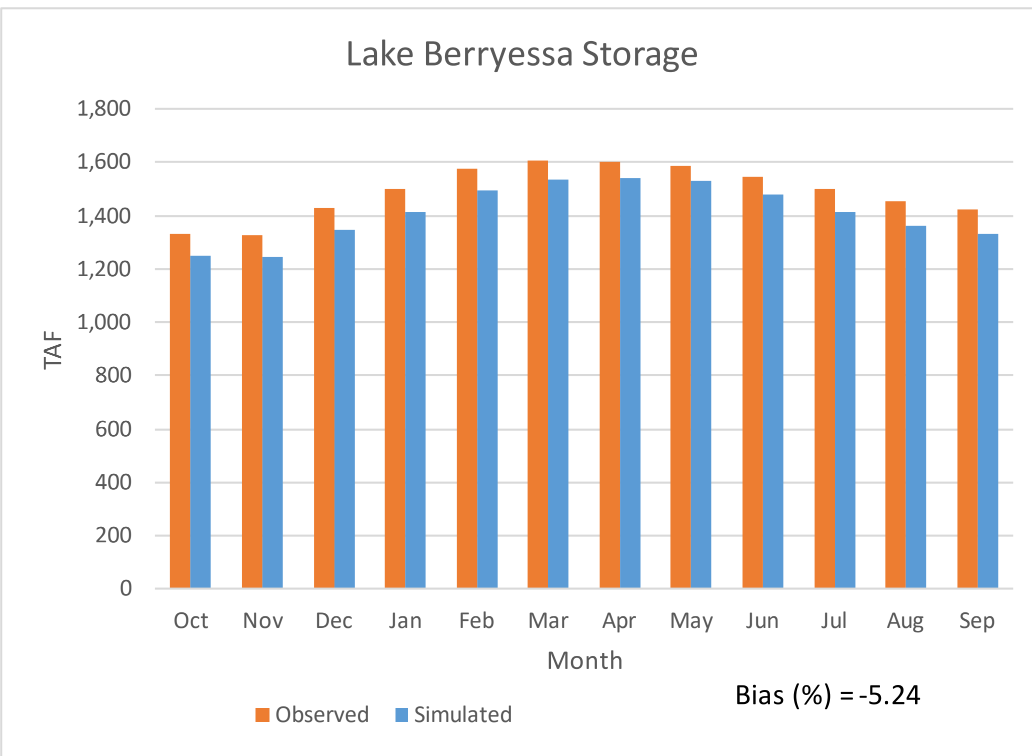


Figure A.9.3f. Lake Berryessa Storage, Average Monthly (Above Normal)

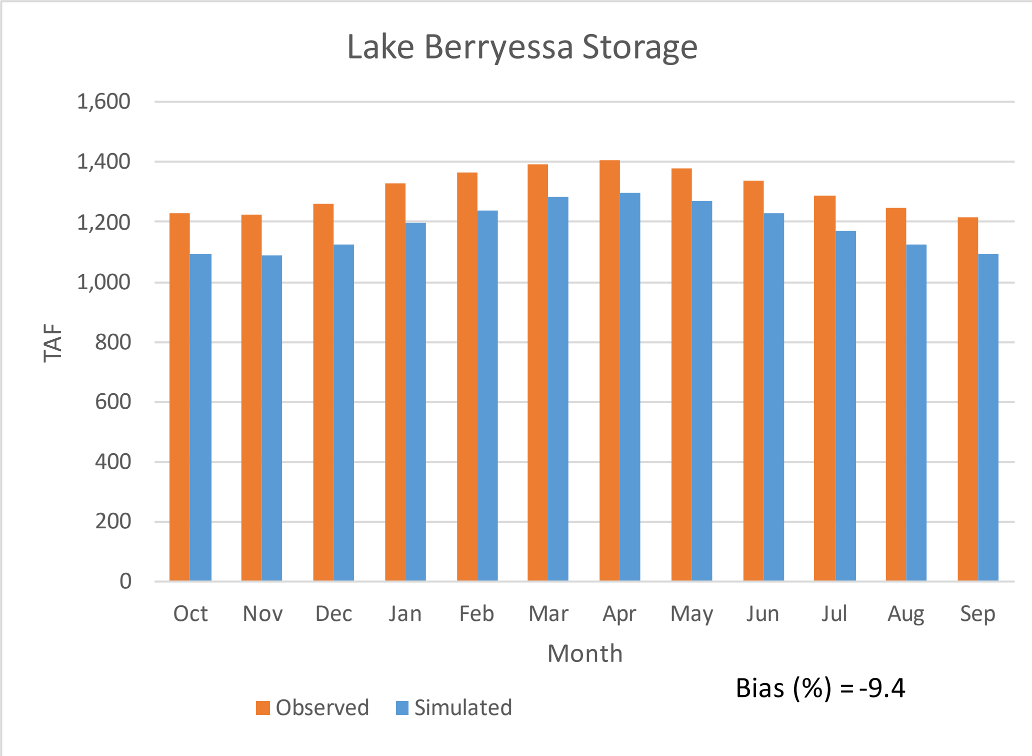


Figure A.9.3g. Lake Berryessa Storage, Average Monthly (Below Normal)

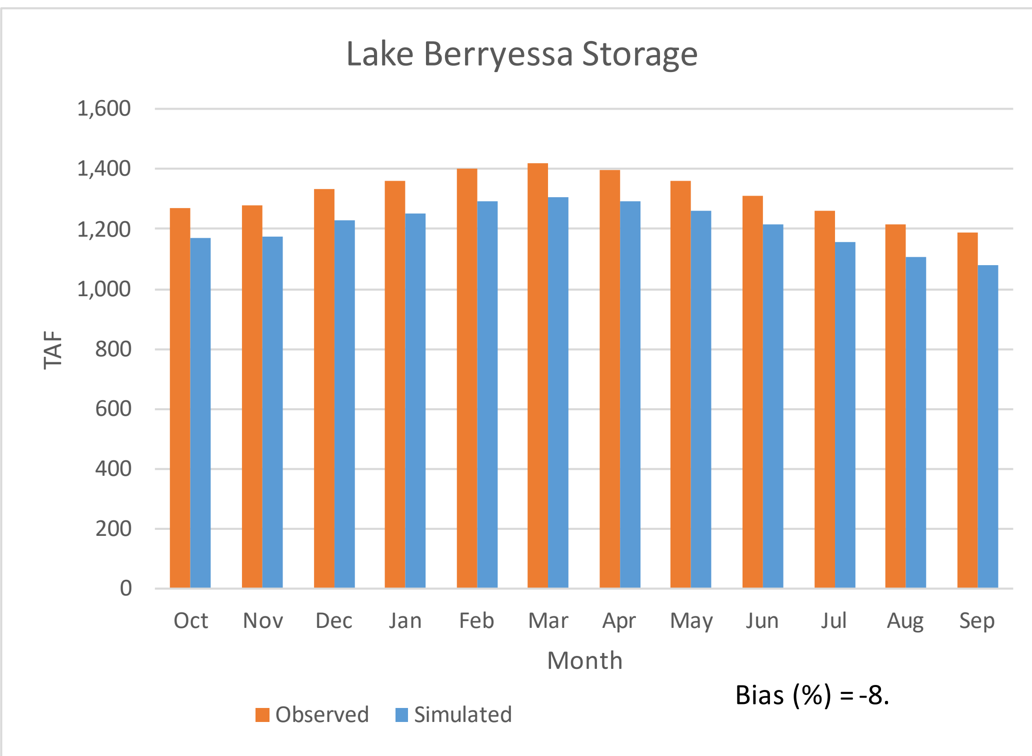


Figure A.9.3h. Lake Berryessa Storage, Average Monthly (Dry)

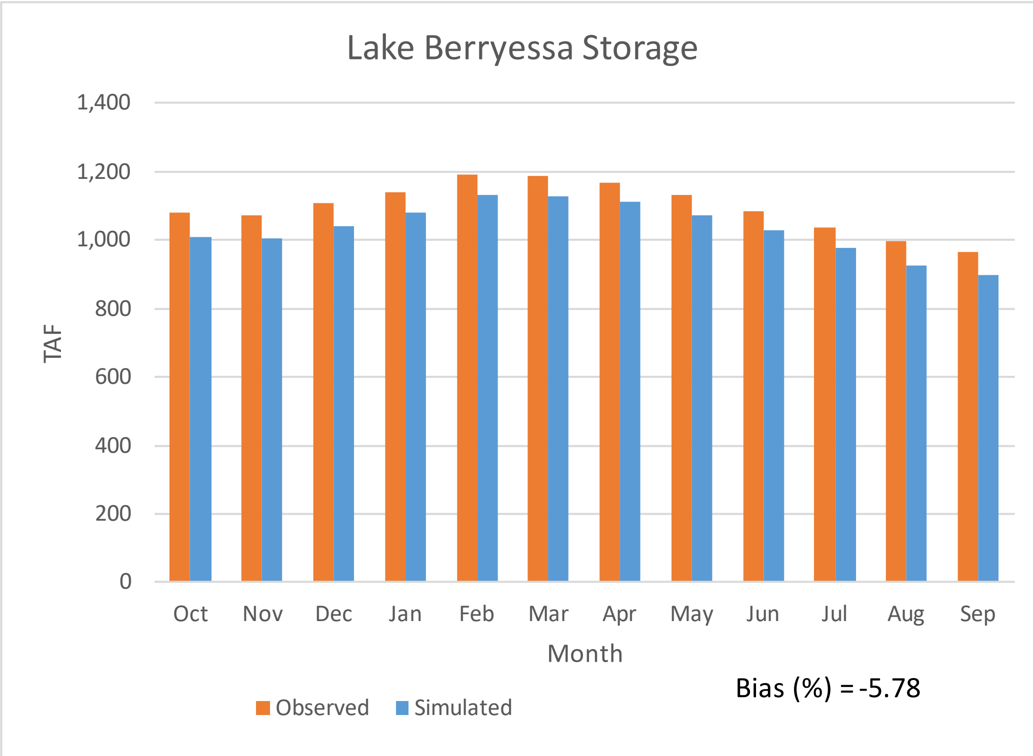


Figure A.9.3i. Lake Berryessa Storage, Average Monthly (Critical)

A.9.4 New Bullards Bar Storage

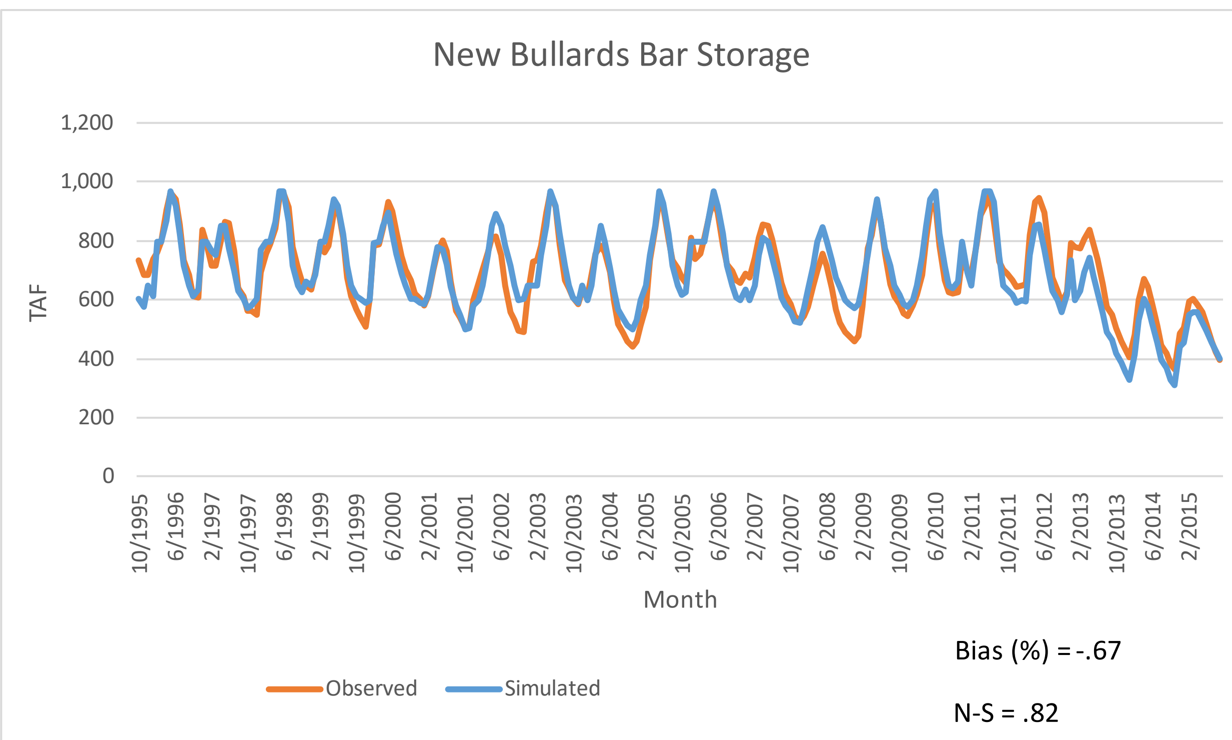


Figure A.9.4a. New Bullards Bar Storage, Monthly 1996 to 2015

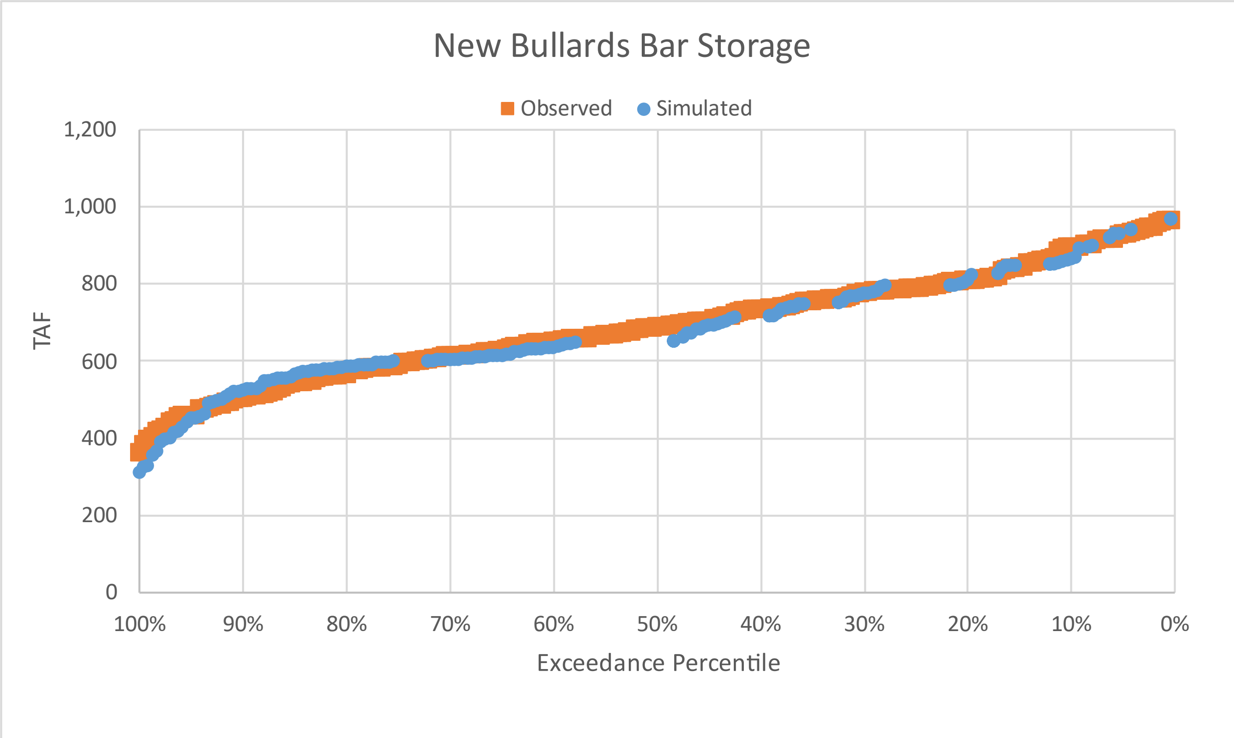


Figure A.9.4b. New Bullards Bar Storage, Exceedance

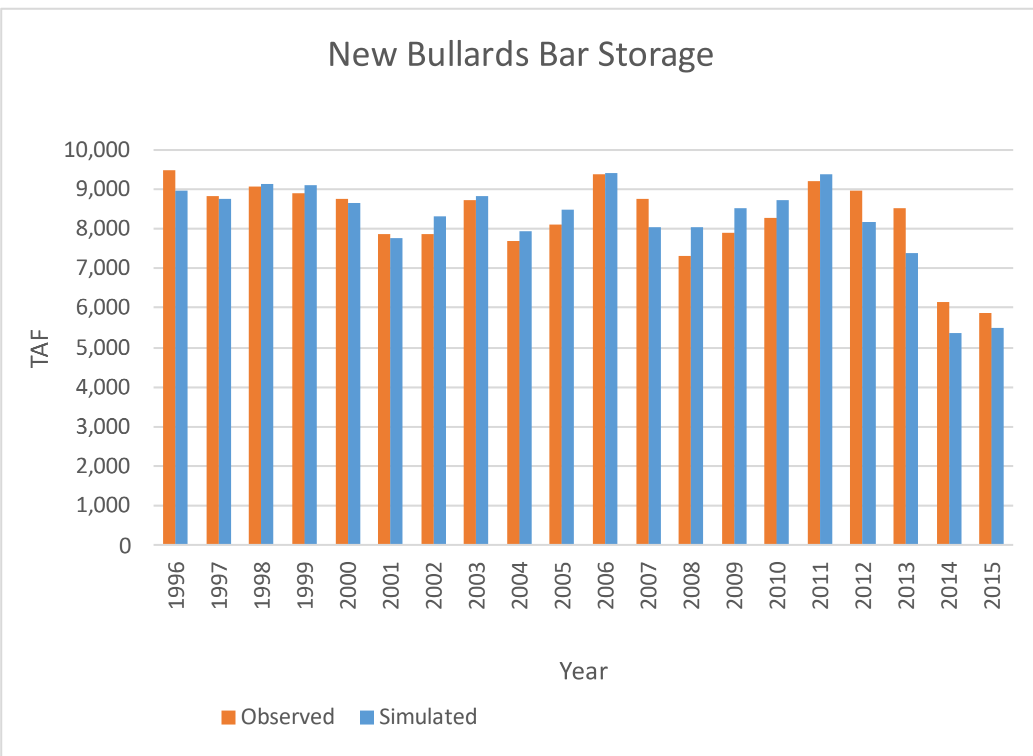


Figure A.9.4c. New Bullards Bar Storage, Annual 1996 to 2015

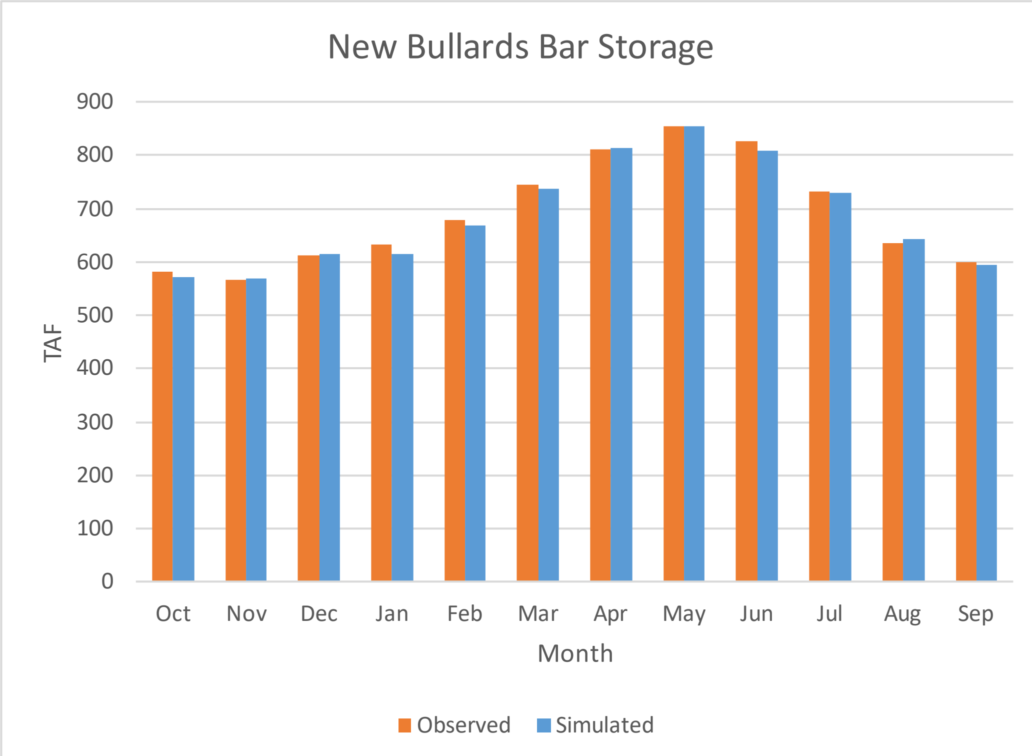


Figure A.9.4d. New Bullards Bar Storage, Average Monthly

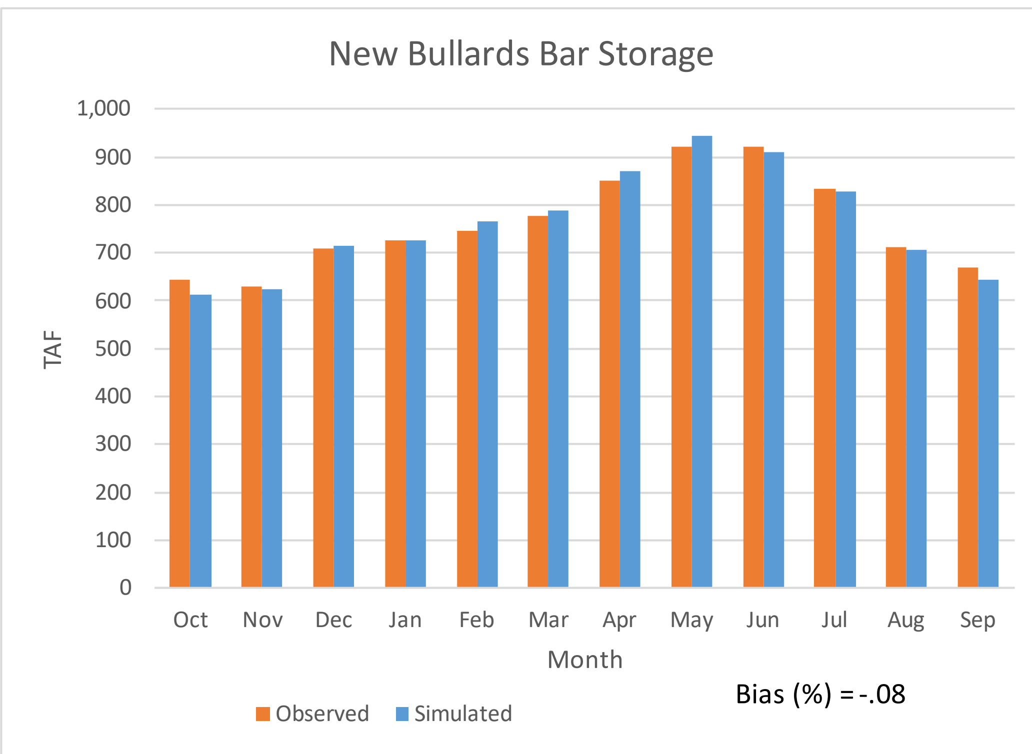


Figure A.9.4e. New Bullards Bar Storage, Average Monthly (Wet)

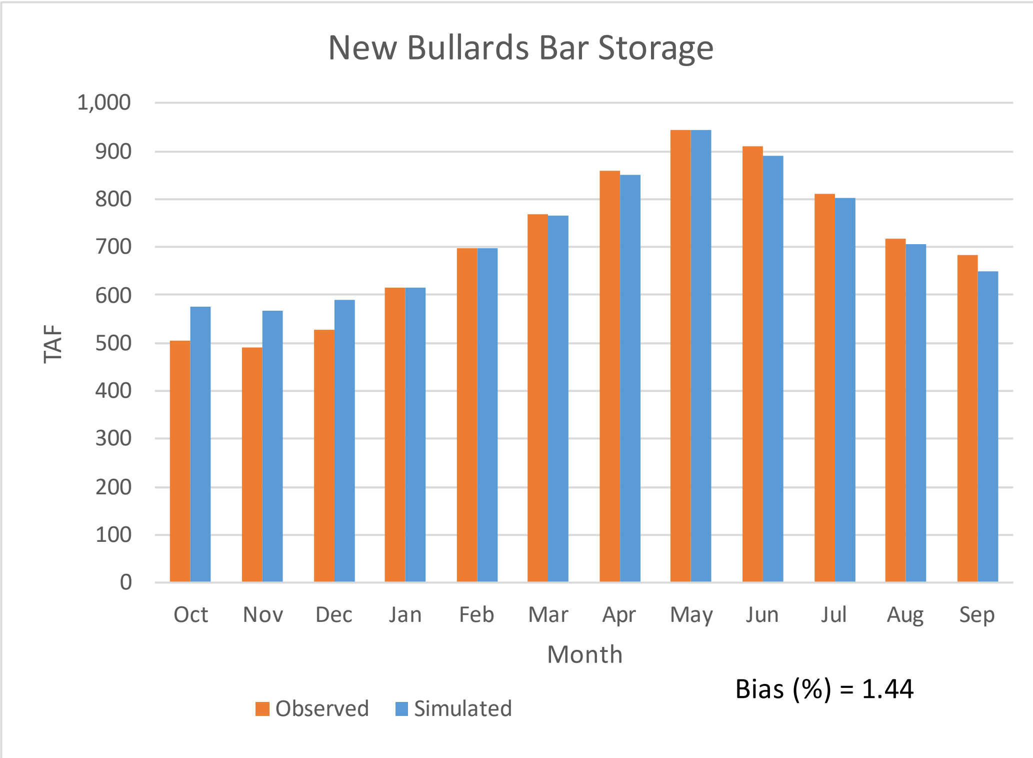


Figure A.9.4f. New Bullards Bar Storage, Average Monthly (Above Normal)

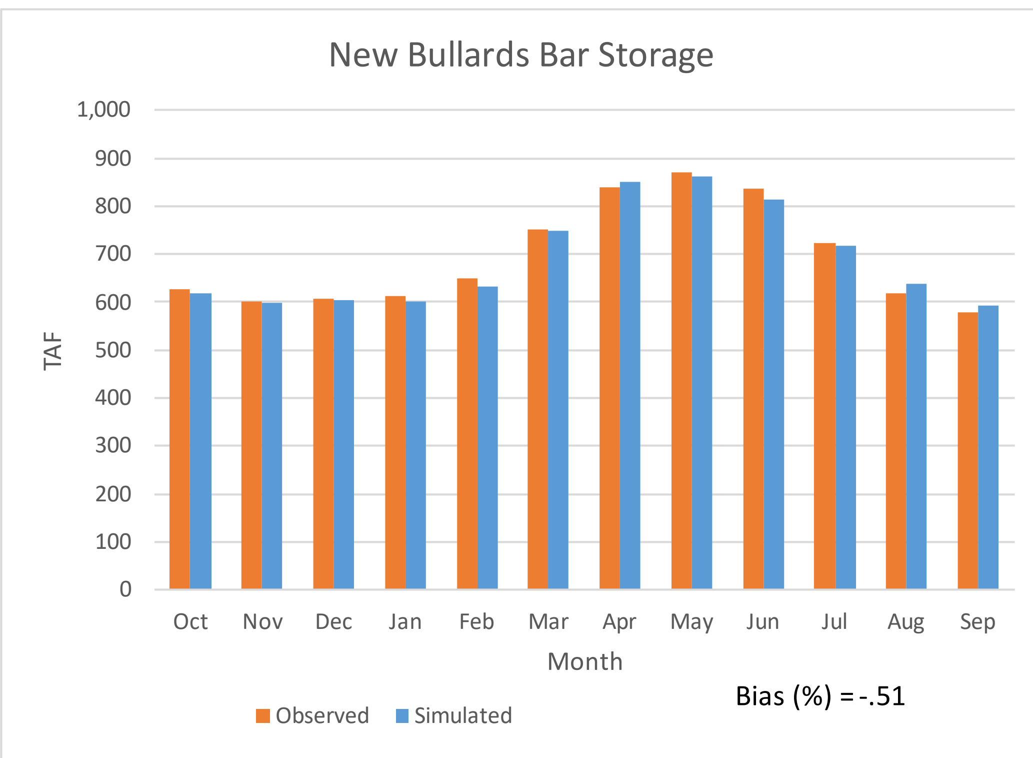


Figure A.9.4g. New Bullards Bar Storage, Average Monthly (Below Normal)

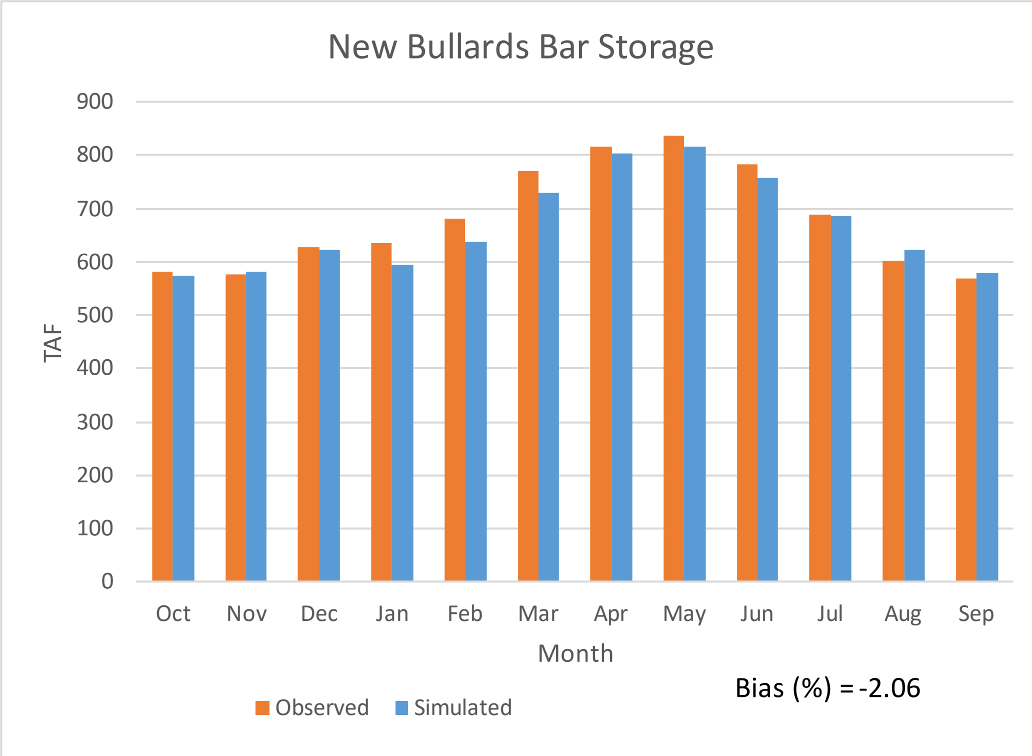


Figure A.9.4h. New Bullards Bar Storage, Average Monthly (Dry)

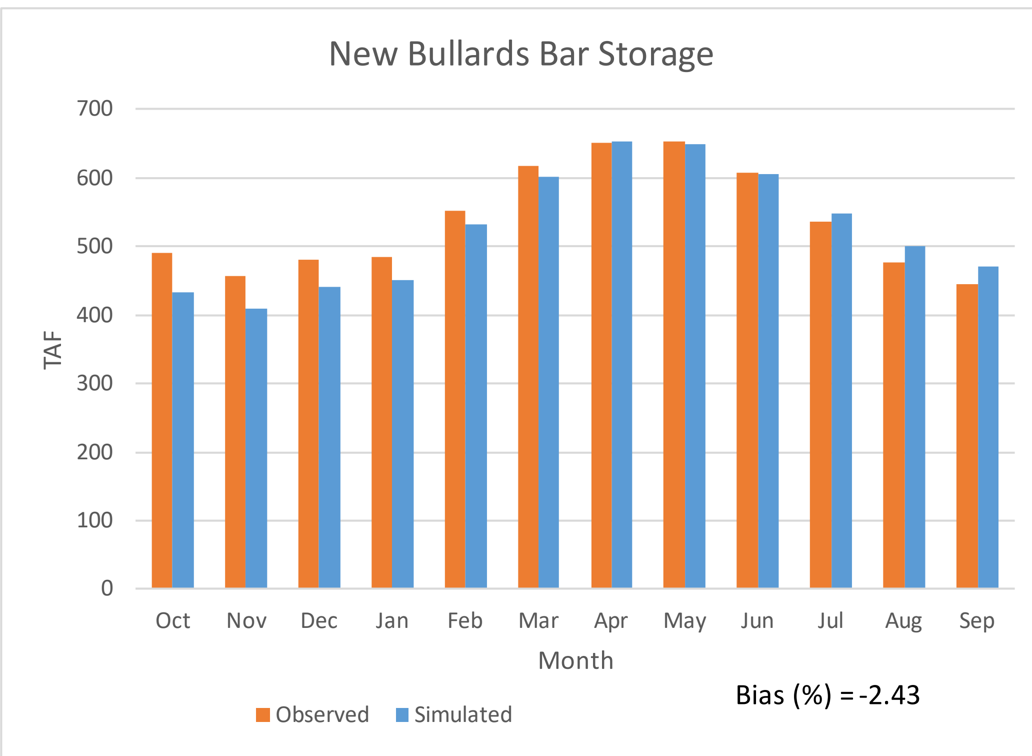


Figure A.9.4i. New Bullards Bar Storage, Average Monthly (Critical)

A.9.5 Camp Far West Storage

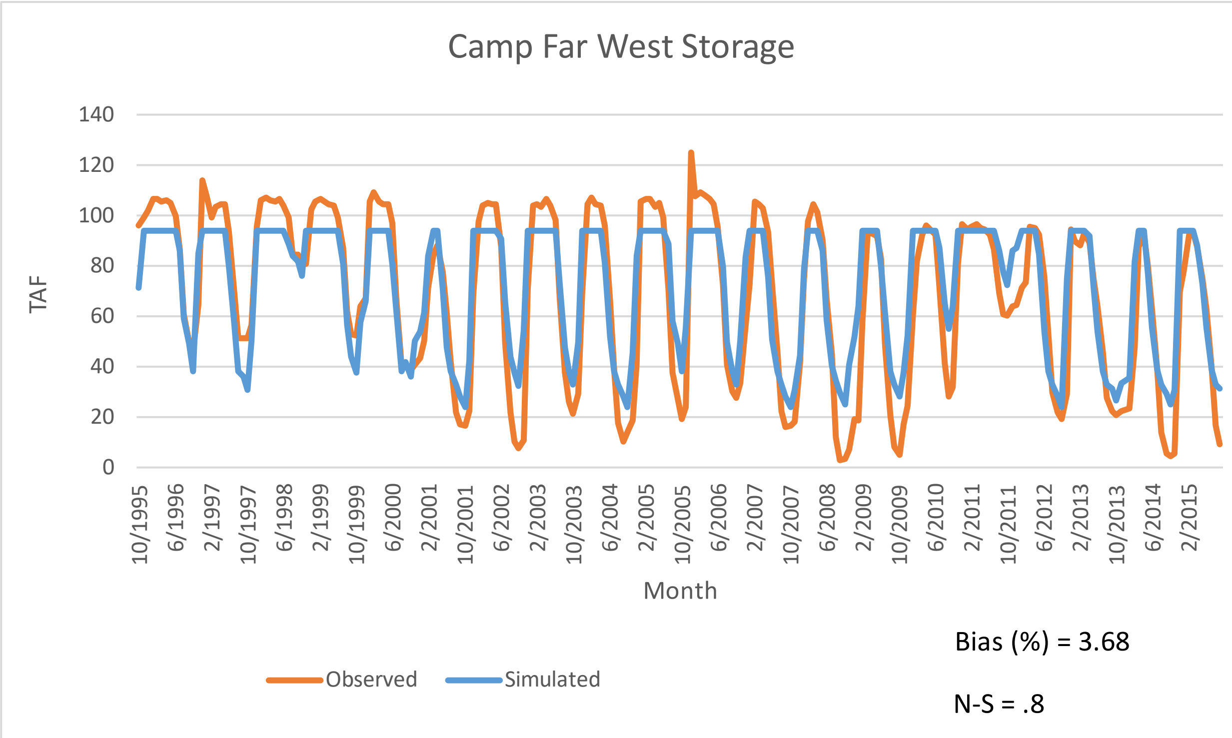


Figure A.9.5a. Camp Far West Storage, Monthly 1996 to 2015

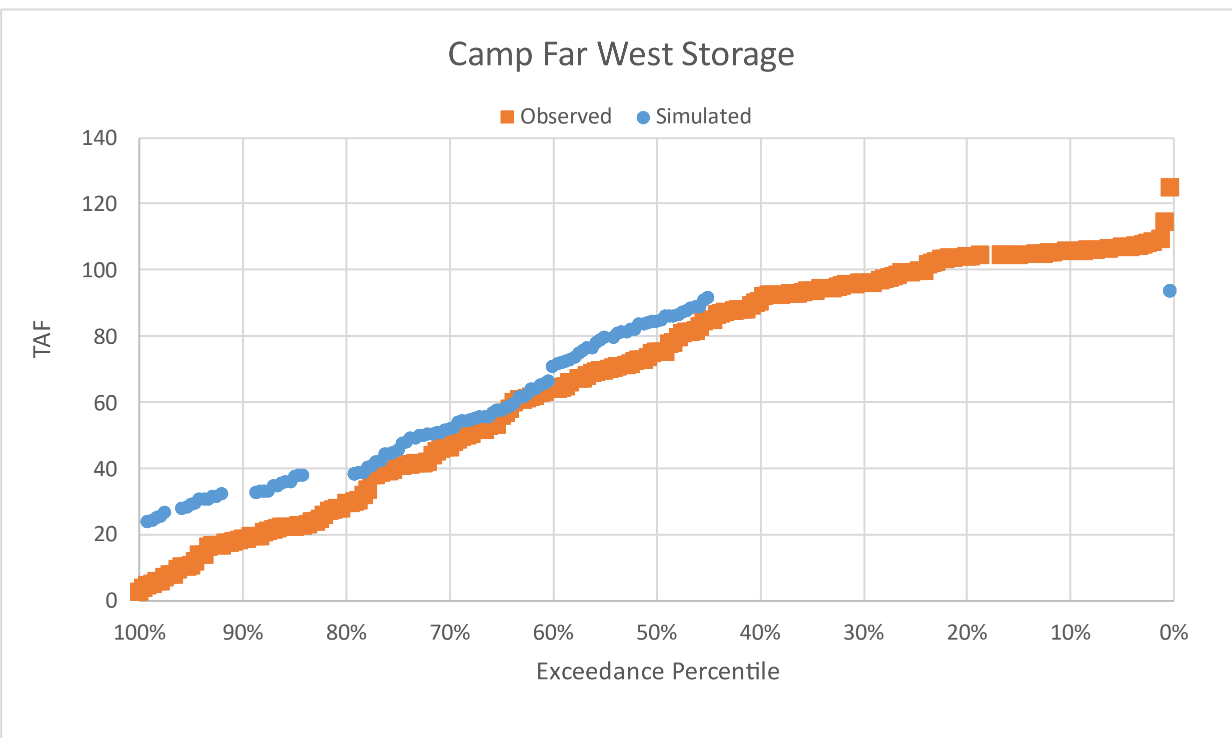


Figure A.9.5b. Camp Far West Storage, Exceedance

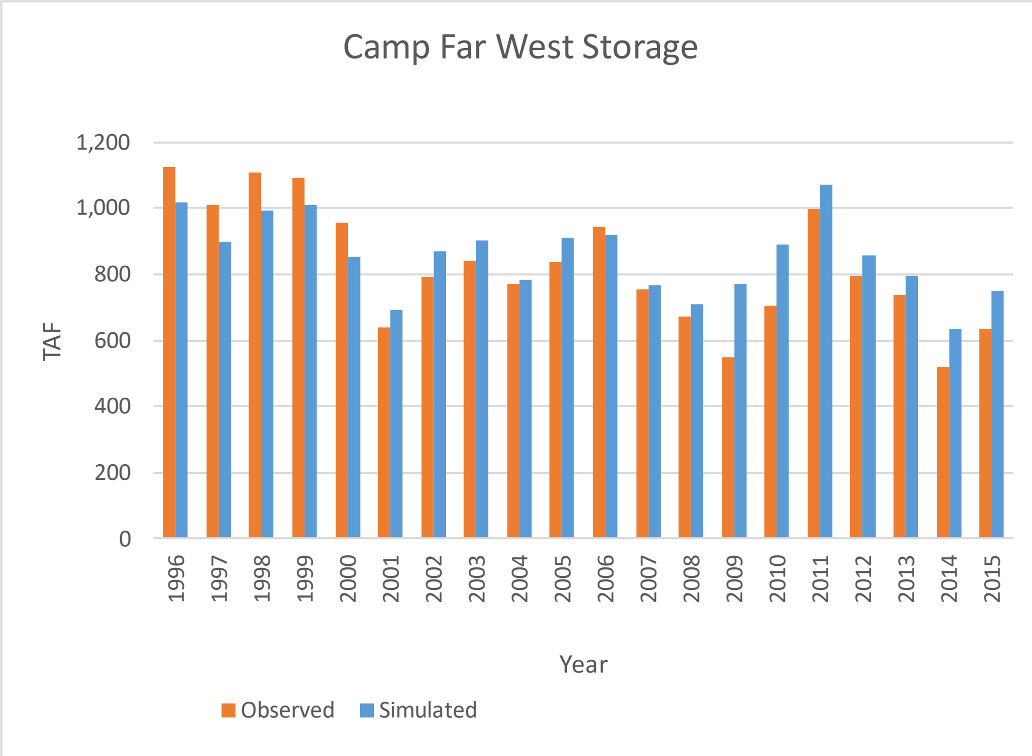


Figure A.9.5c. Camp Far West Storage, Annual 1996 to 2015

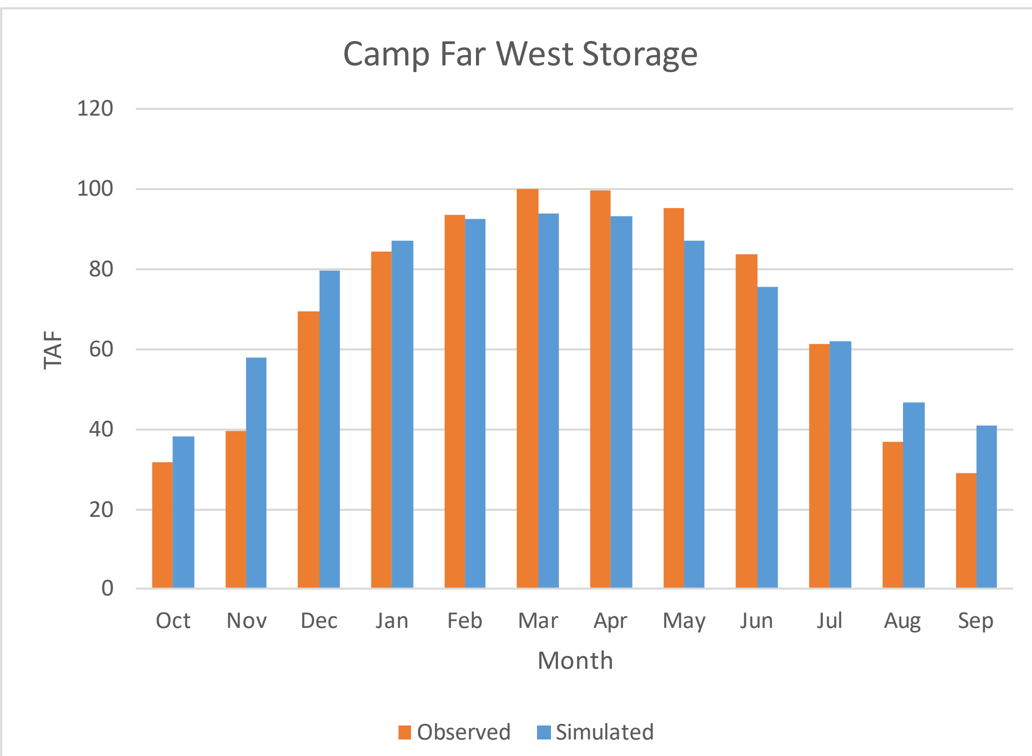


Figure A.9.5d. Camp Far West Storage, Average Monthly

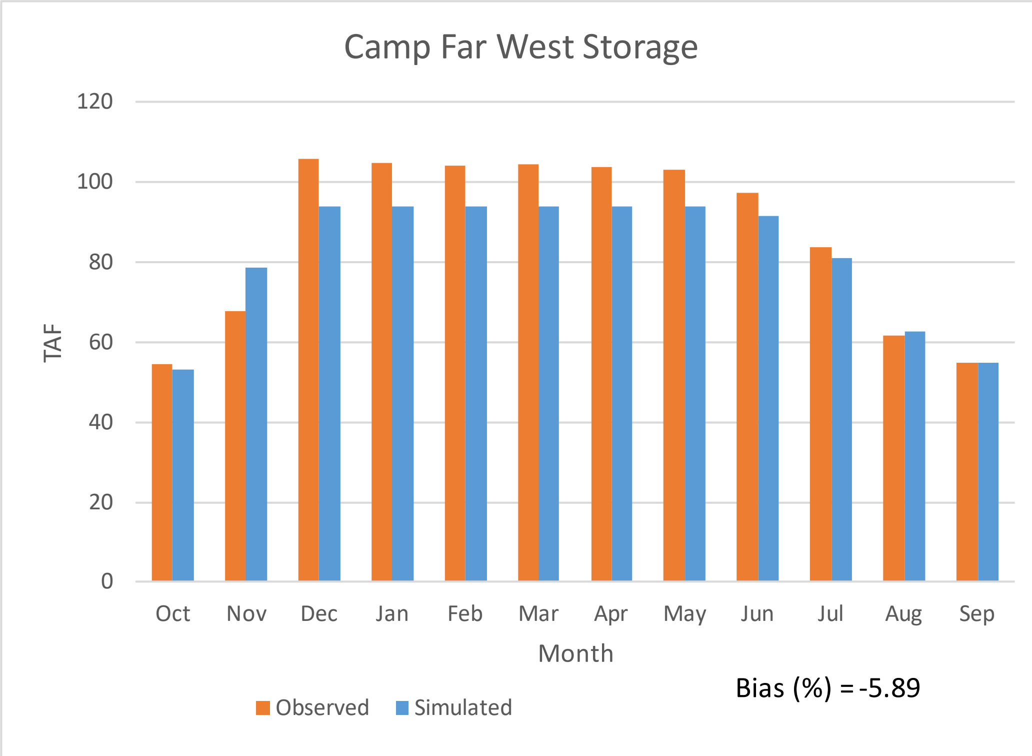


Figure A.9.5e. Camp Far West Storage, Average Monthly (Wet)

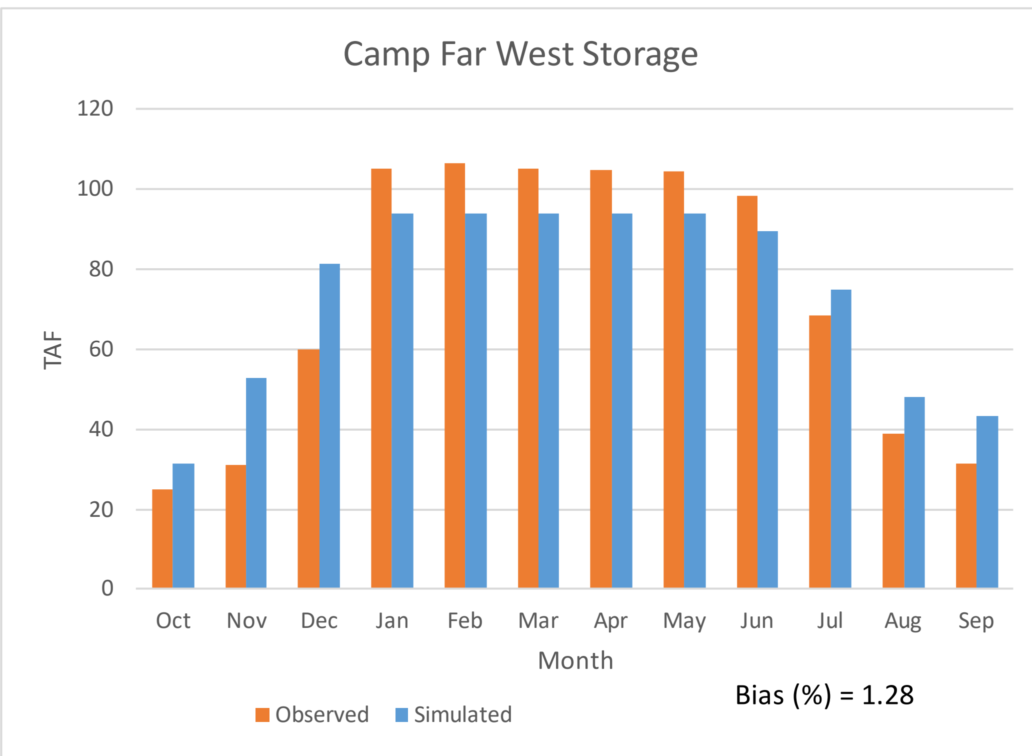


Figure A.9.5f. Camp Far West Storage, Average Monthly (Above Normal)

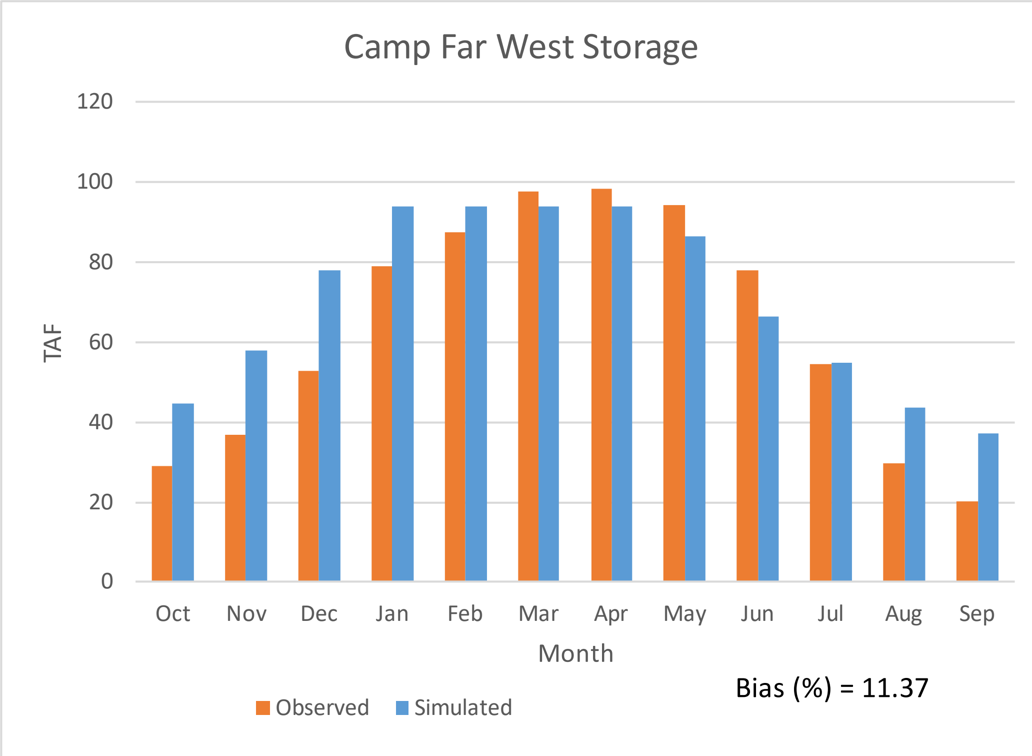


Figure A.9.5g. Camp Far West Storage, Average Monthly (Below Normal)

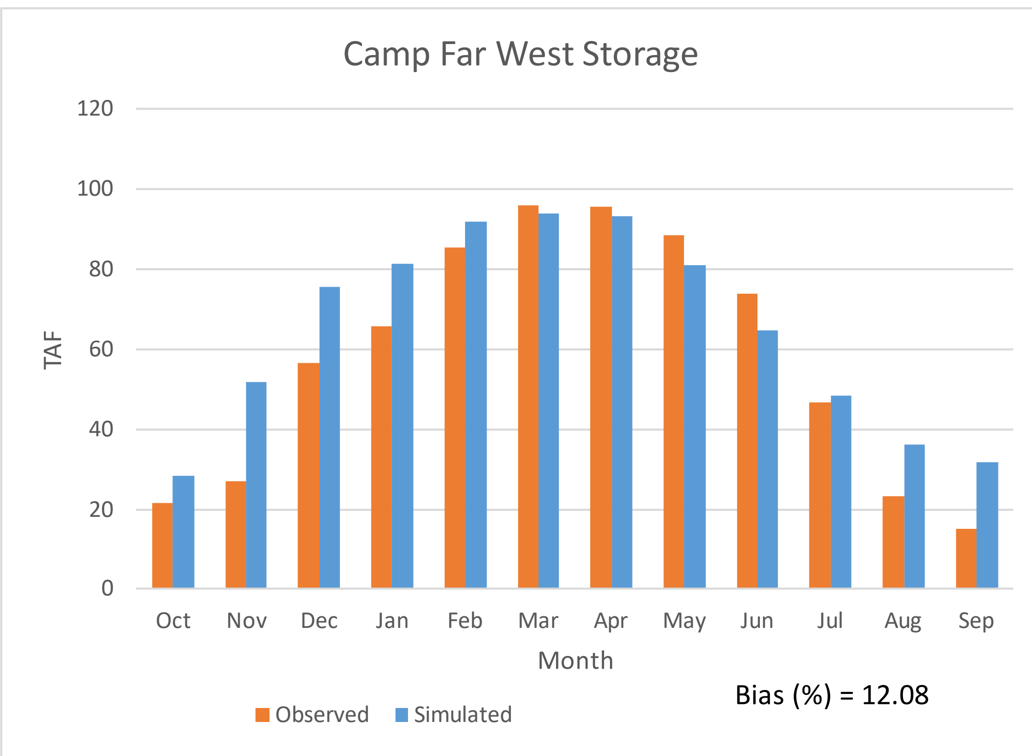


Figure A.9.5h. Camp Far West Storage, Average Monthly (Dry)

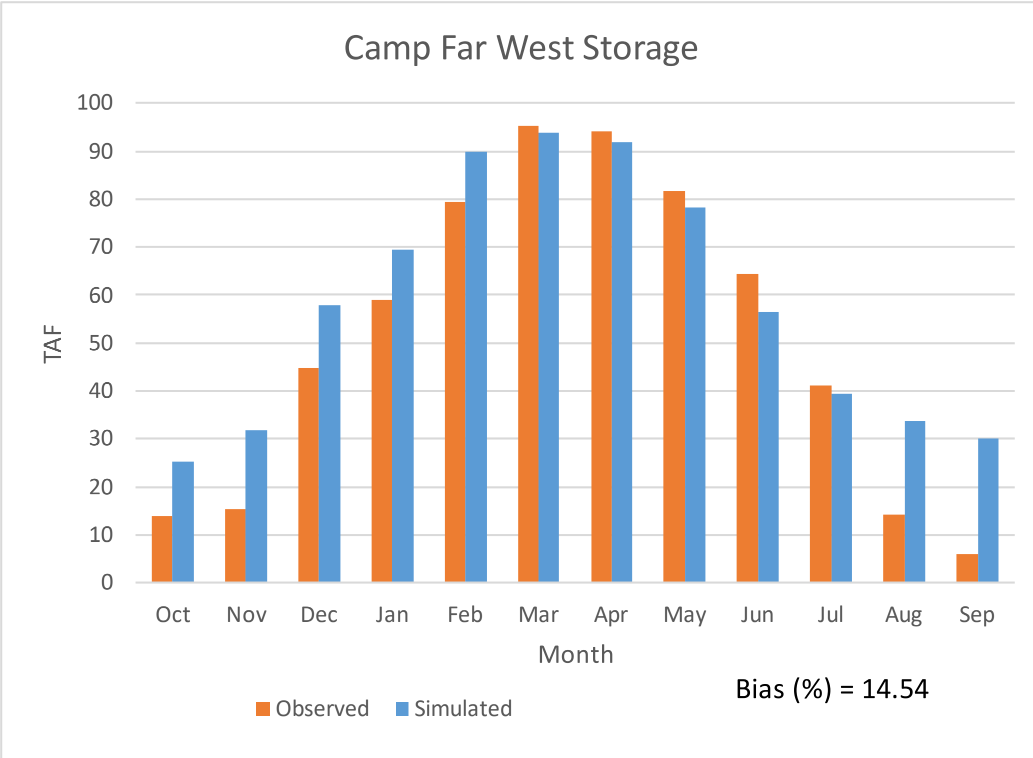


Figure A.9.5i. Camp Far West Storage, Average Monthly (Critical)

A.9.6 Camanche Reservoir Storage

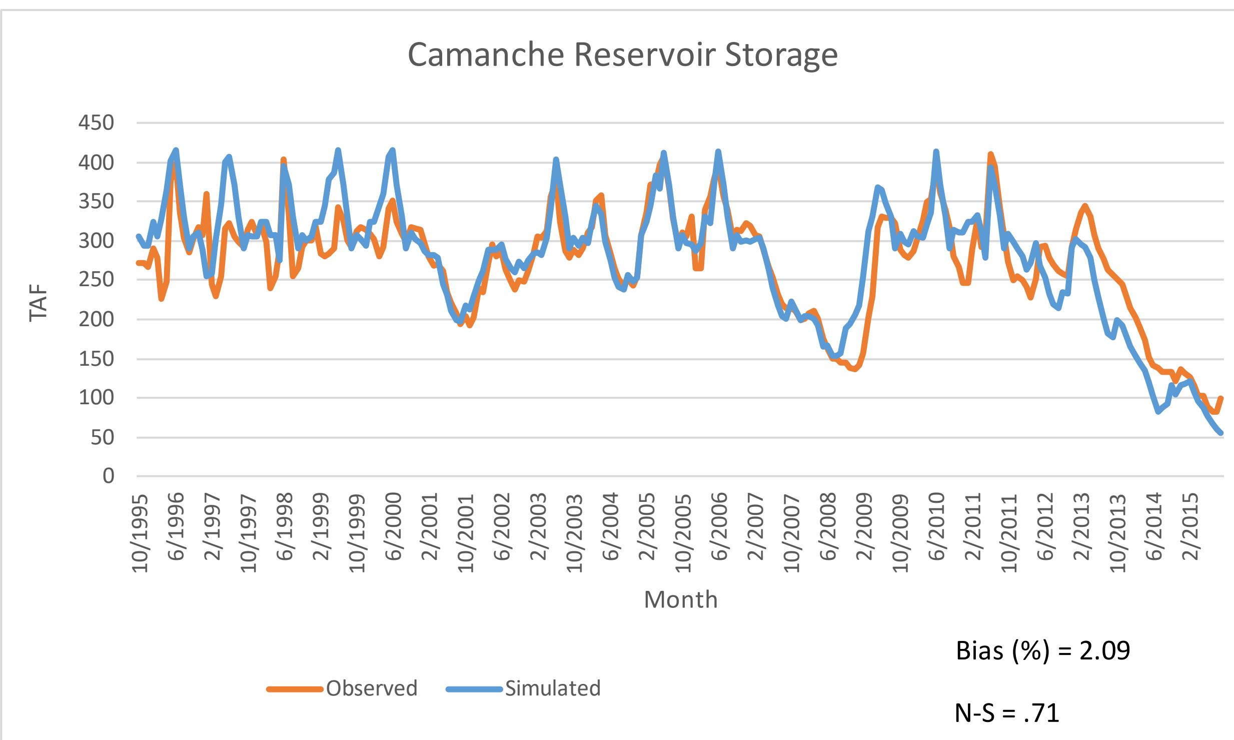


Figure A.9.6a. Camanche Reservoir Storage, Monthly 1996 to 2015

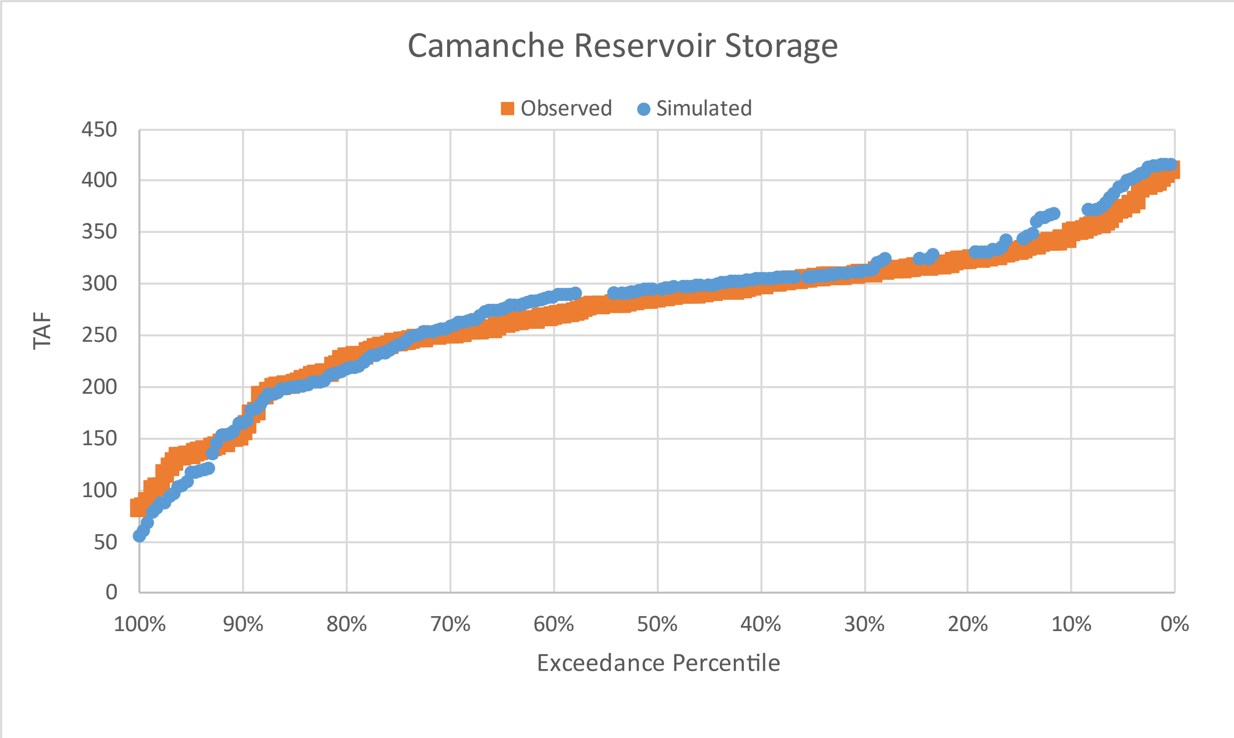


Figure A.9.6b. Camanche Reservoir Storage, Exceedance

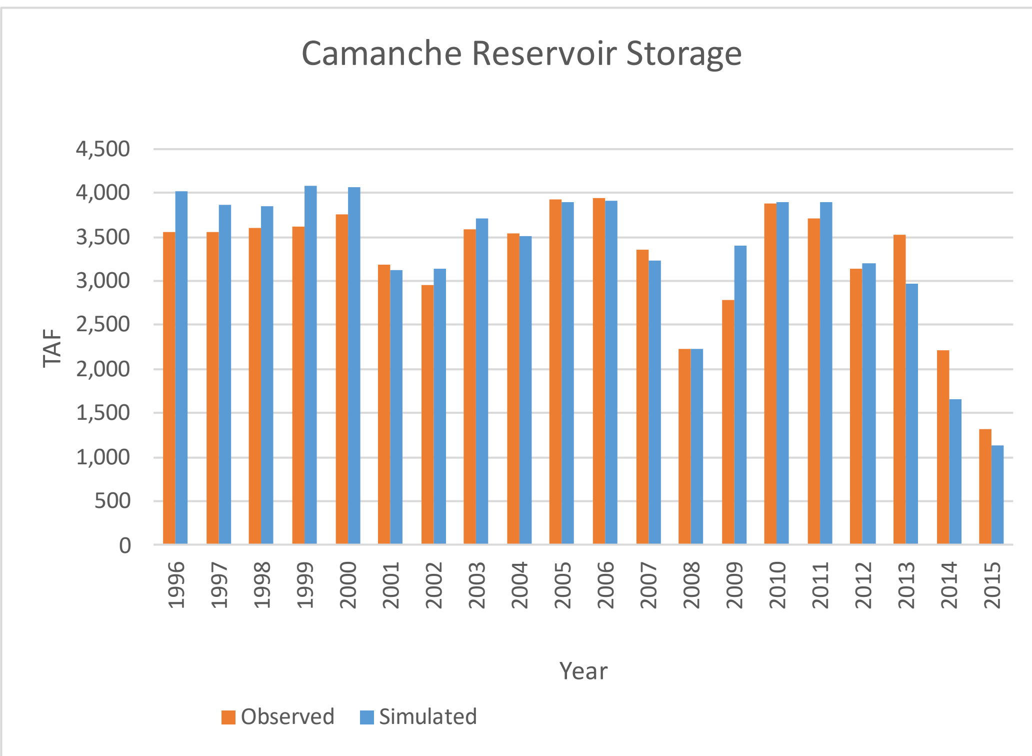


Figure A.9.6c. Camanche Reservoir Storage, Annual 1996 to 2015

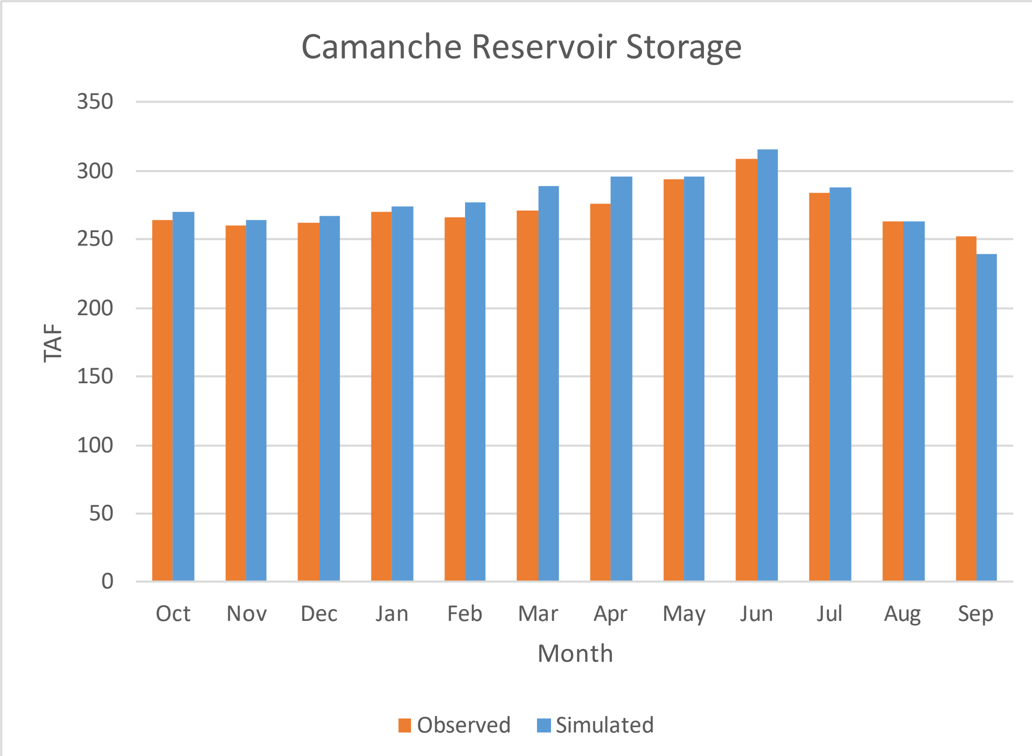


Figure A.9.6d. Camanche Reservoir Storage, Average Monthly

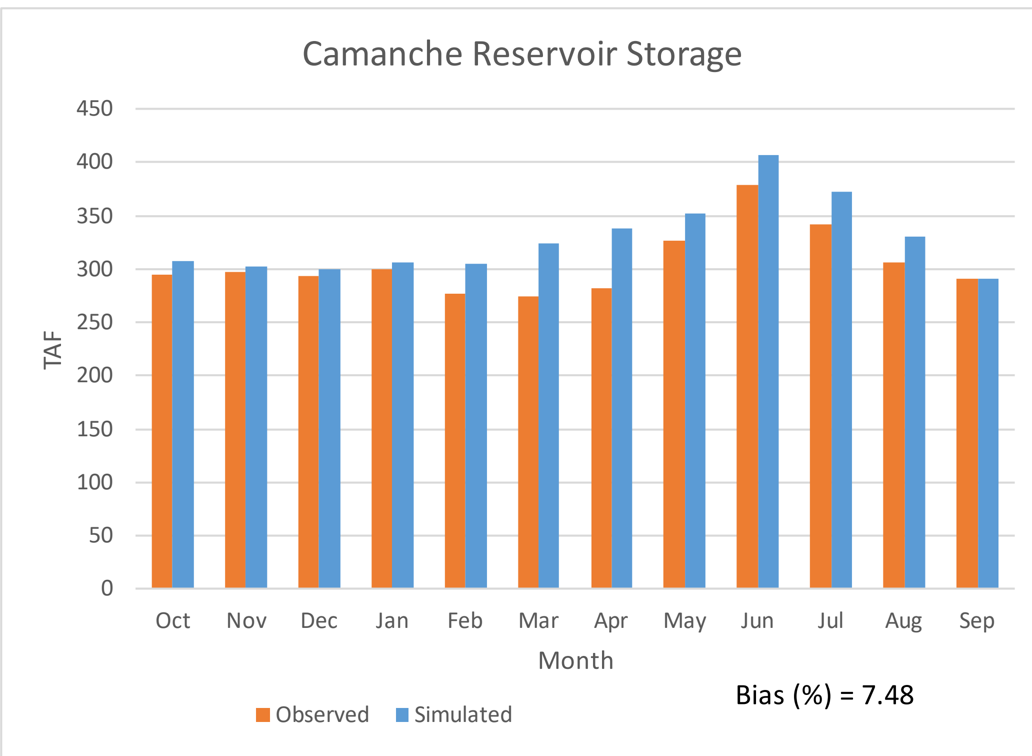


Figure A.9.6e. Camanche Reservoir Storage, Average Monthly (Wet)

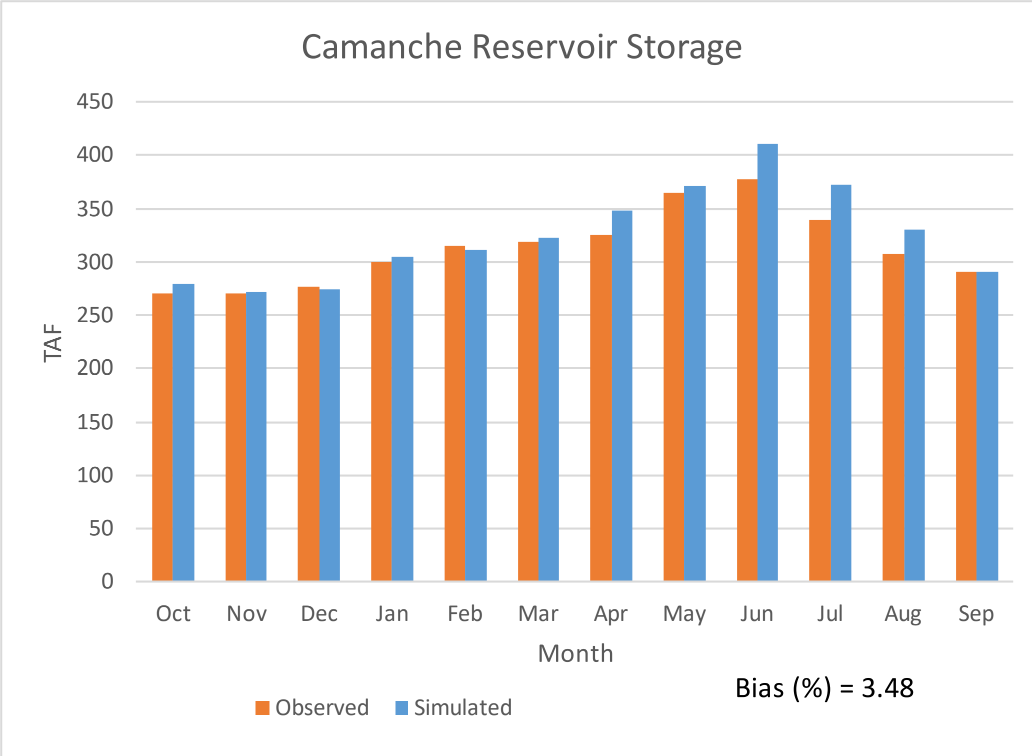


Figure A.9.6f. Camanche Reservoir Storage, Average Monthly (Above Normal)

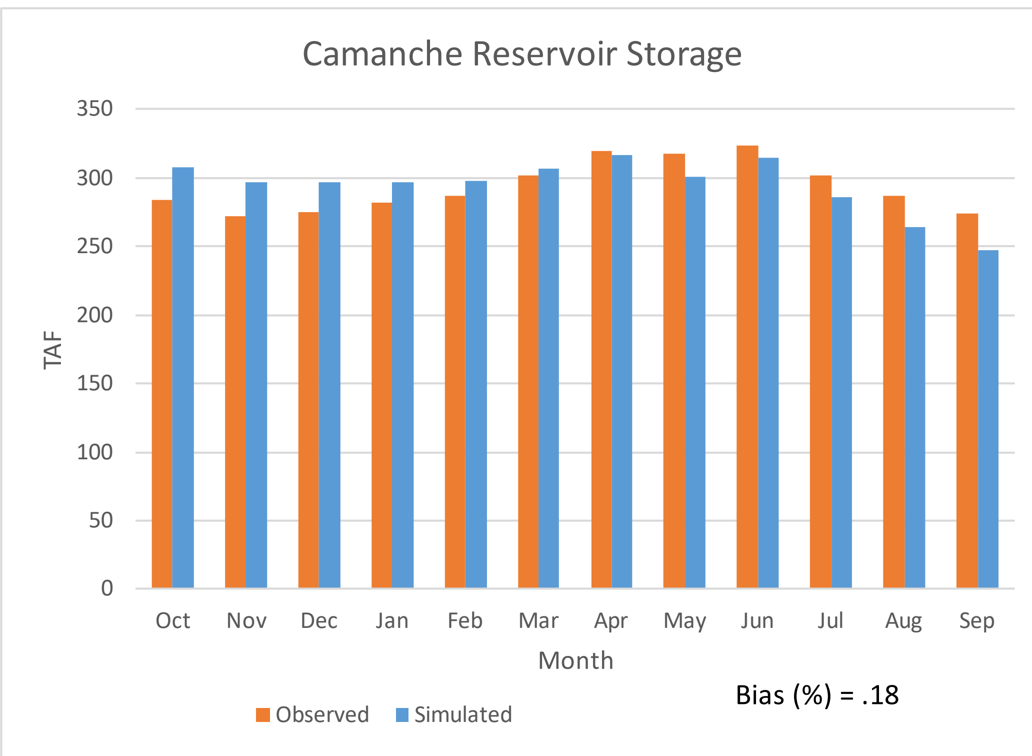


Figure A.9.6g. Camanche Reservoir Storage, Average Monthly (Below Normal)

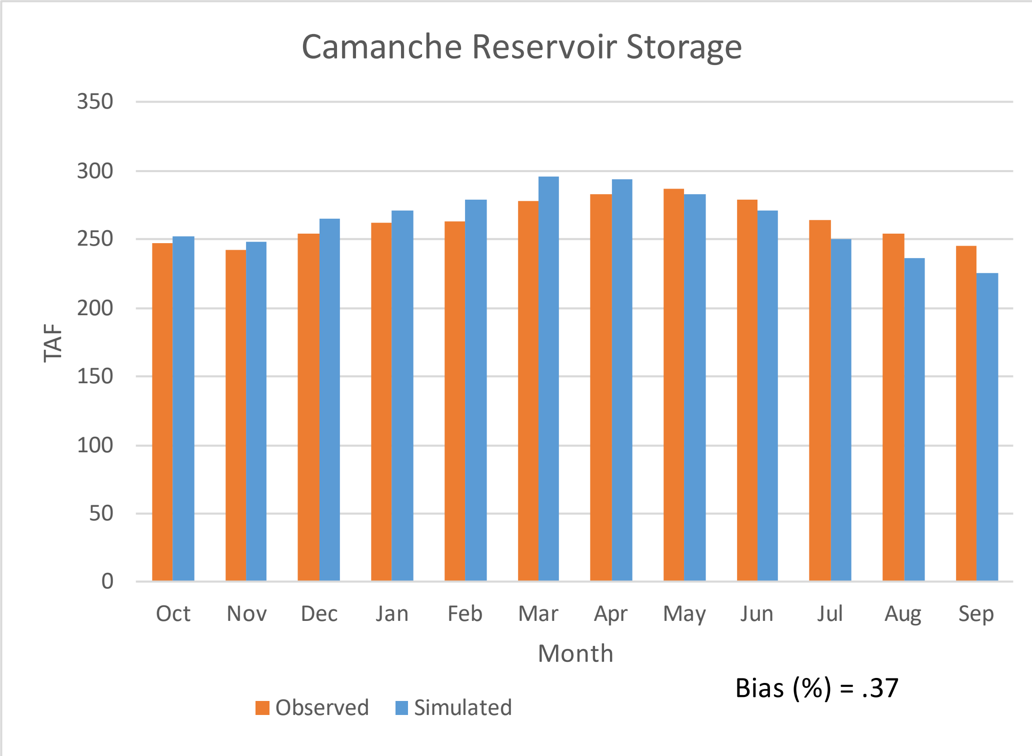


Figure A.9.6h. Camanche Reservoir Storage, Average Monthly (Dry)

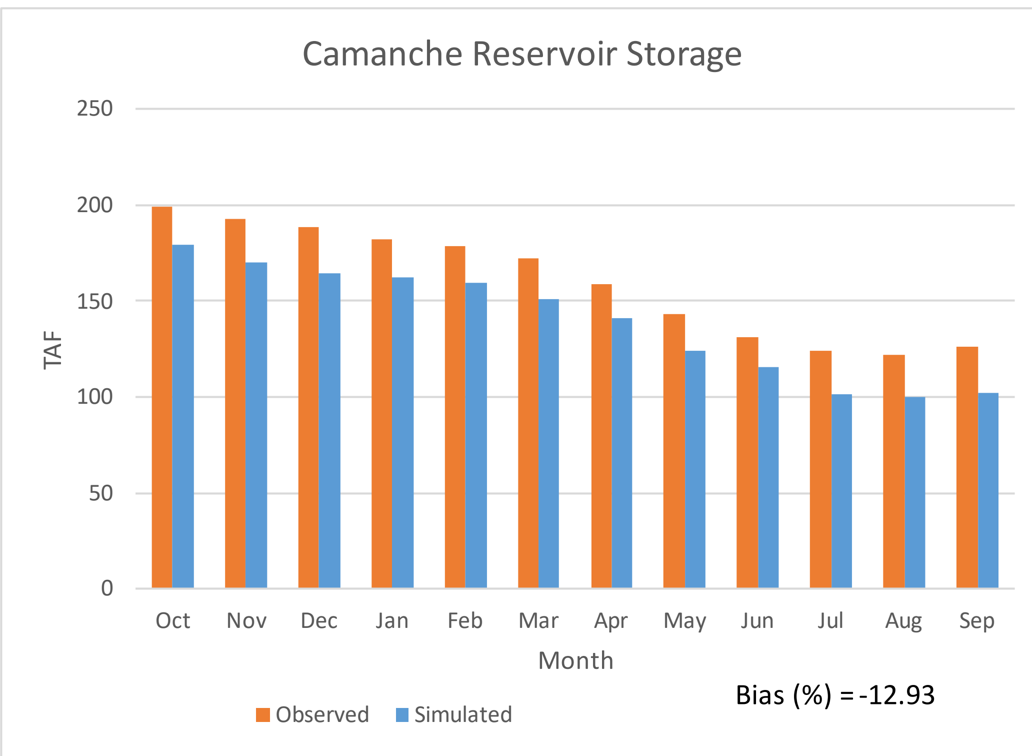


Figure A.9.6i. Camanche Reservoir Storage, Average Monthly (Critical)

A.9.7 New Hogan Lake Storage

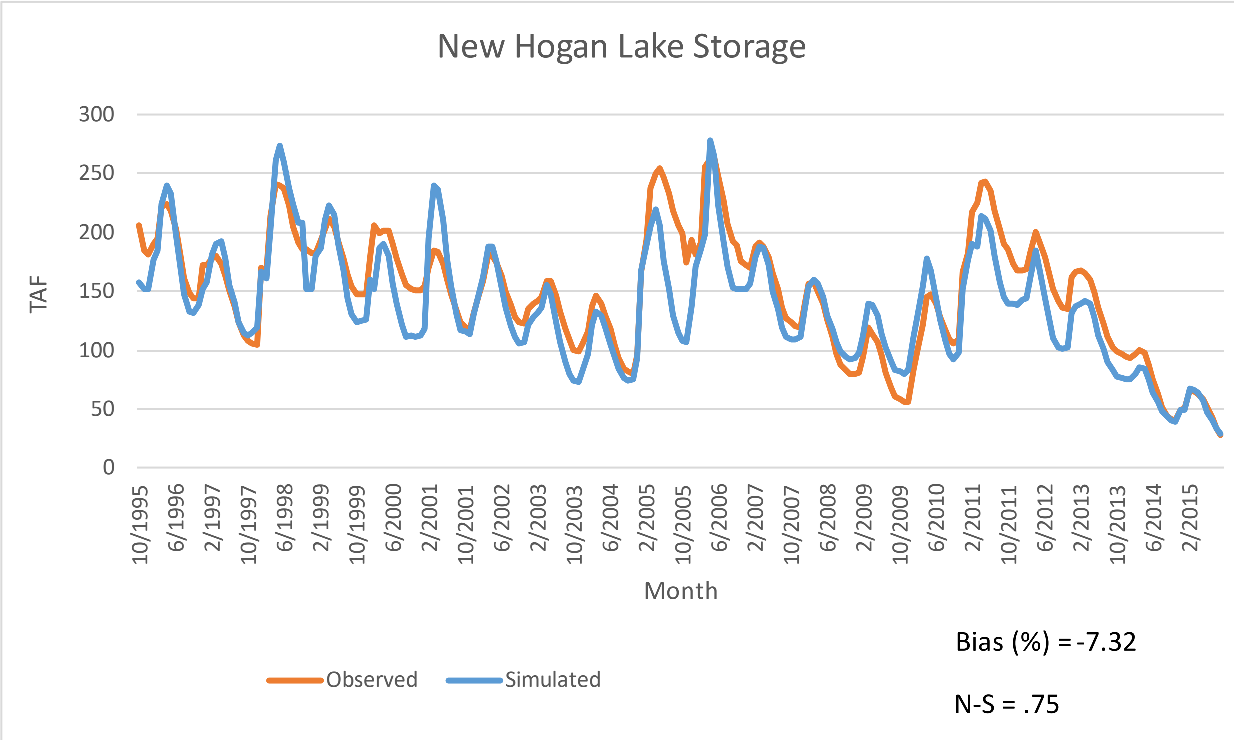


Figure A.9.7a. New Hogan Lake Storage, Monthly 1996 to 2015

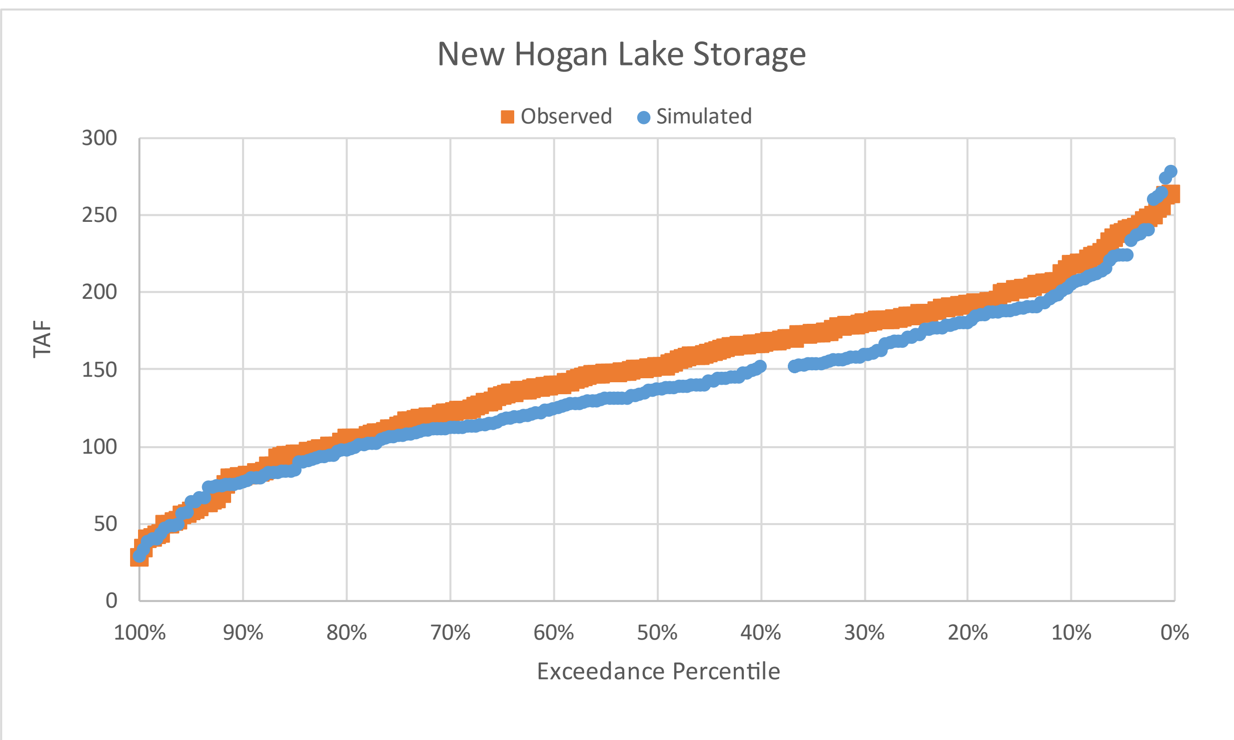


Figure A.9.7b. New Hogan Lake Storage, Exceedance

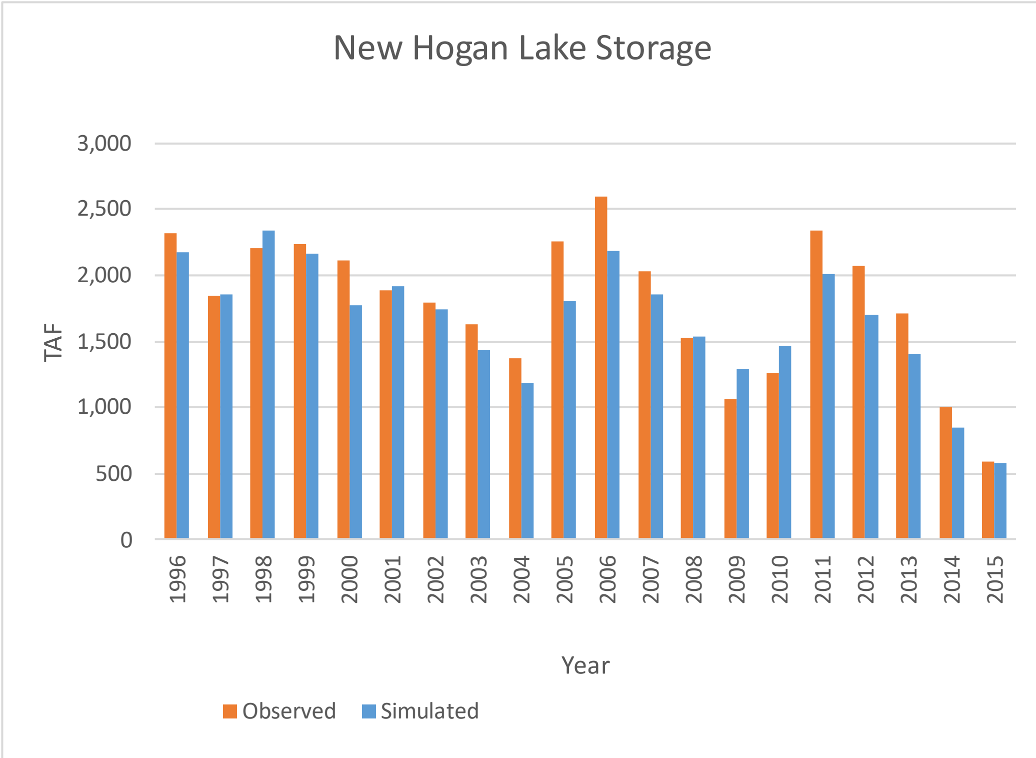


Figure A.9.7c. New Hogan Lake Storage, Annual 1996 to 2015

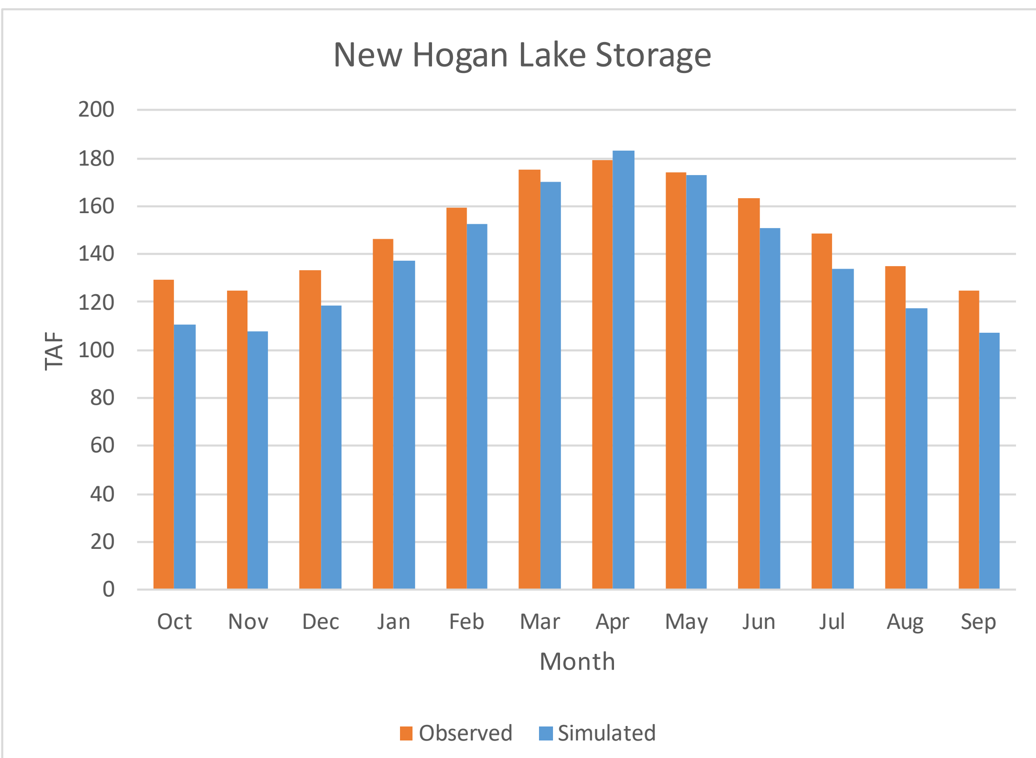


Figure A.9.7d. New Hogan Lake Storage, Average Monthly

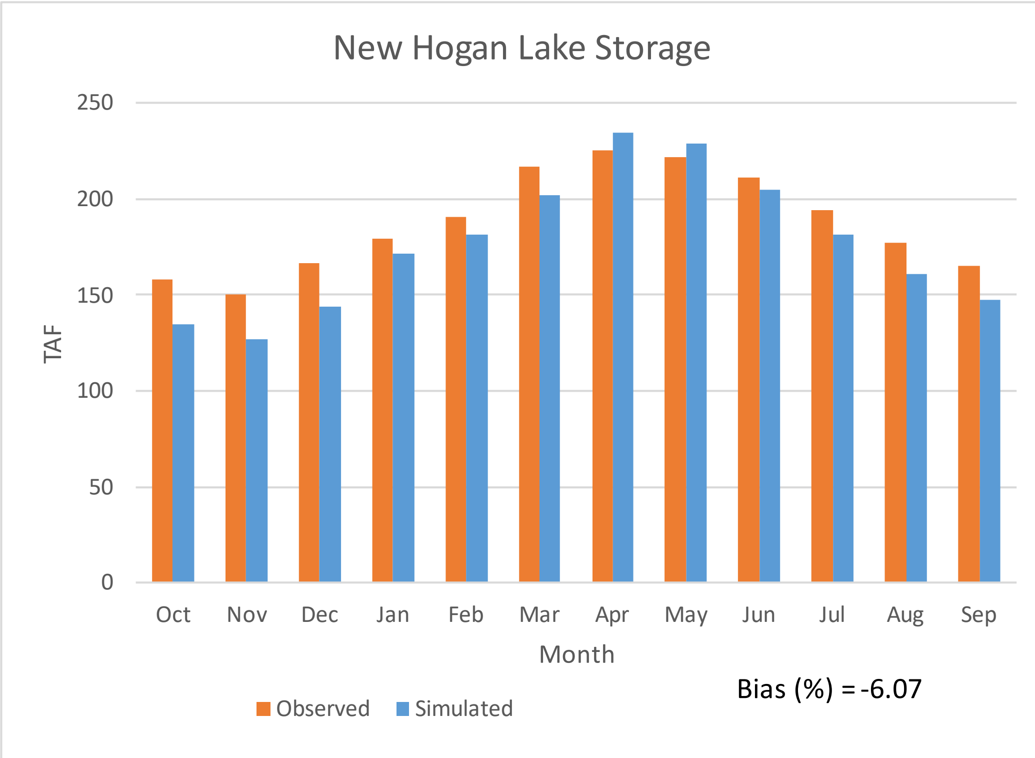


Figure A.9.7e. New Hogan Lake Storage, Average Monthly (Wet)

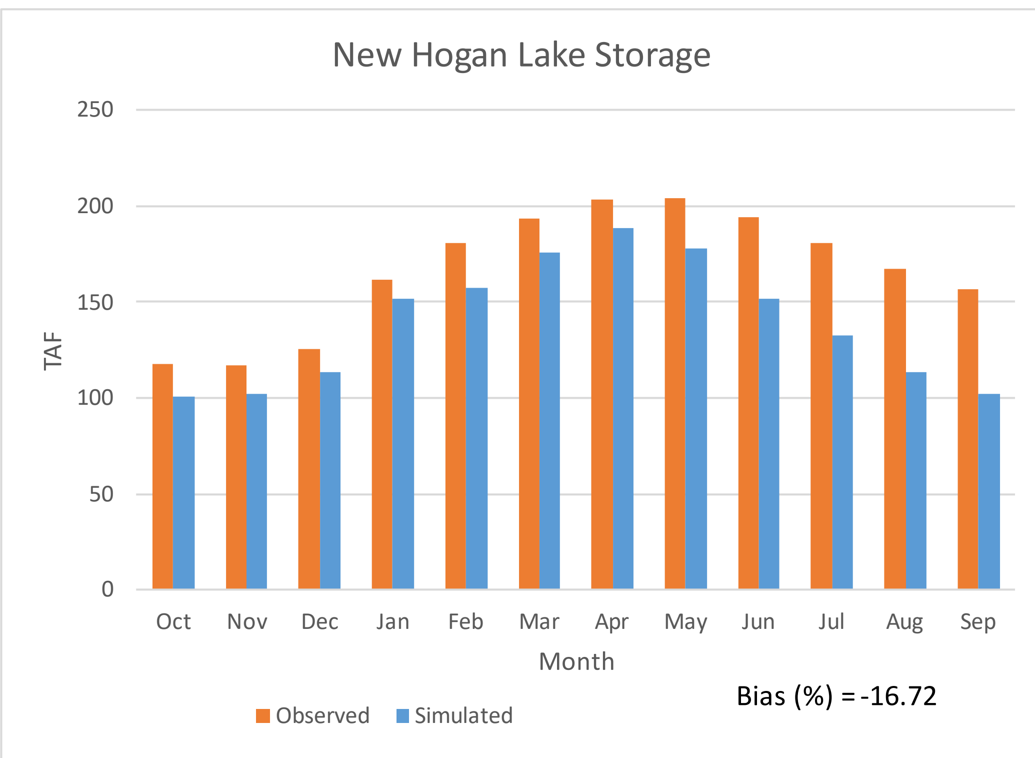


Figure A.9.7f. New Hogan Lake Storage, Average Monthly (Above Normal)

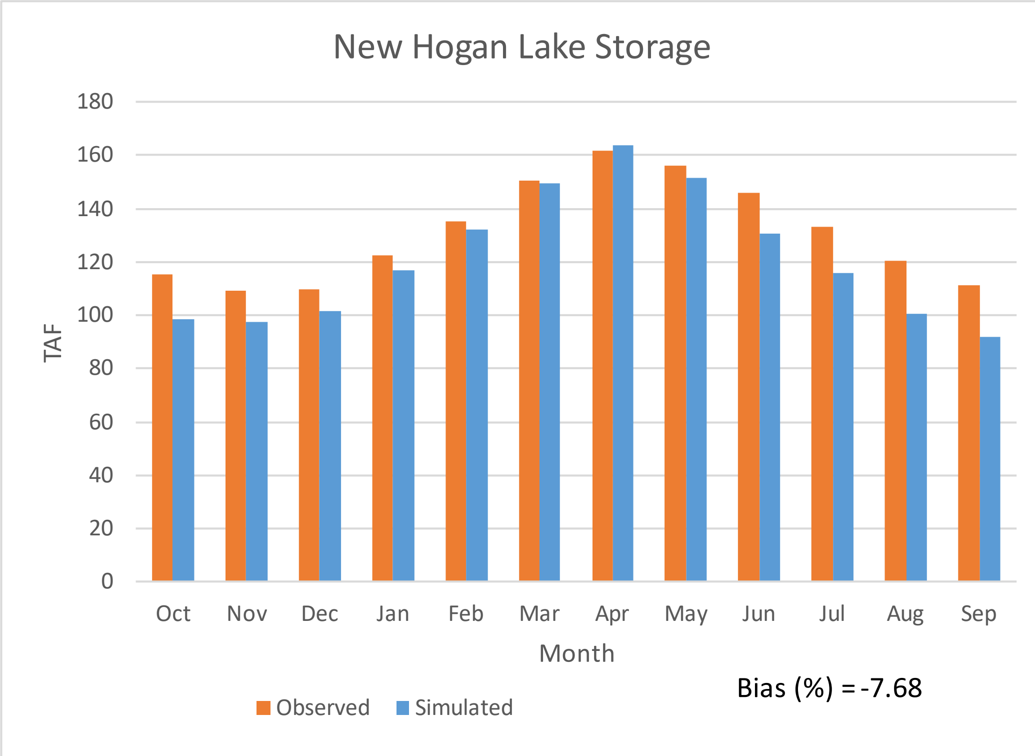


Figure A.9.7g. New Hogan Lake Storage, Average Monthly (Below Normal)

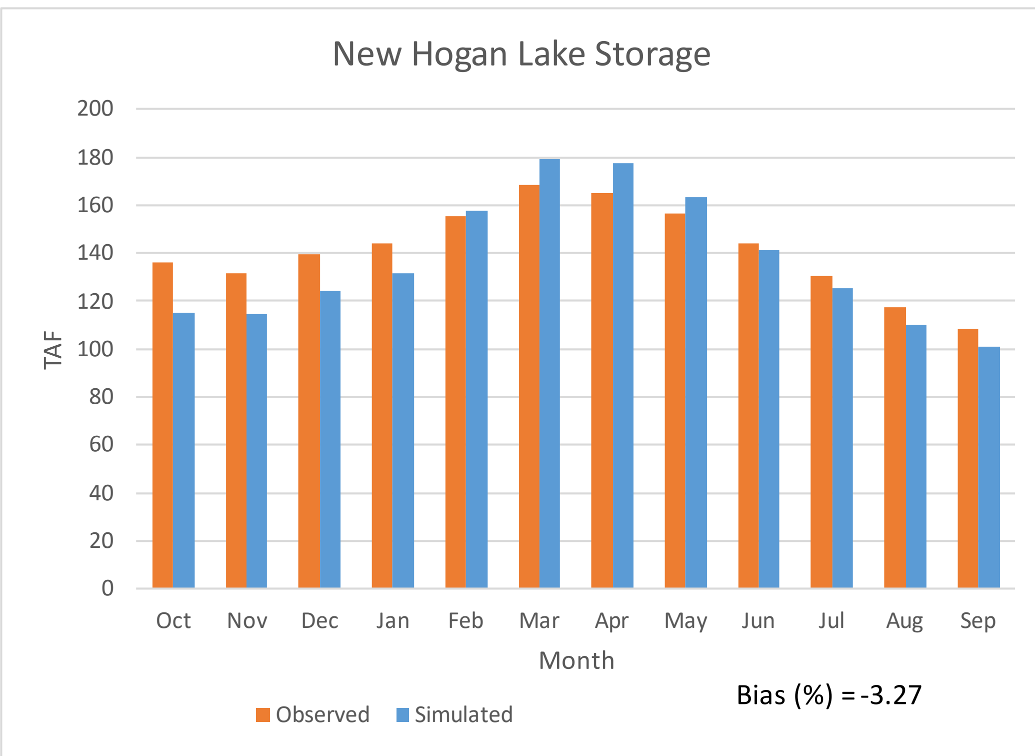


Figure A.9.7h. New Hogan Lake Storage, Average Monthly (Dry)

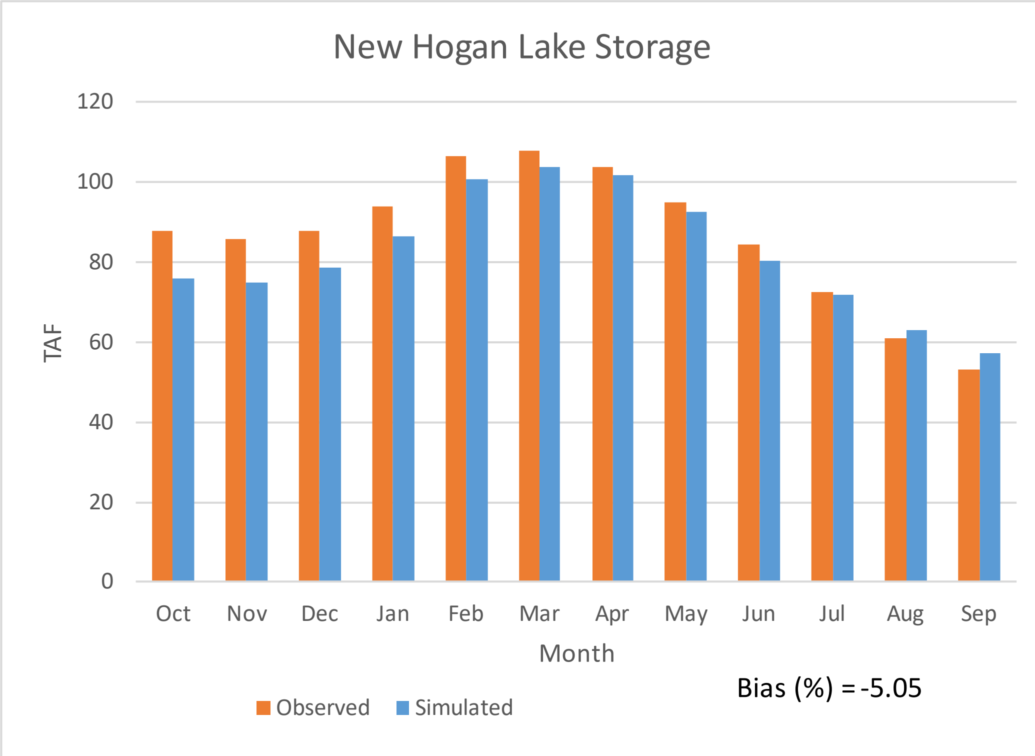


Figure A.9.7i. New Hogan Lake Storage, Average Monthly (Critical)

A.9.8 East Park, Stony Gorge, and Black Butte Reservoirs (combined)

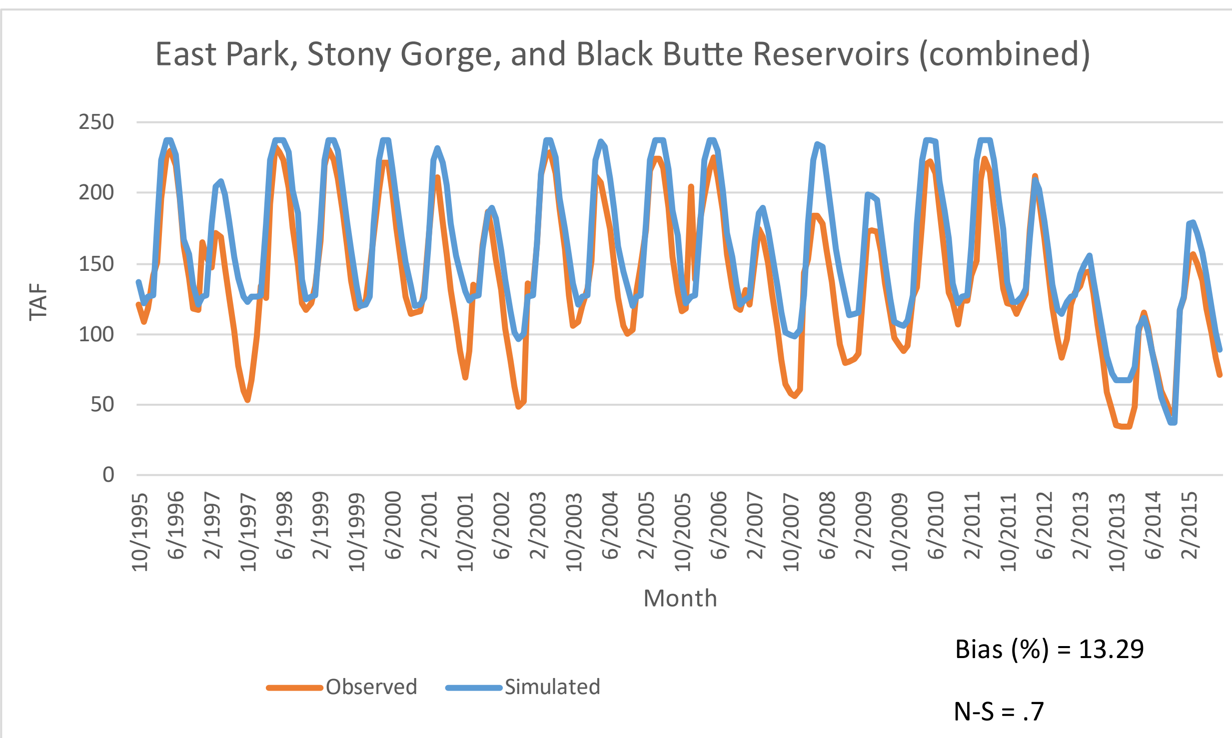


Figure A.9.8a. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Monthly 1996 to 2015

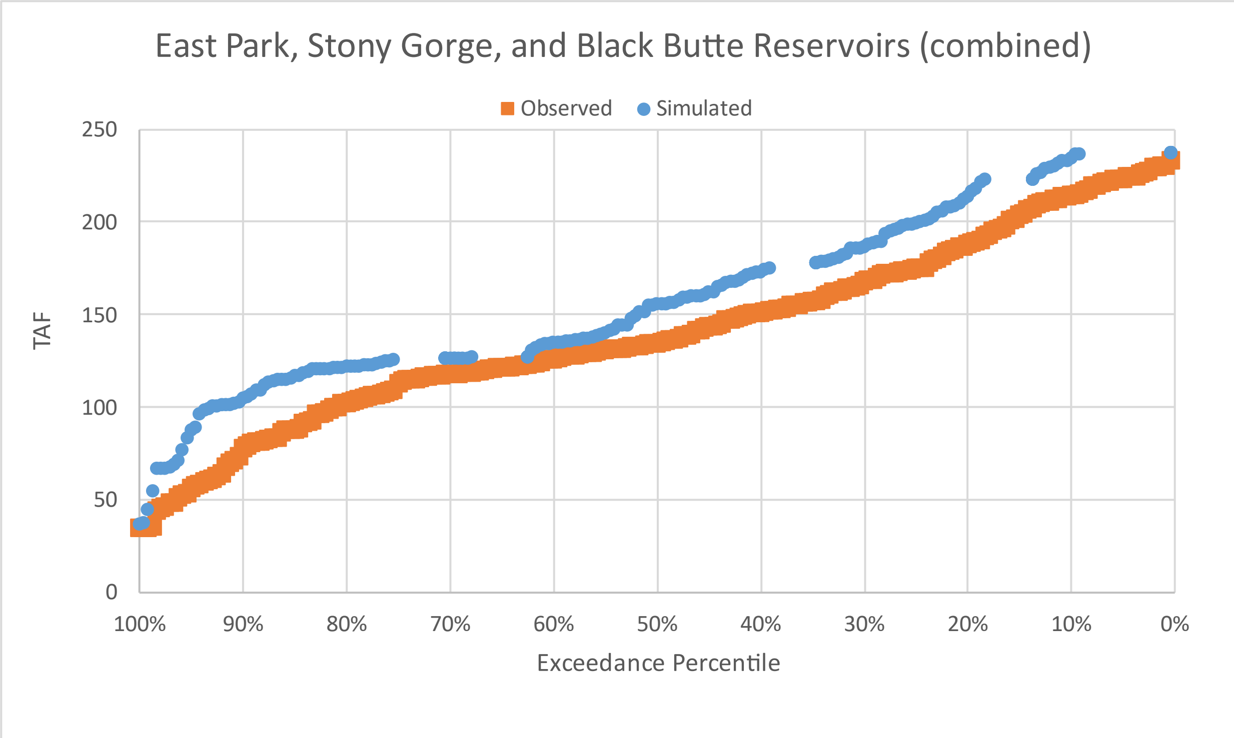


Figure A.9.8b. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Exceedance

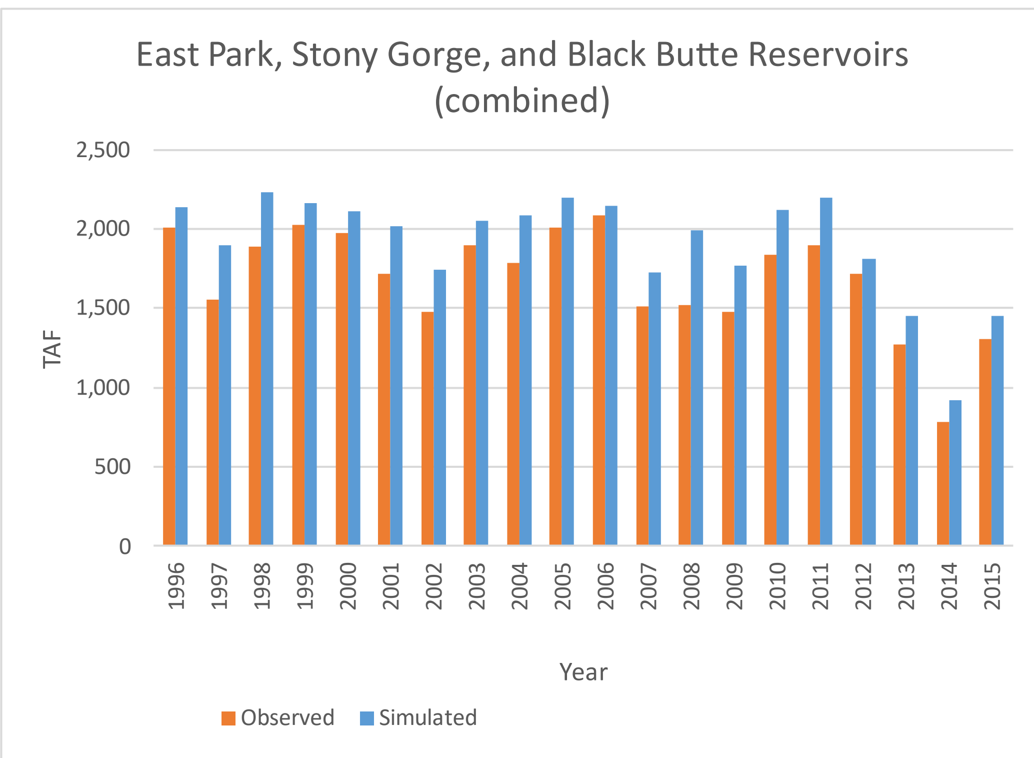


Figure A.9.8c. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Annual 1996 to 2015

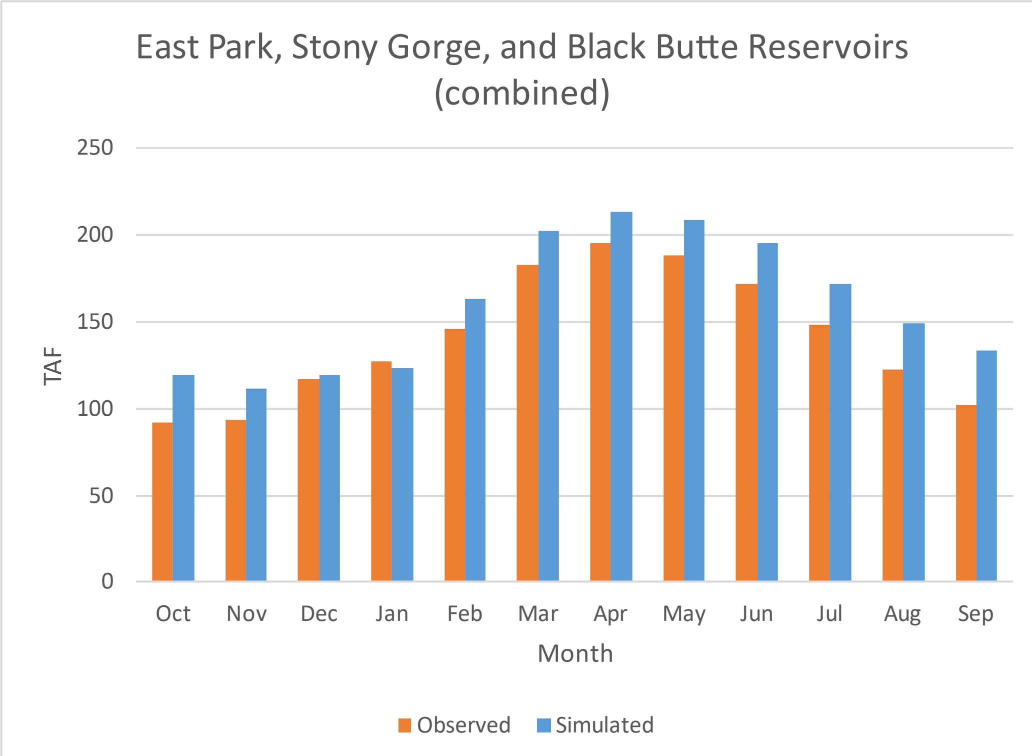


Figure A.9.8d. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Average Monthly

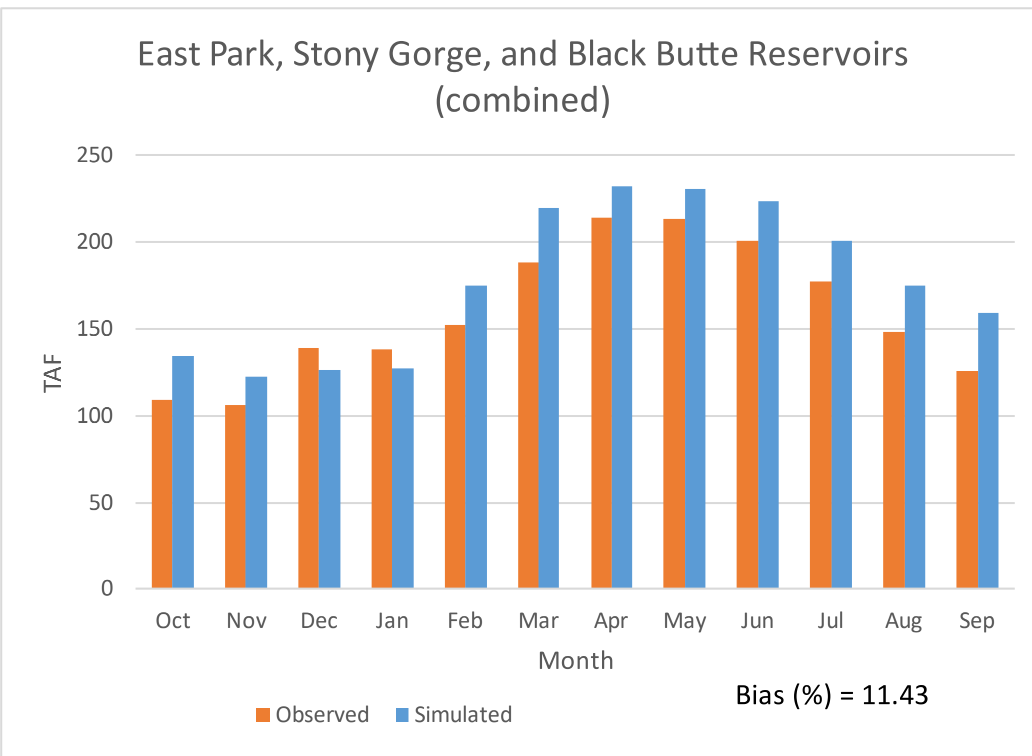


Figure A.9.8e. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Average Monthly (Wet)

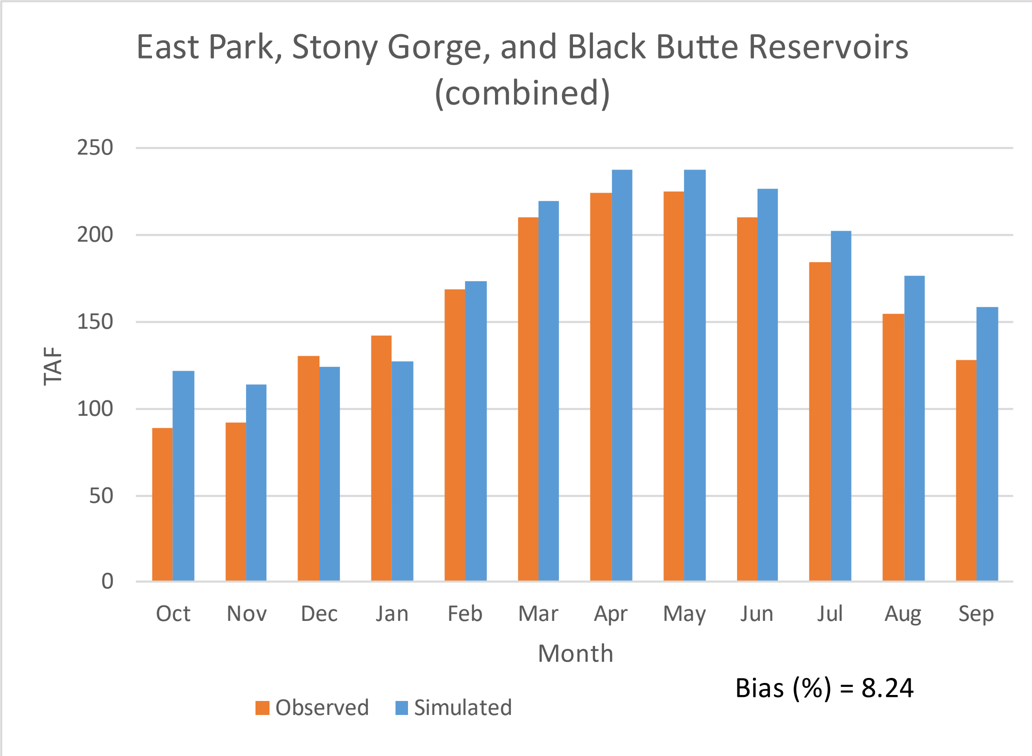


Figure A.9.8f. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Average Monthly (Above Normal)

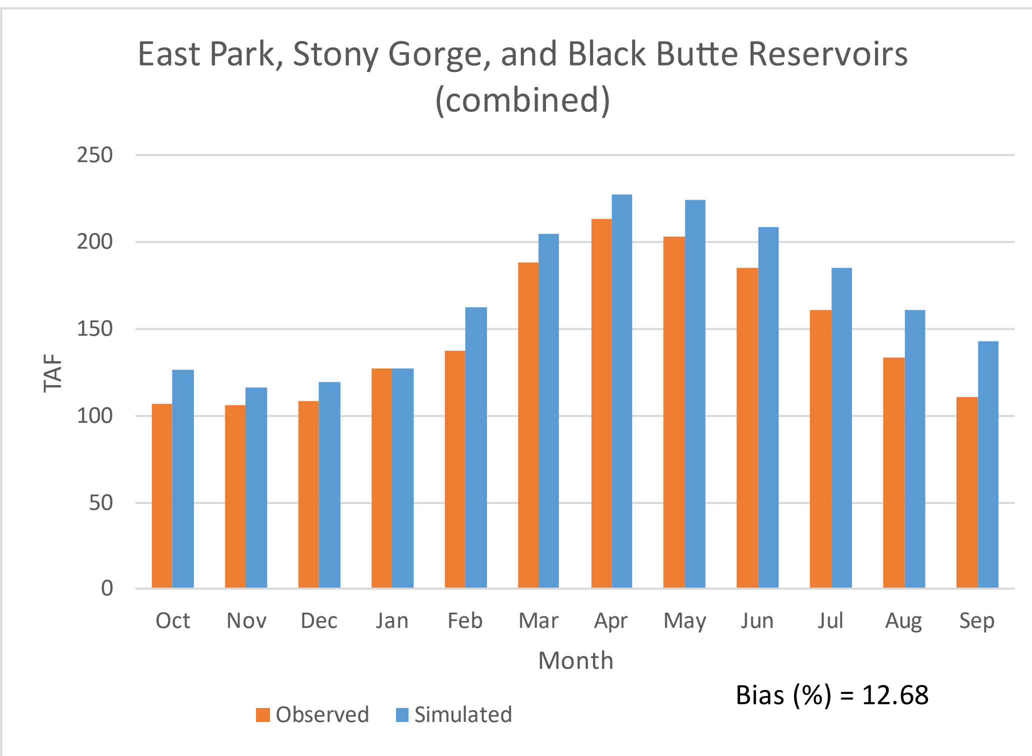


Figure A.9.8g. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Average Monthly (Below Normal)

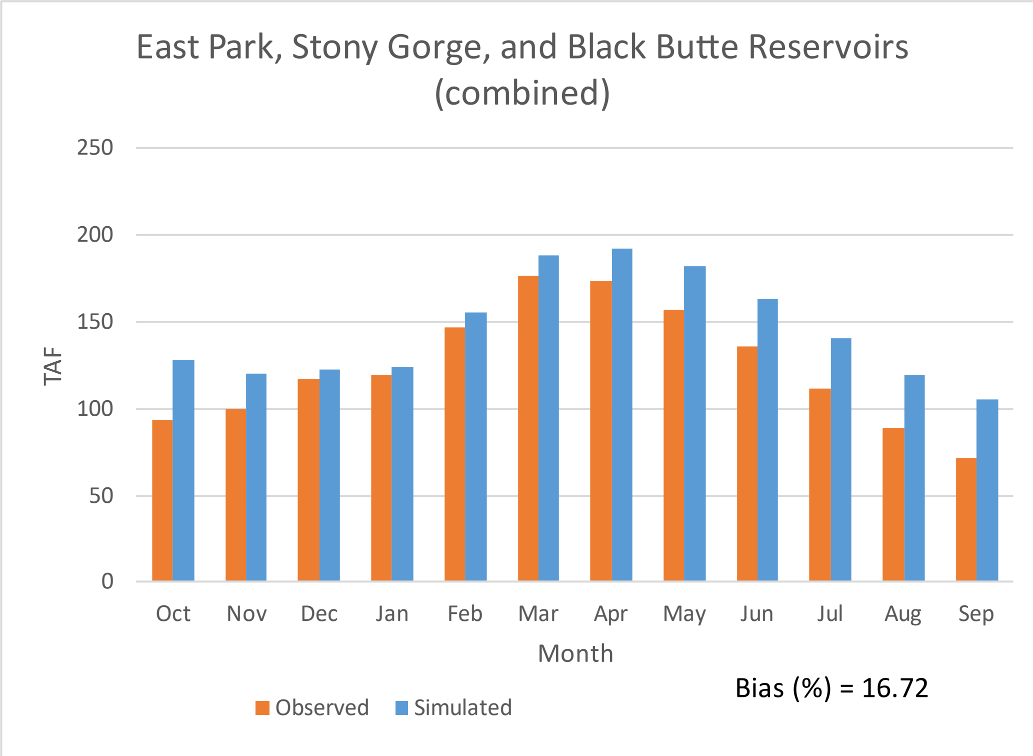


Figure A.9.8h. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Average Monthly (Dry)

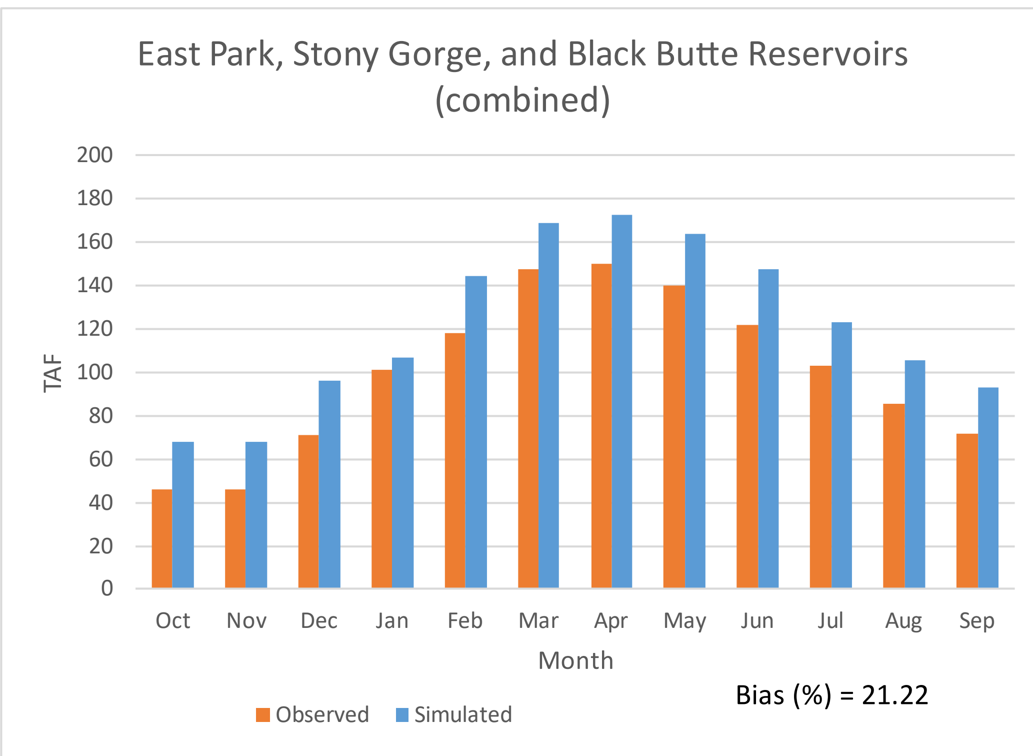


Figure A.9.8i. East Park, Stony Gorge, and Black Butte Reservoirs (combined), Average Monthly (Critical)

A.9.9 Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined)

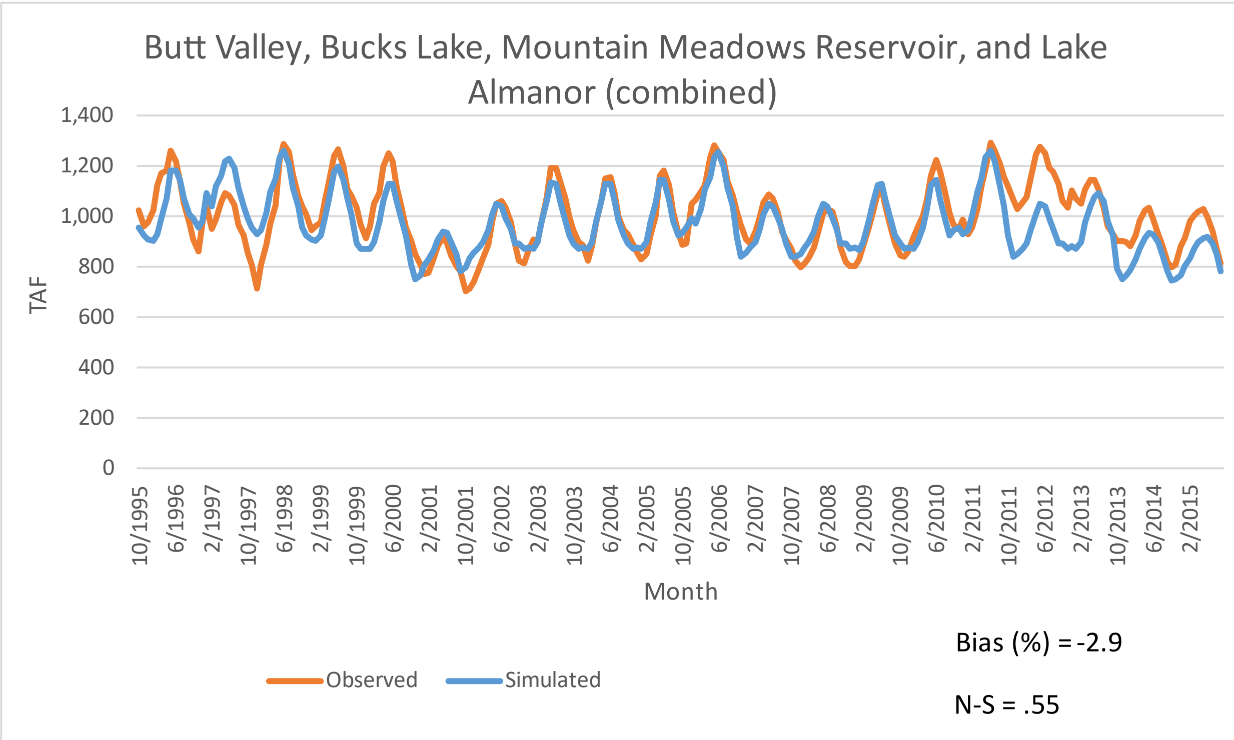


Figure A.9.9a. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Monthly 1996 to 2015

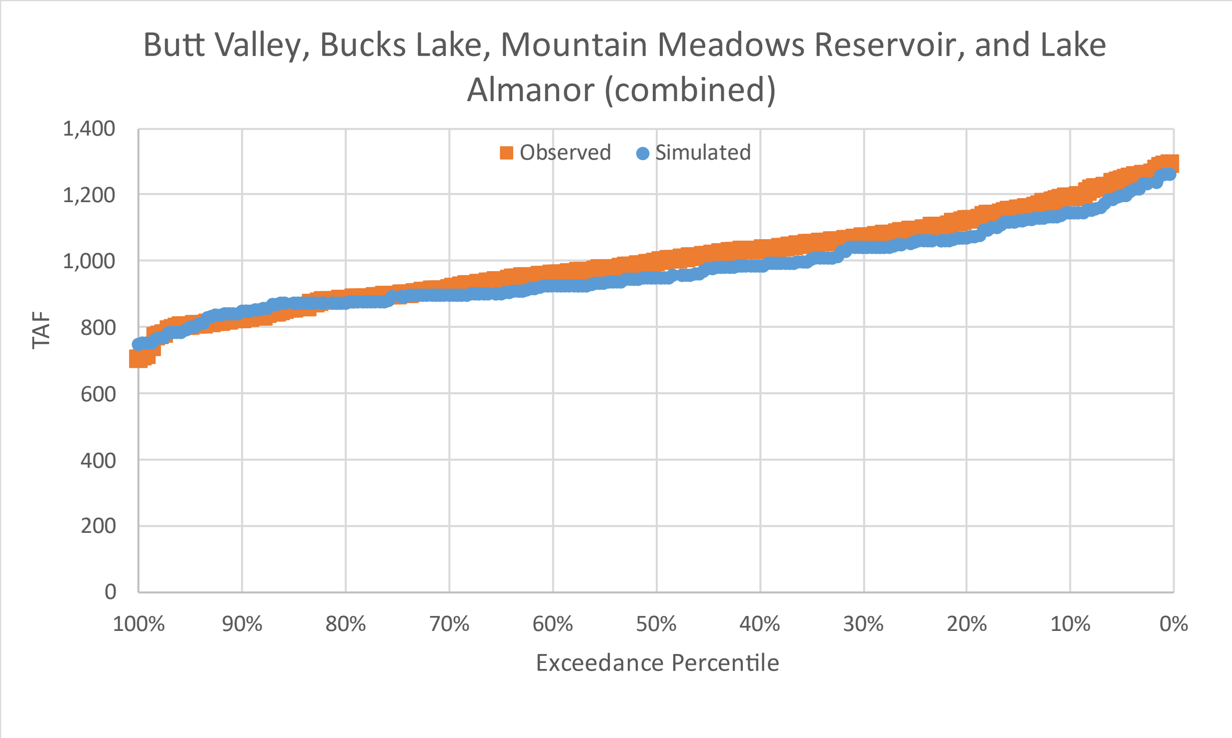


Figure A.9.9b. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Exceedance

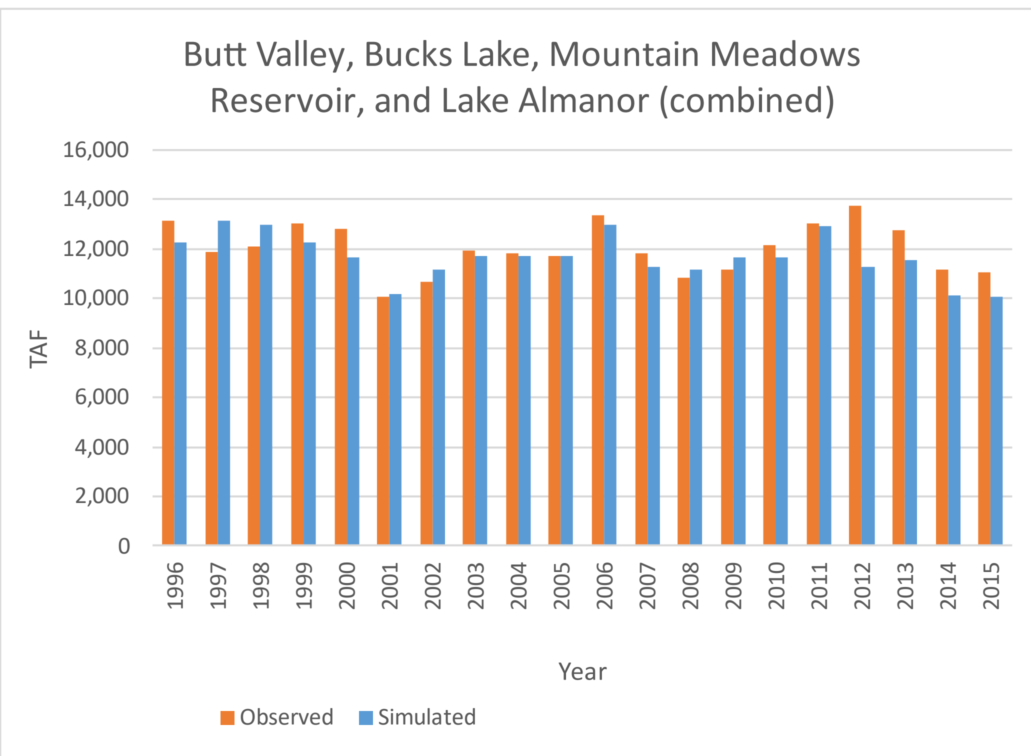


Figure A.9.9c. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Annual 1996 to 2015

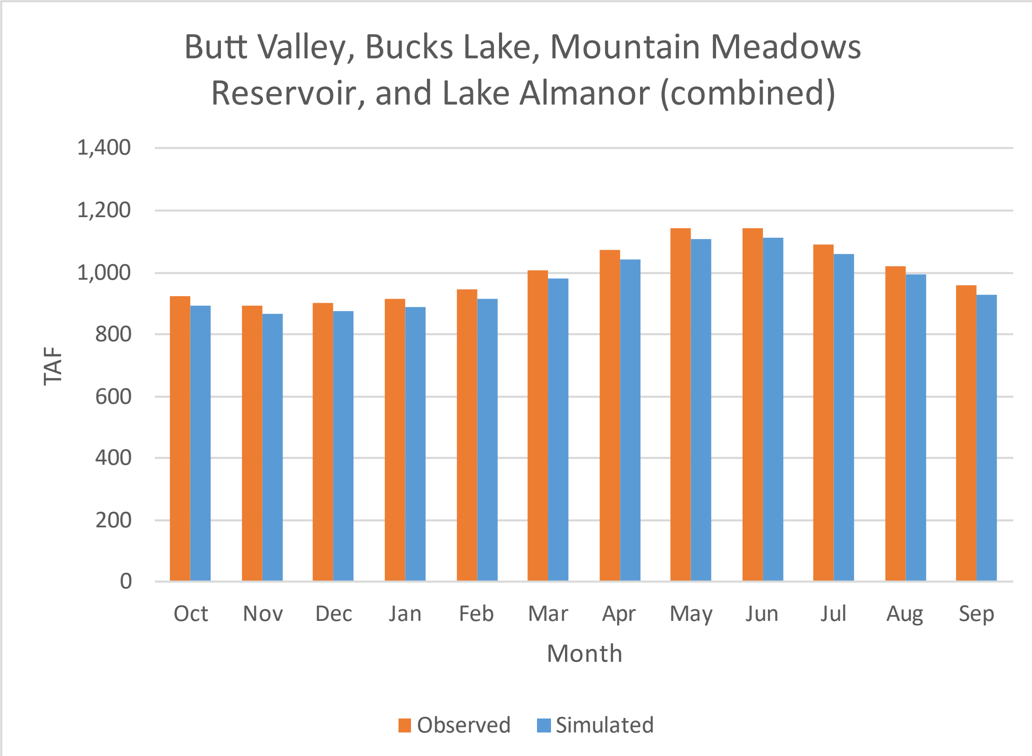


Figure A.9.9d. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Average Monthly

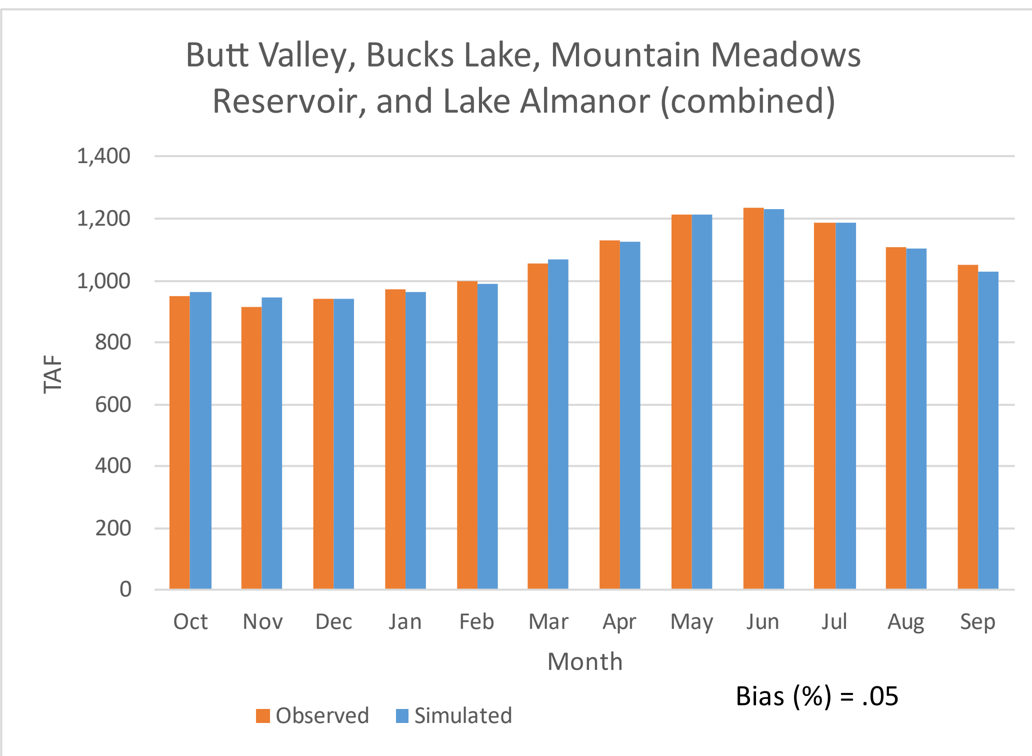


Figure A.9.9e. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Average Monthly (Wet)

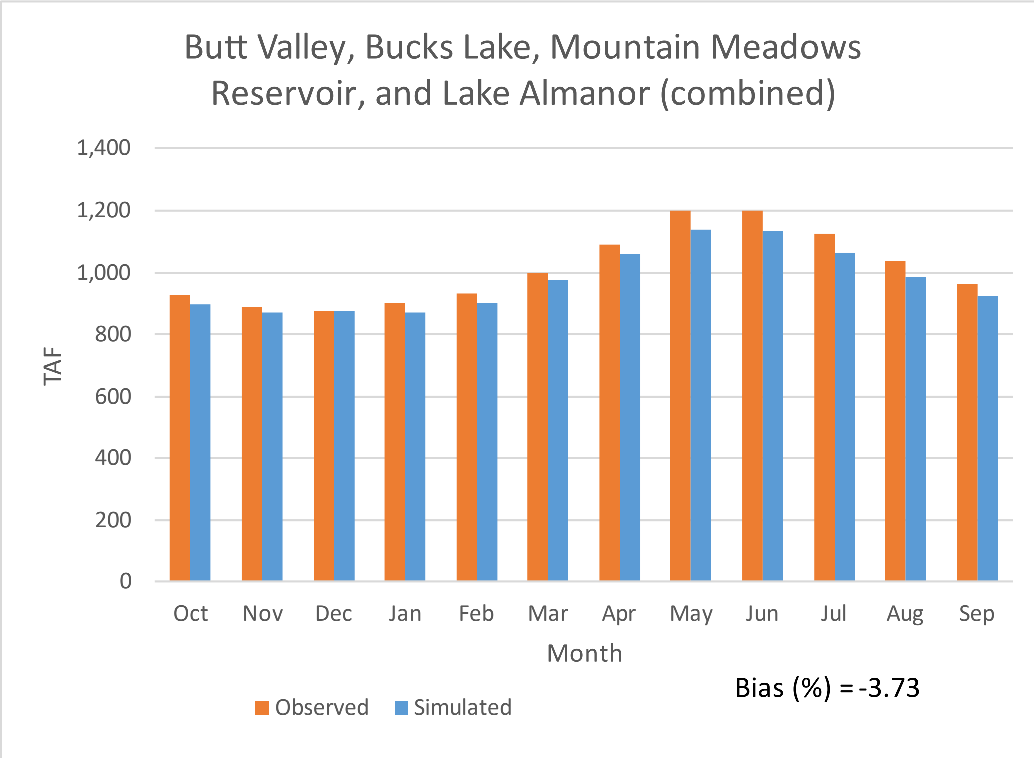


Figure A.9.9f. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Average Monthly (Above Normal)

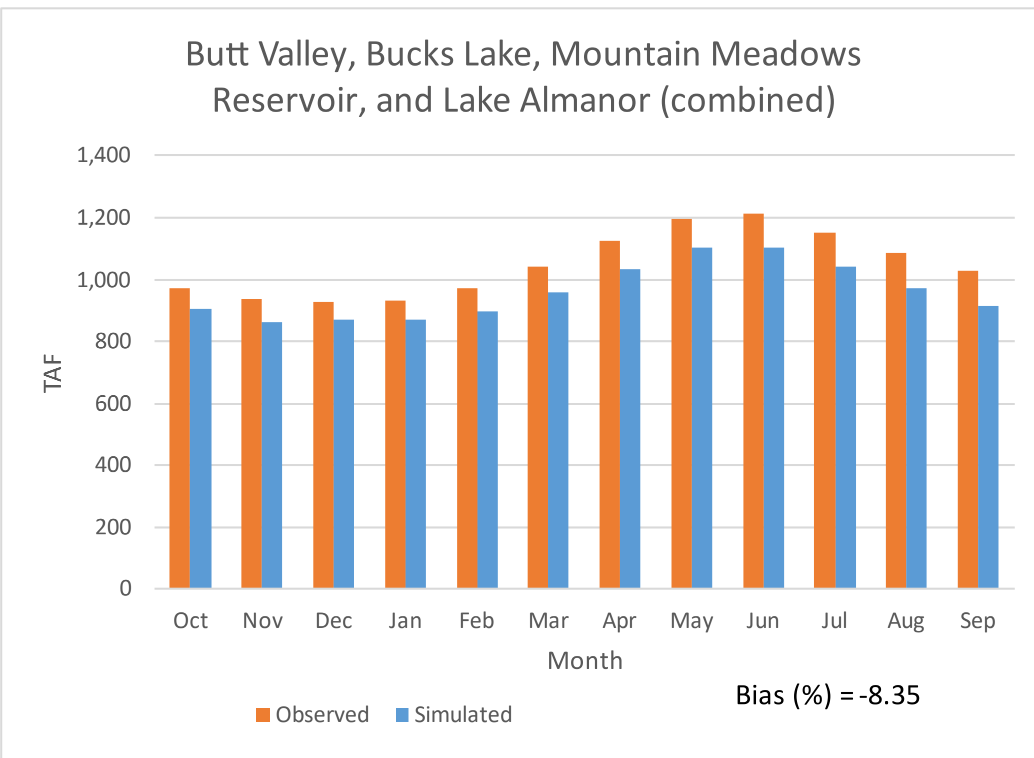


Figure A.9.9g. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Average Monthly (Below Normal)

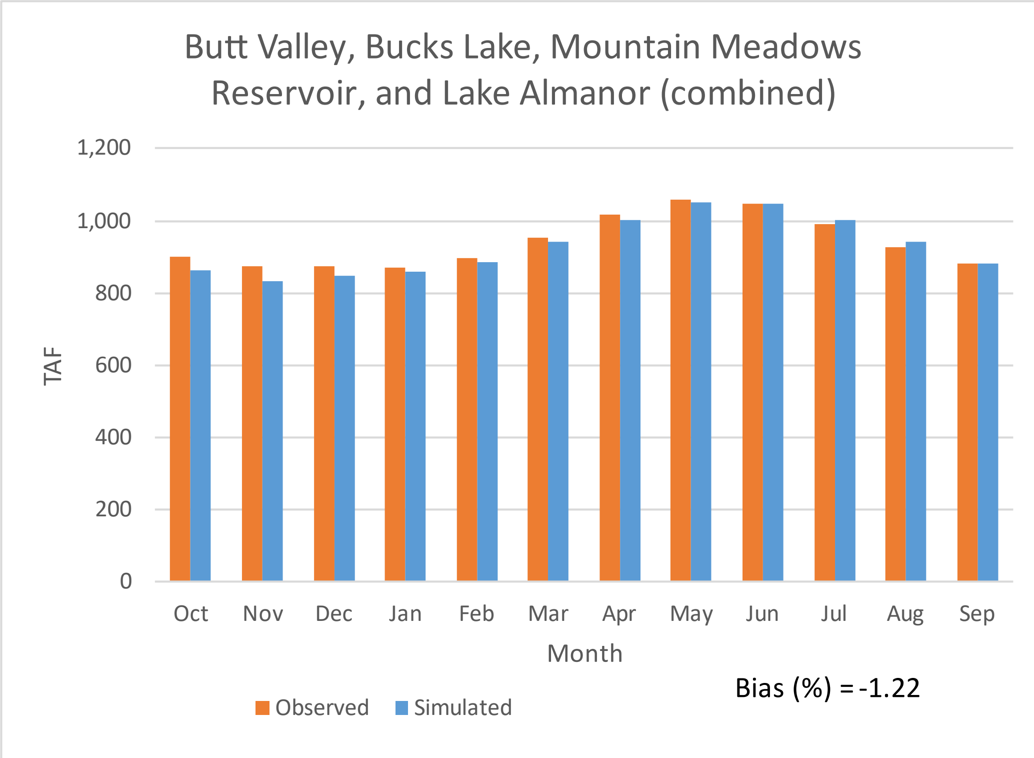


Figure A.9.9h. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Average Monthly (Dry)

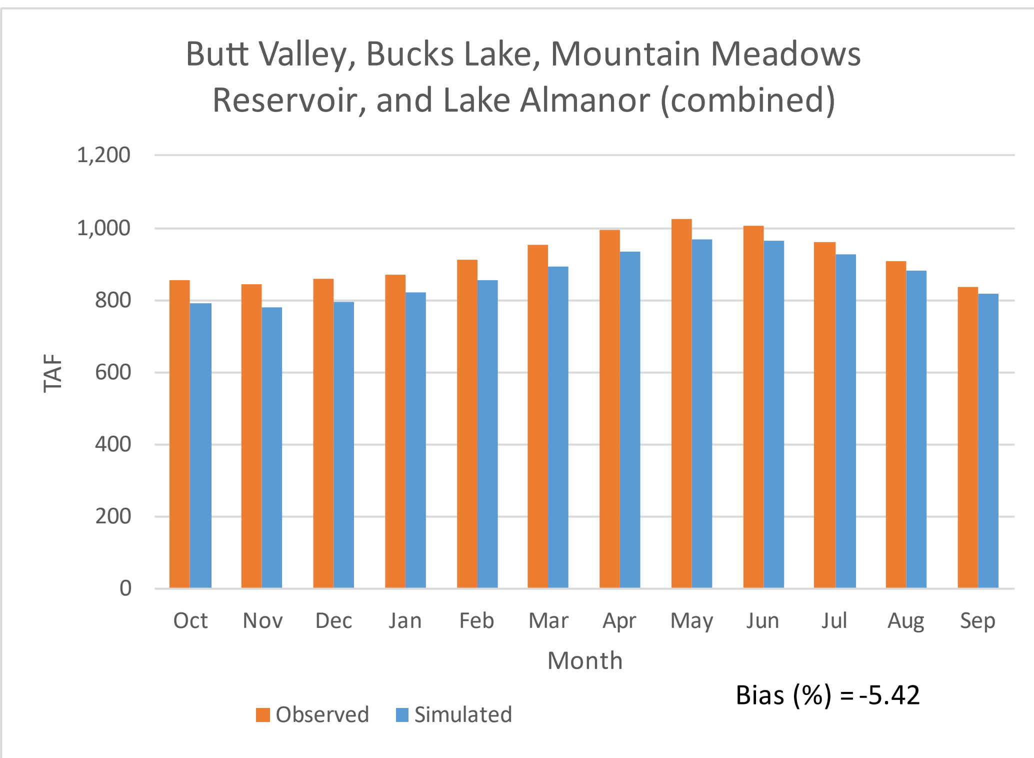


Figure A.9.9i. Butt Valley, Bucks Lake, Mountain Meadows Reservoir, and Lake Almanor (combined), Average Monthly (Critical)

A.9.10 Jackson Meadows Reservoir and Bowman Lake (combined)

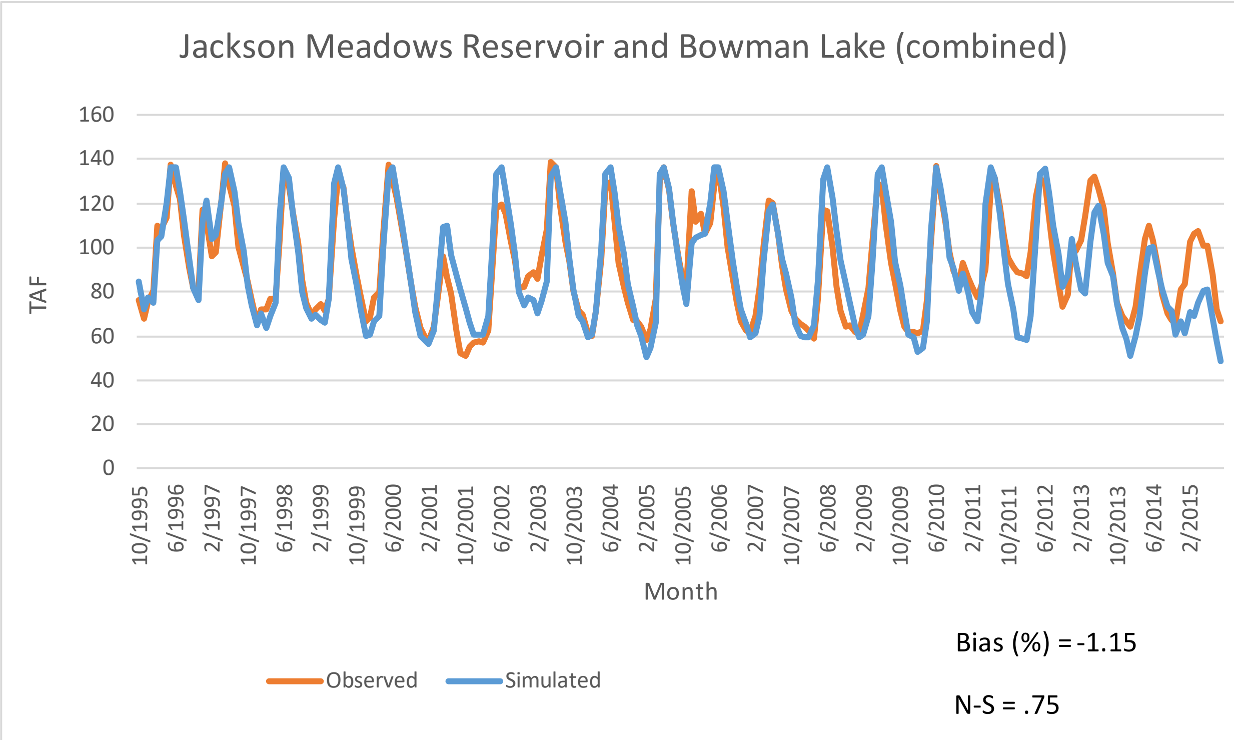


Figure A.9.10a. Jackson Meadows Reservoir and Bowman Lake (combined), Monthly 1996 to 2015

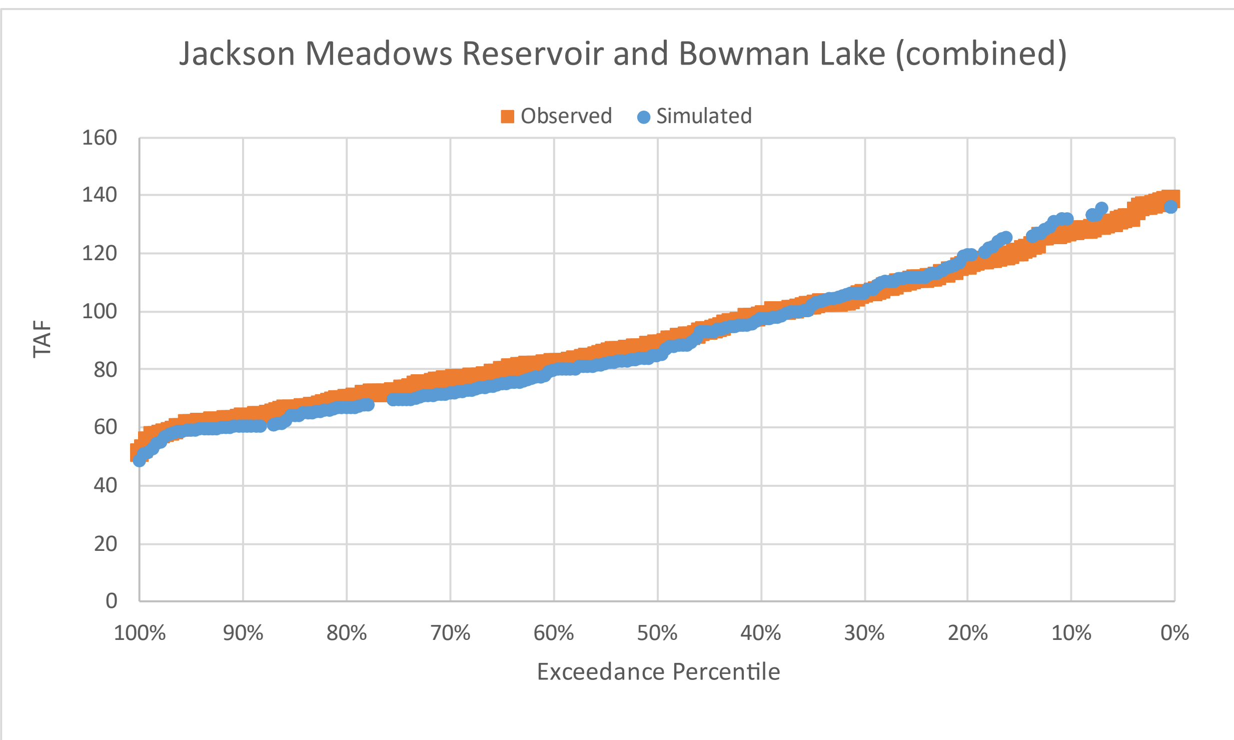


Figure A.9.10b. Jackson Meadows Reservoir and Bowman Lake (combined), Exceedance

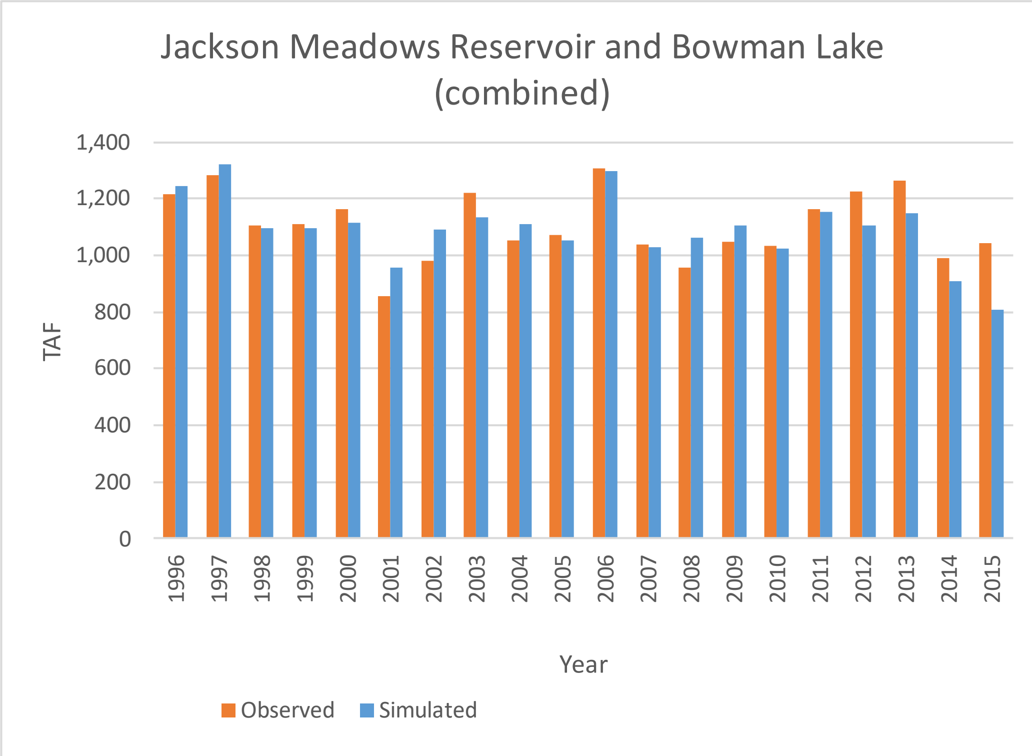


Figure A.9.10c. Jackson Meadows Reservoir and Bowman Lake (combined), Annual 1996 to 2015

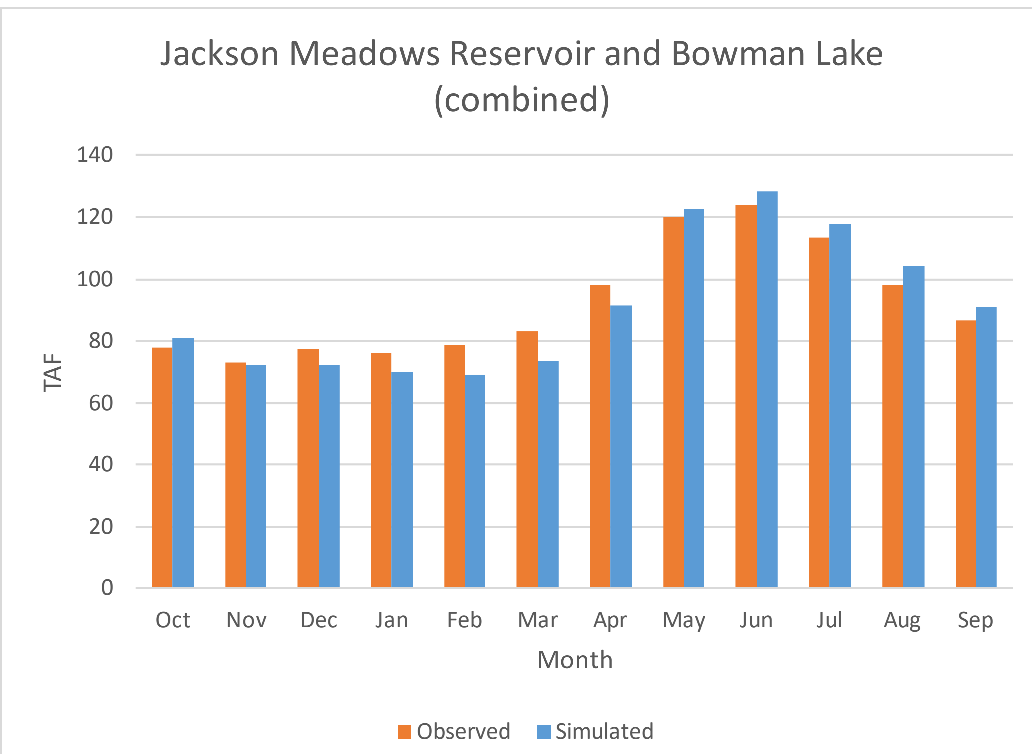


Figure A.9.10d. Jackson Meadows Reservoir and Bowman Lake (combined), Average Monthly

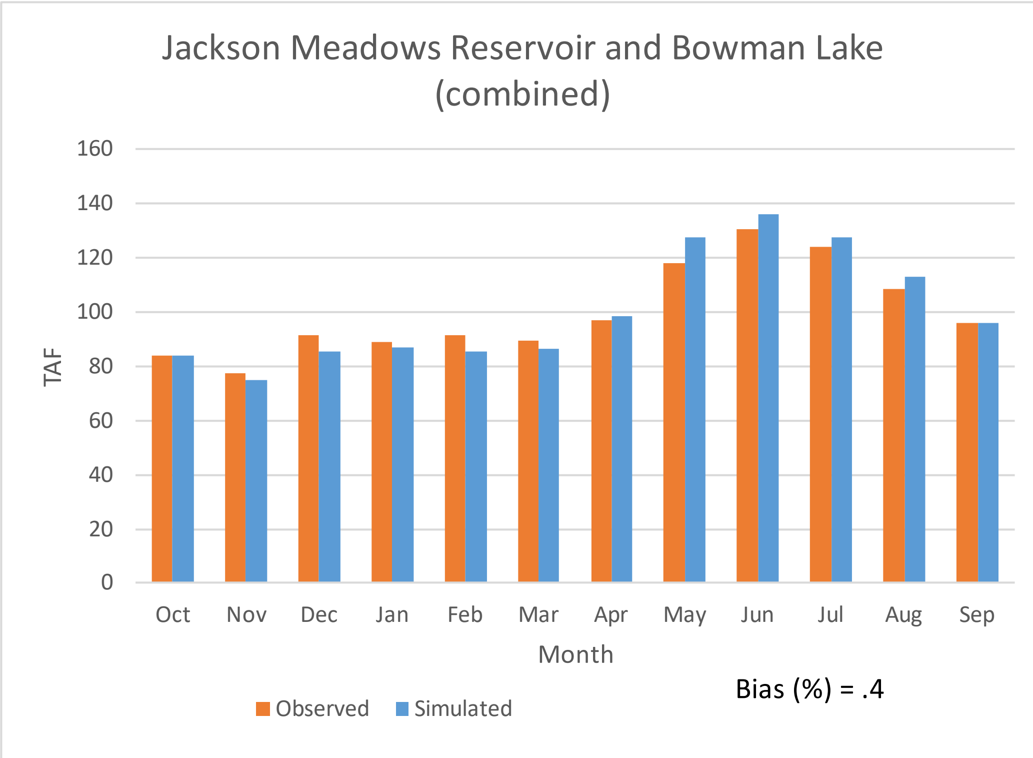


Figure A.9.10e. Jackson Meadows Reservoir and Bowman Lake (combined), Average Monthly (Wet)

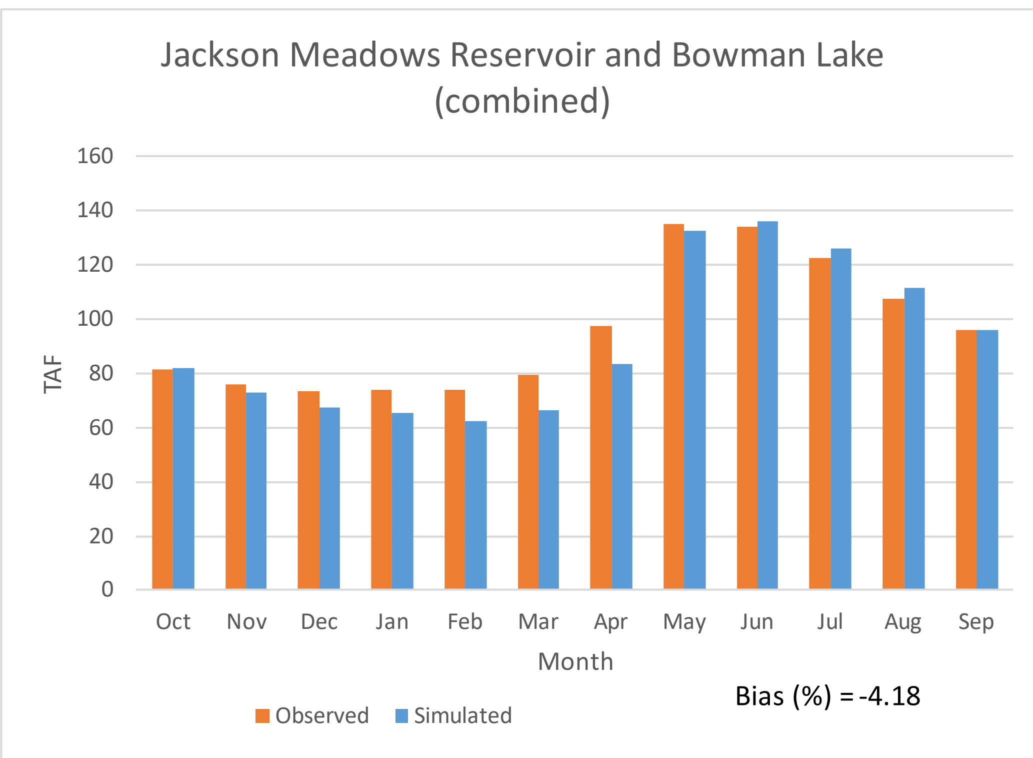


Figure A.9.10f. Jackson Meadows Reservoir and Bowman Lake (combined), Average Monthly (Above Normal)

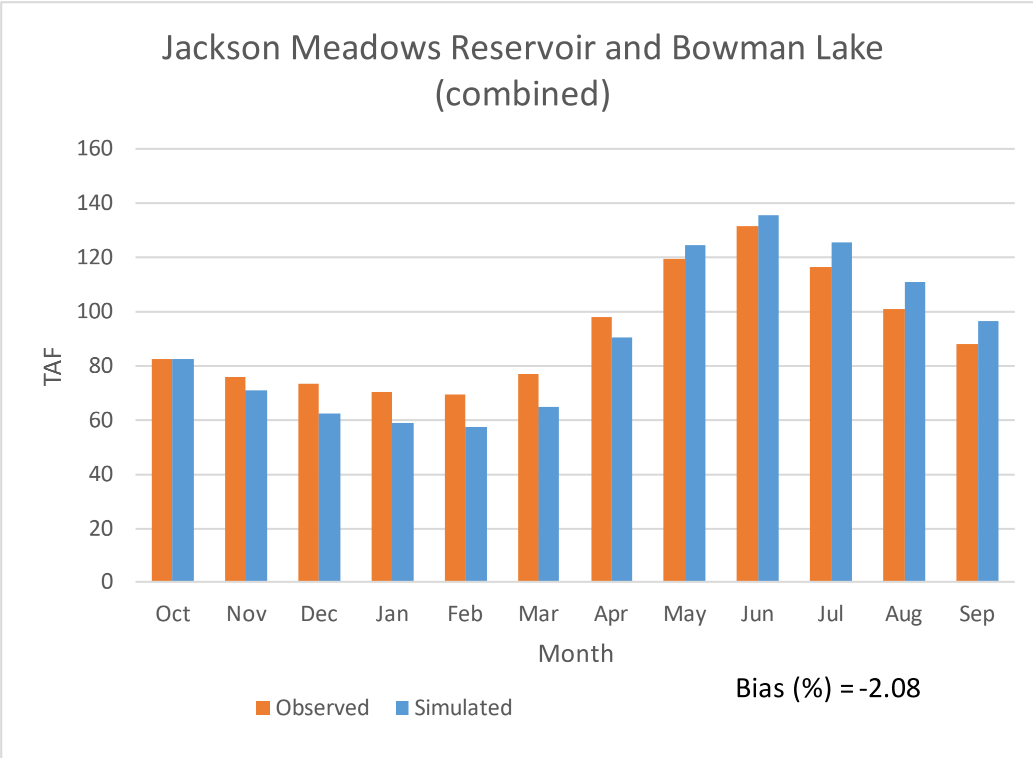


Figure A.9.10g. Jackson Meadows Reservoir and Bowman Lake (combined), Average Monthly (Below Normal)

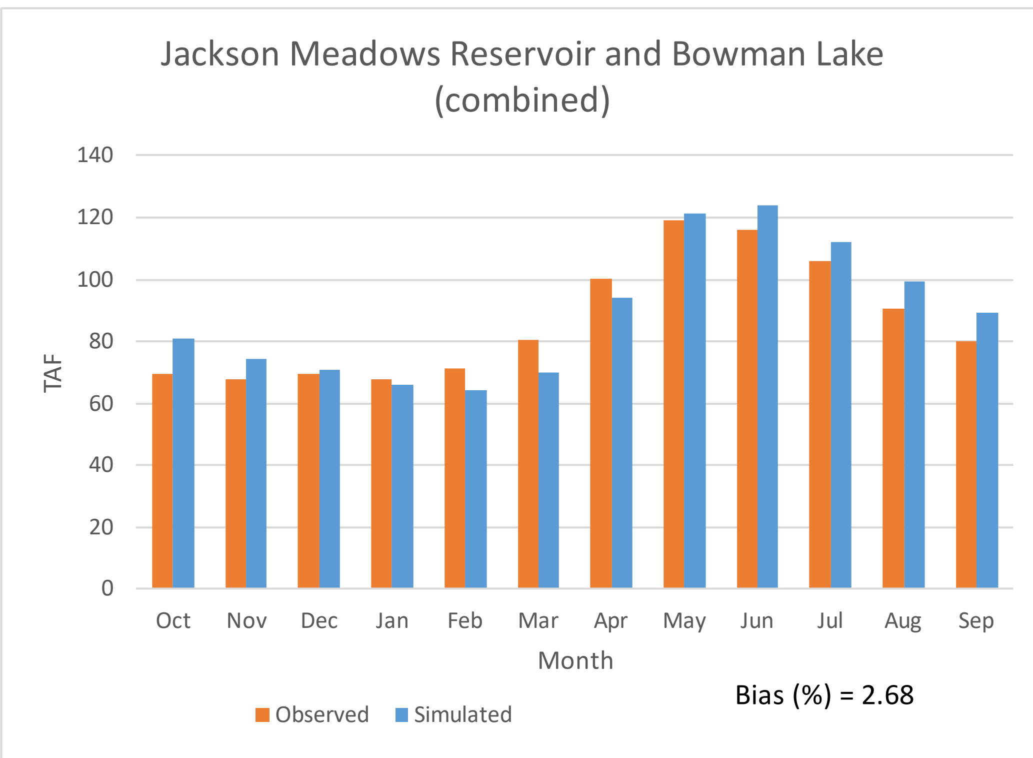


Figure A.9.10h. Jackson Meadows Reservoir and Bowman Lake (combined), Average Monthly (Dry)

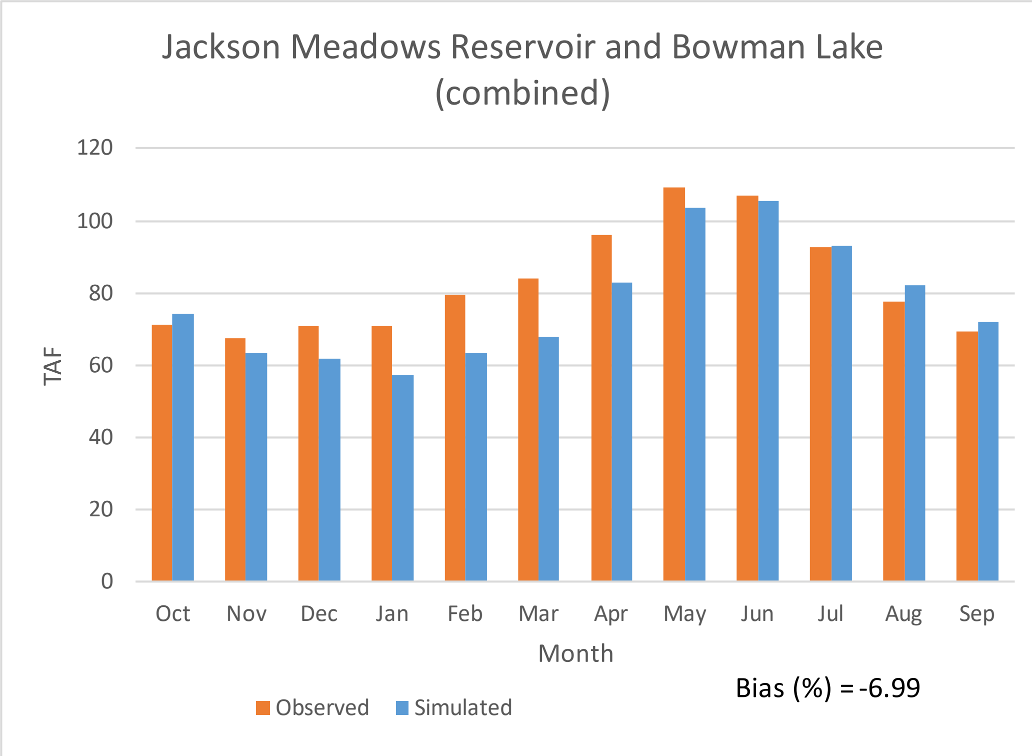


Figure A.9.10i. Jackson Meadows Reservoir and Bowman Lake (combined), Average Monthly (Critical)

A.9.11 Lake Fordyce and Lake Spaulding (combined)

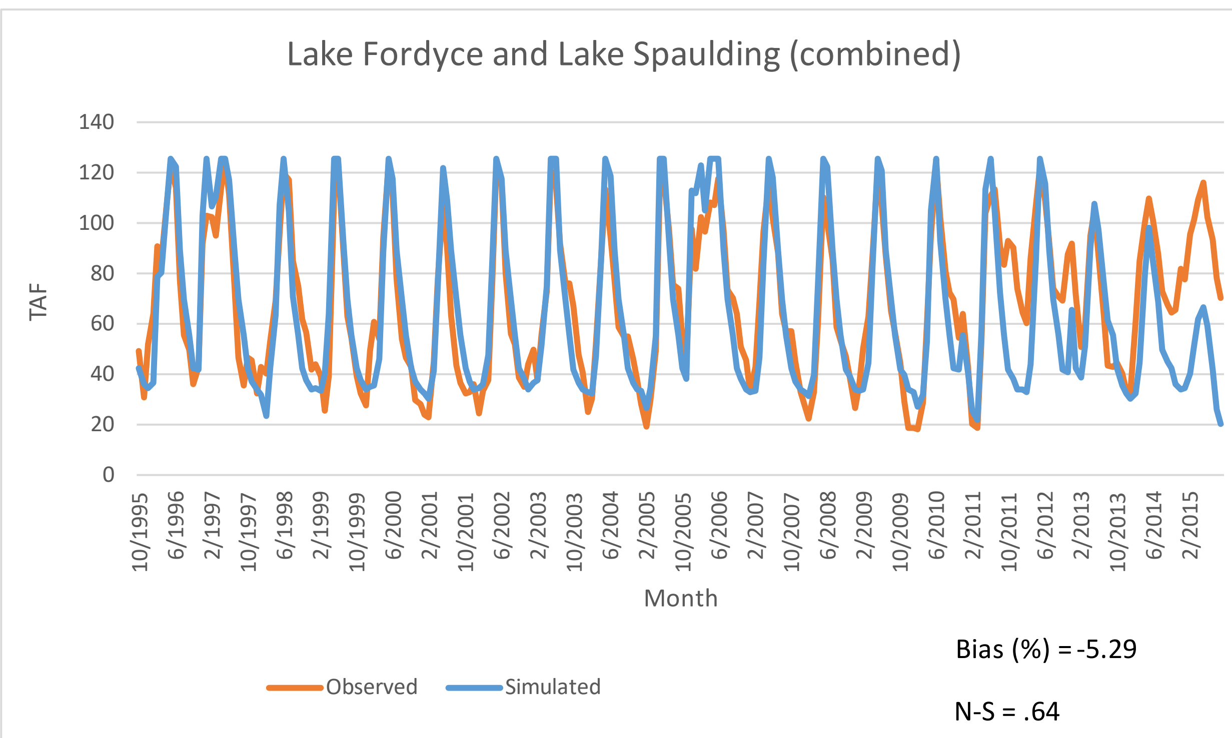


Figure A.9.11a. Lake Fordyce and Lake Spaulding (combined), Monthly 1996 to 2015

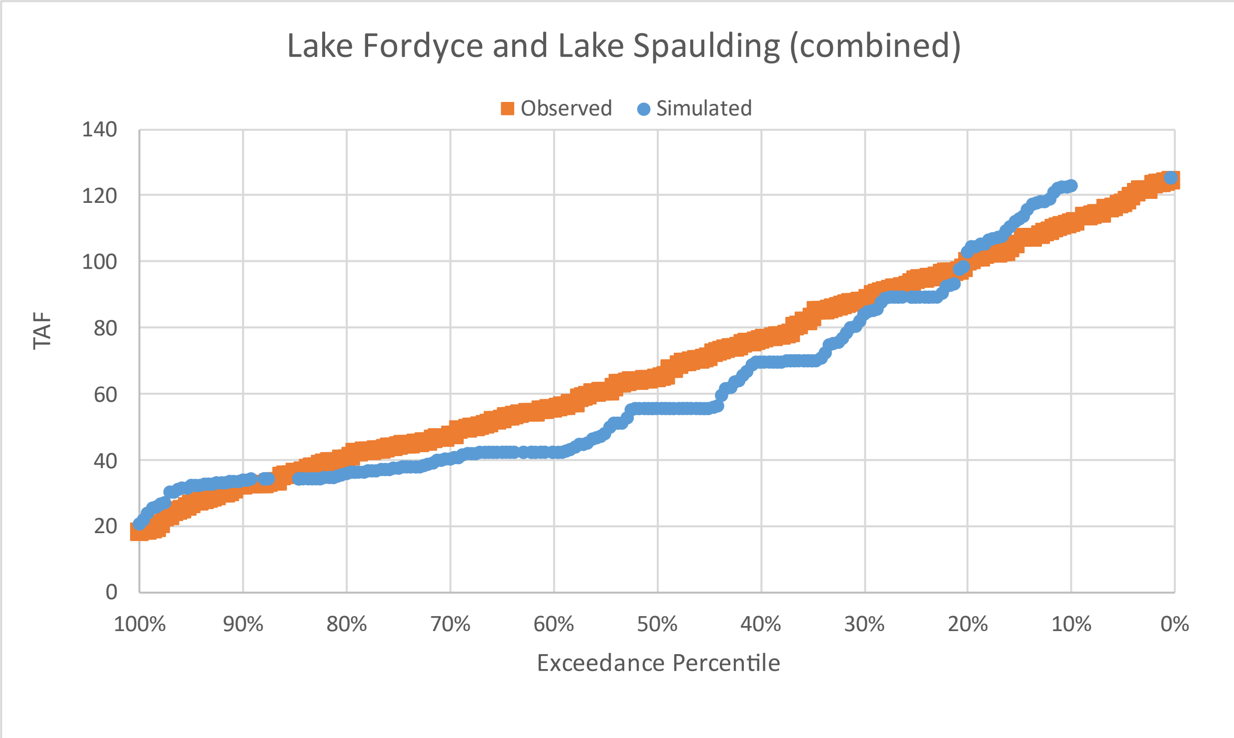


Figure A.9.11b. Lake Fordyce and Lake Spaulding (combined), Exceedance

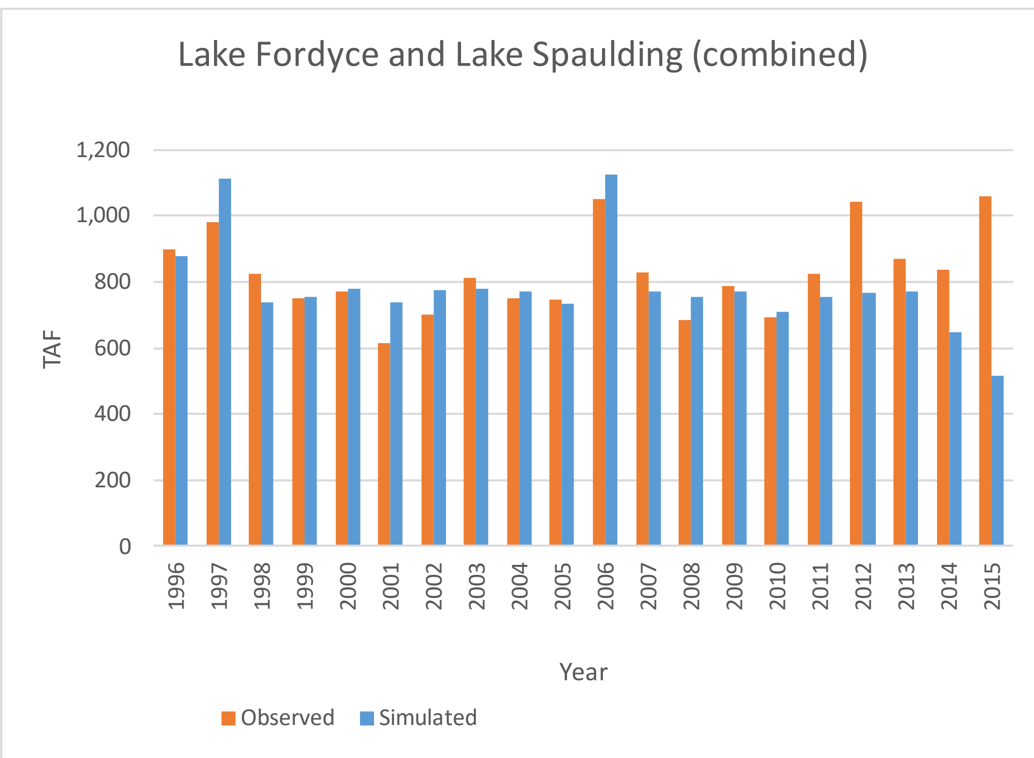


Figure A.9.11c. Lake Fordyce and Lake Spaulding (combined), Annual 1996 to 2015

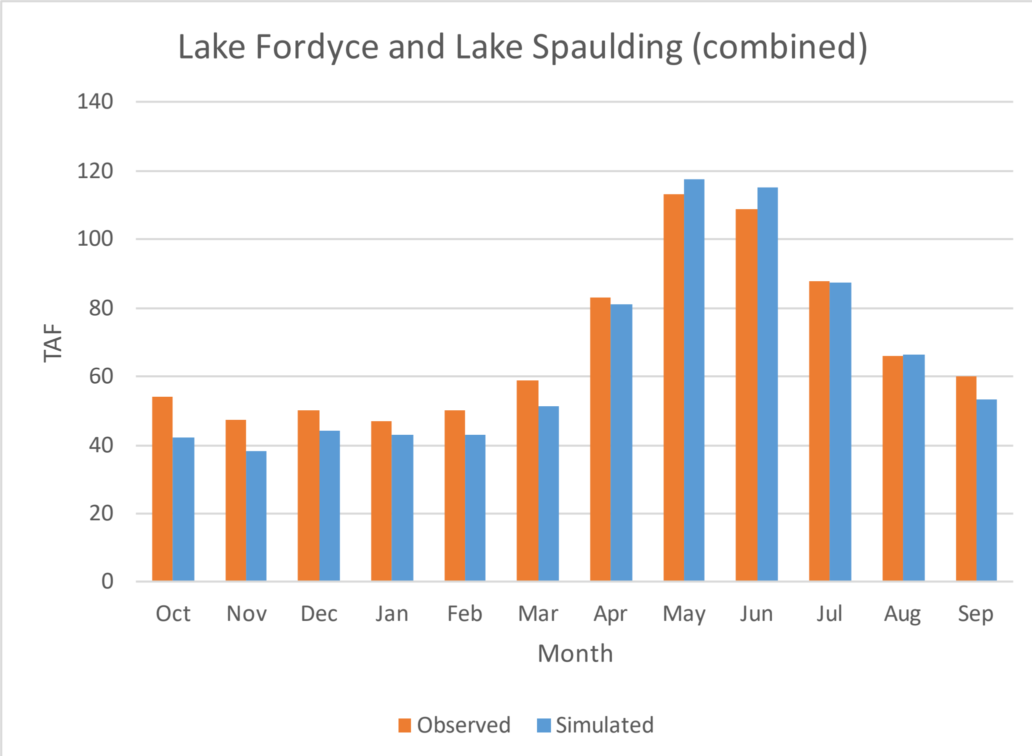


Figure A.9.11d. Lake Fordyce and Lake Spaulding (combined), Average Monthly

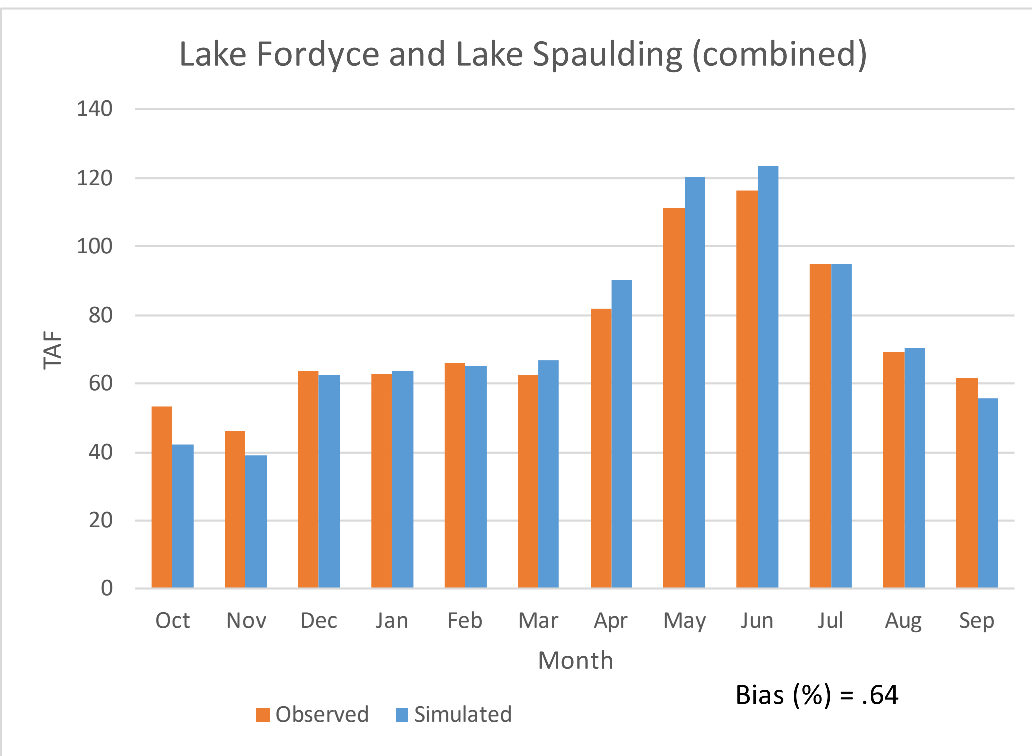


Figure A.9.11e. Lake Fordyce and Lake Spaulding (combined), Average Monthly (Wet)

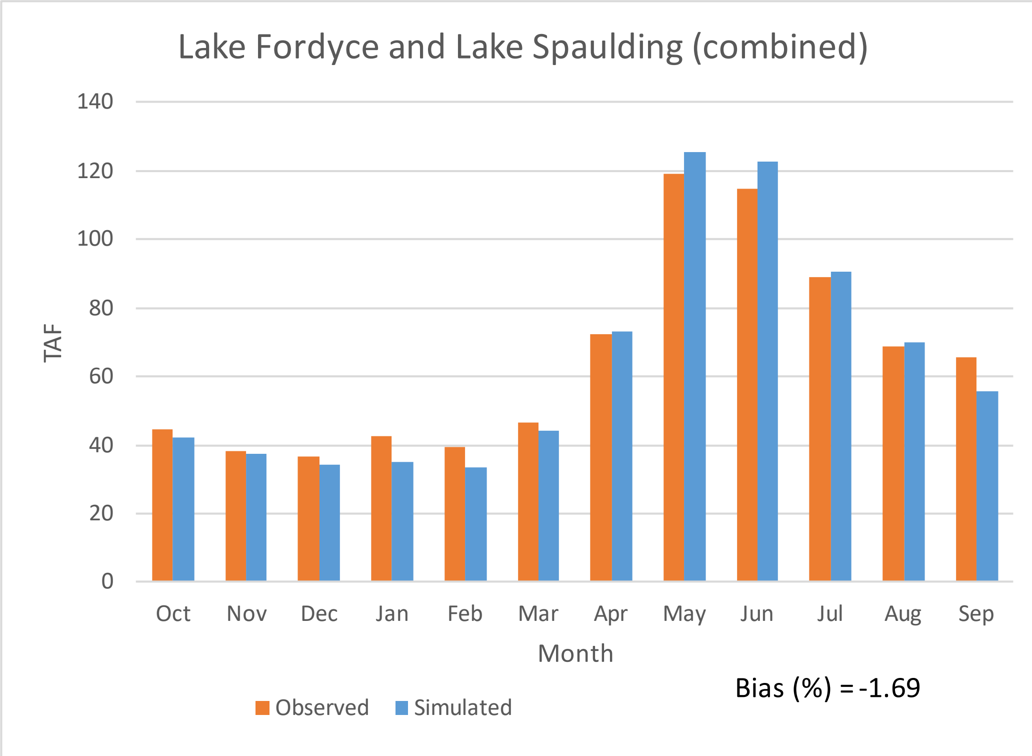


Figure A.9.11f. Lake Fordyce and Lake Spaulding (combined), Average Monthly (Above Normal)

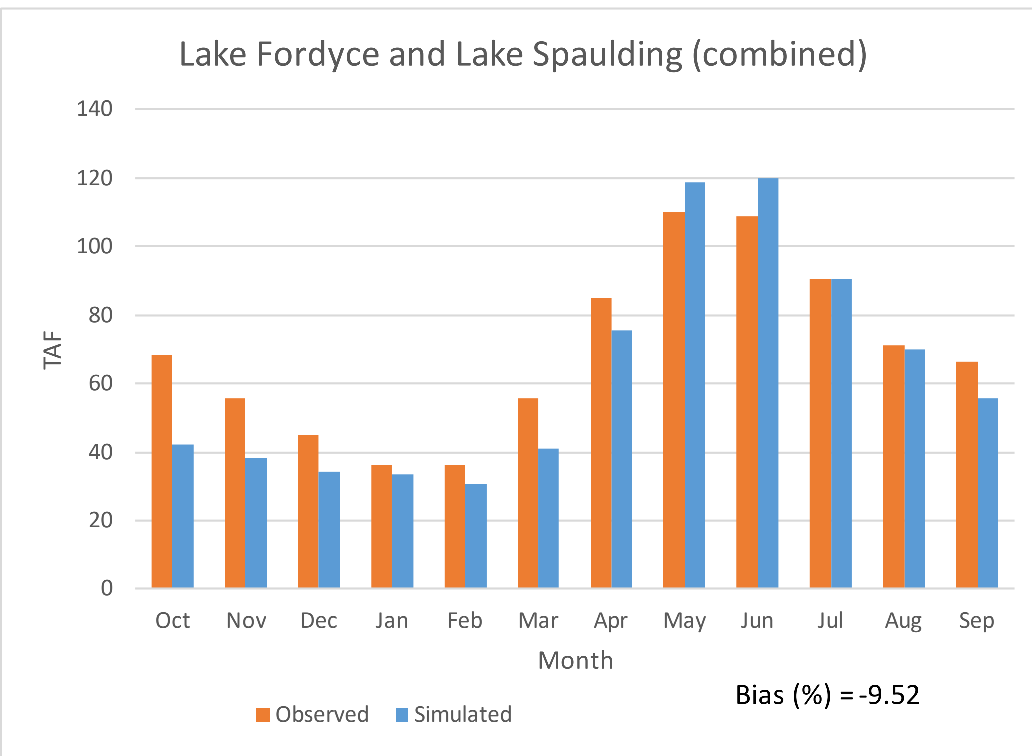


Figure A.9.11g. Lake Fordyce and Lake Spaulding (combined), Average Monthly (Below Normal)

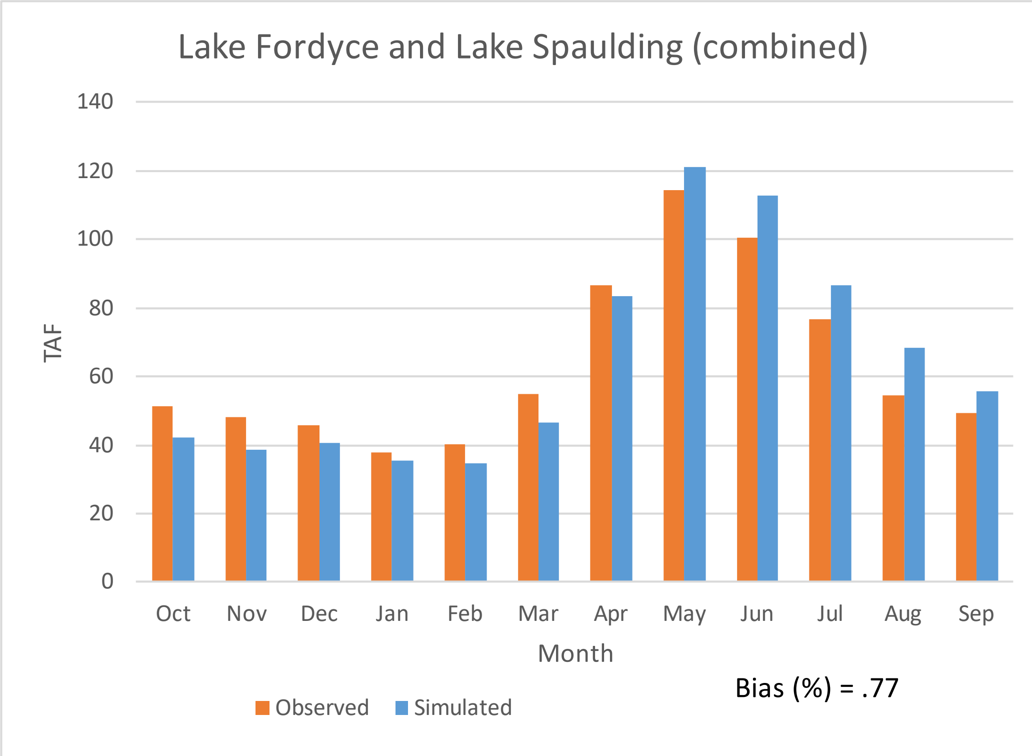


Figure A.9.11h. Lake Fordyce and Lake Spaulding (combined), Average Monthly (Dry)

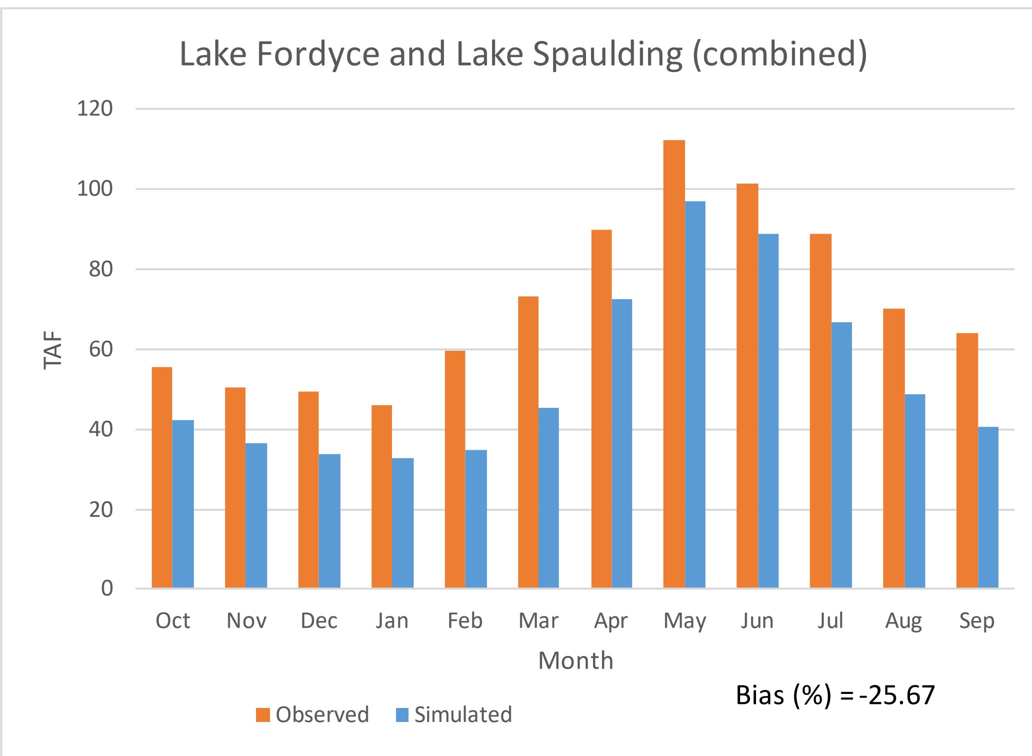


Figure A.9.11i. Lake Fordyce and Lake Spaulding (combined), Average Monthly (Critical)

A.9.12 French Meadows and Hell Hole Reservoirs (combined)

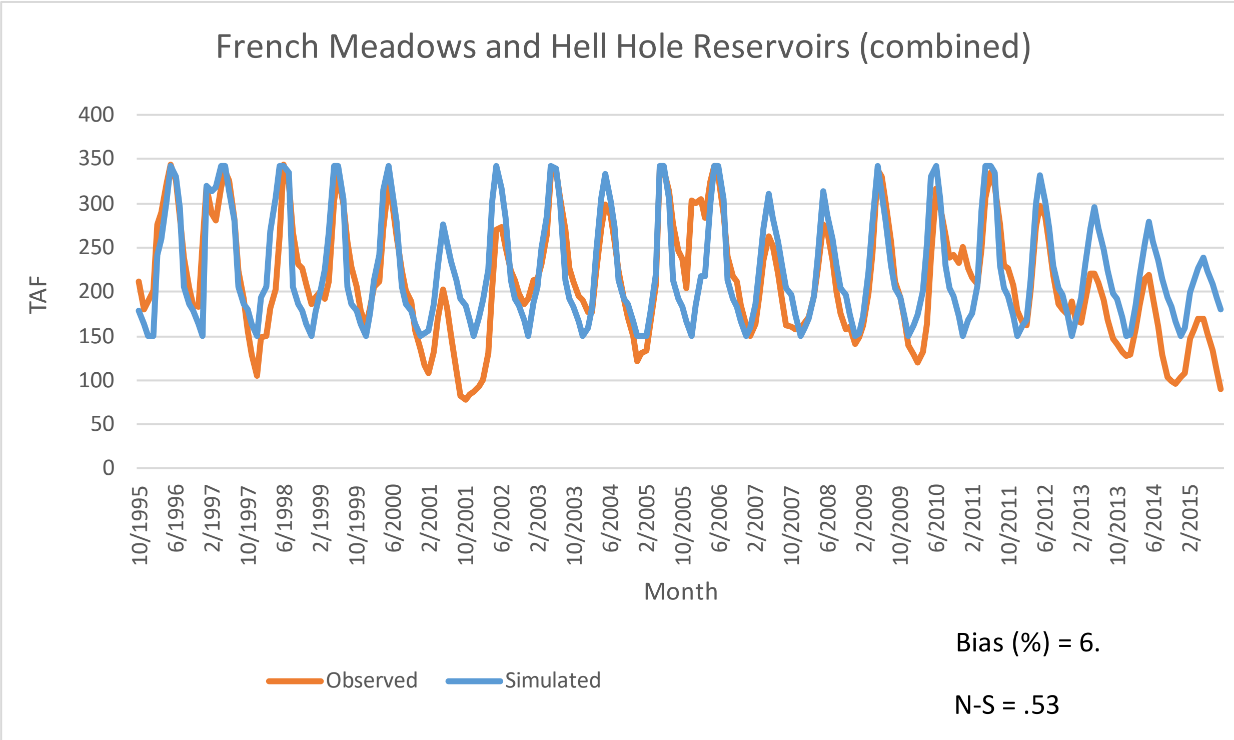


Figure A.9.12a. French Meadows and Hell Hole Reservoirs (combined), Monthly 1996 to 2015

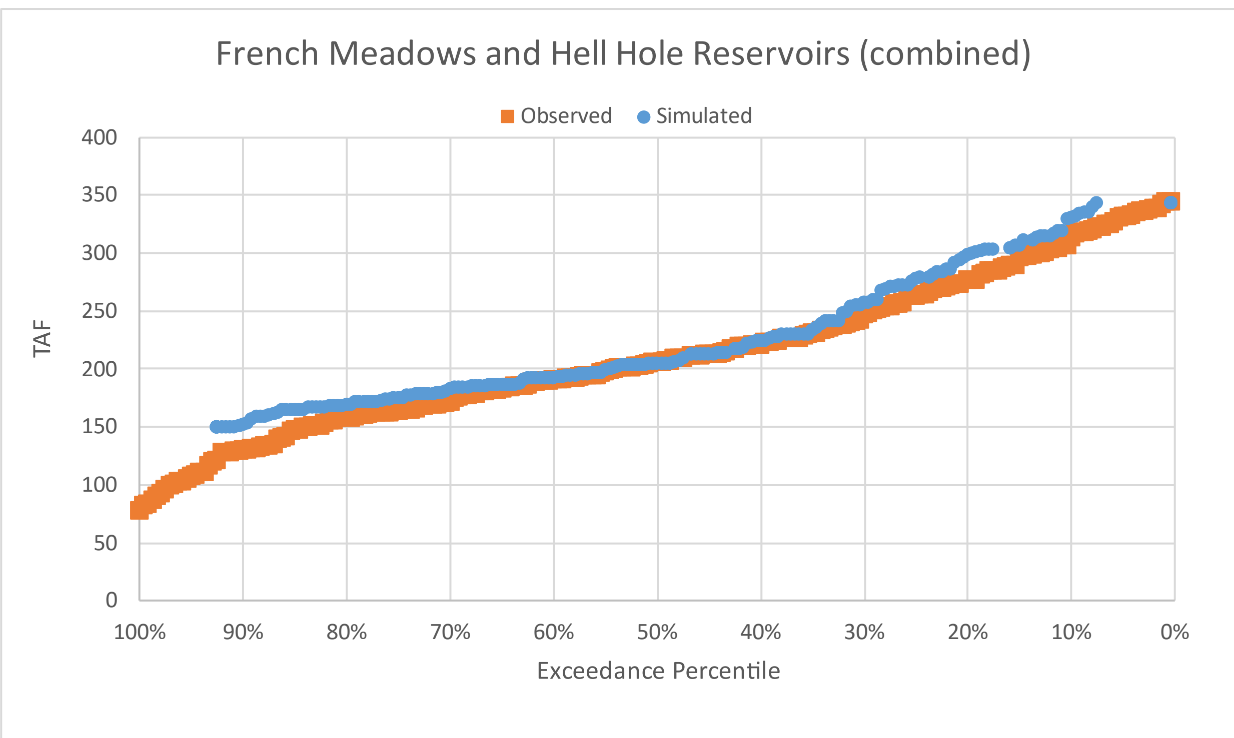


Figure A.9.12b. French Meadows and Hell Hole Reservoirs (combined), Exceedance

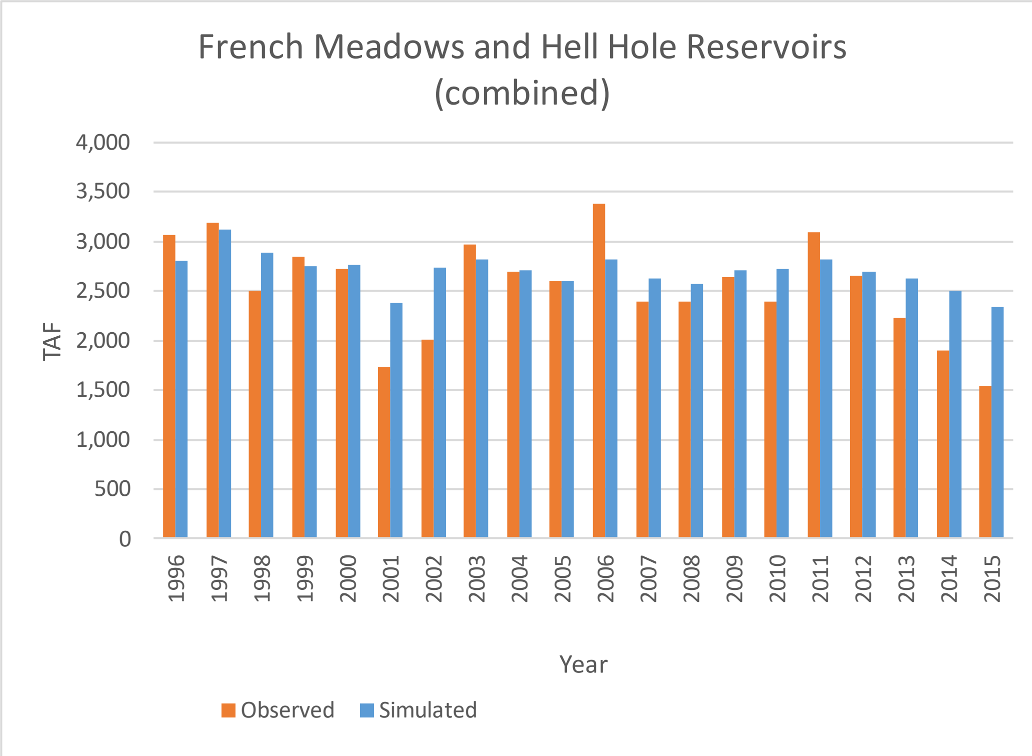


Figure A.9.12c. French Meadows and Hell Hole Reservoirs (combined), Annual 1996 to 2015

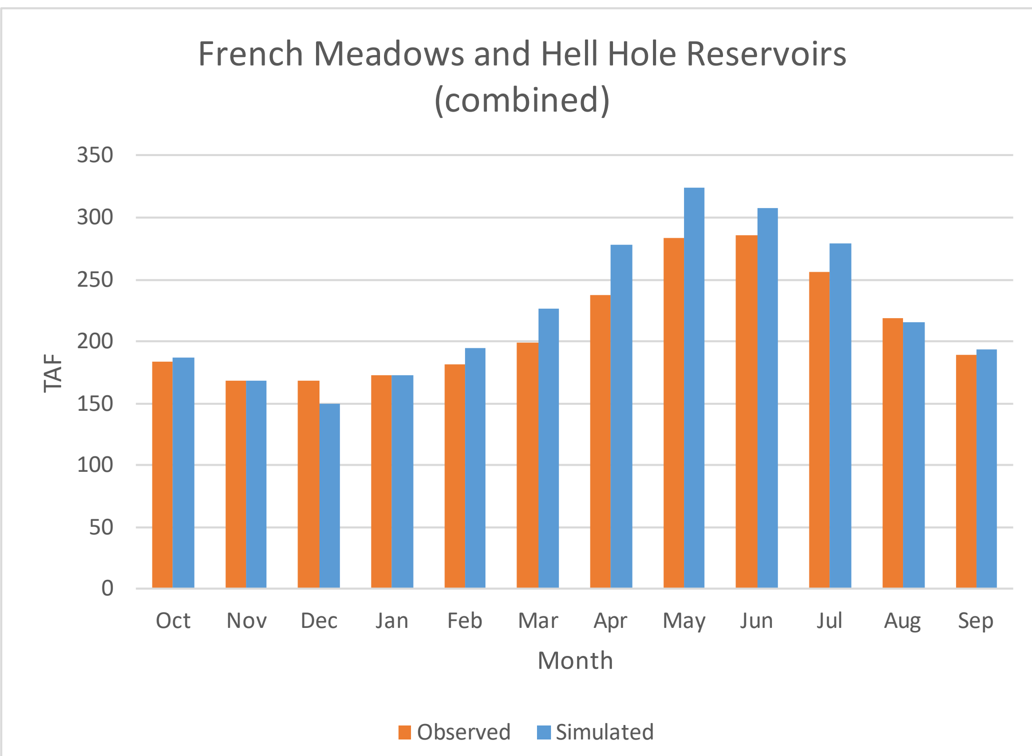


Figure A.9.12d. French Meadows and Hell Hole Reservoirs (combined), Average Monthly

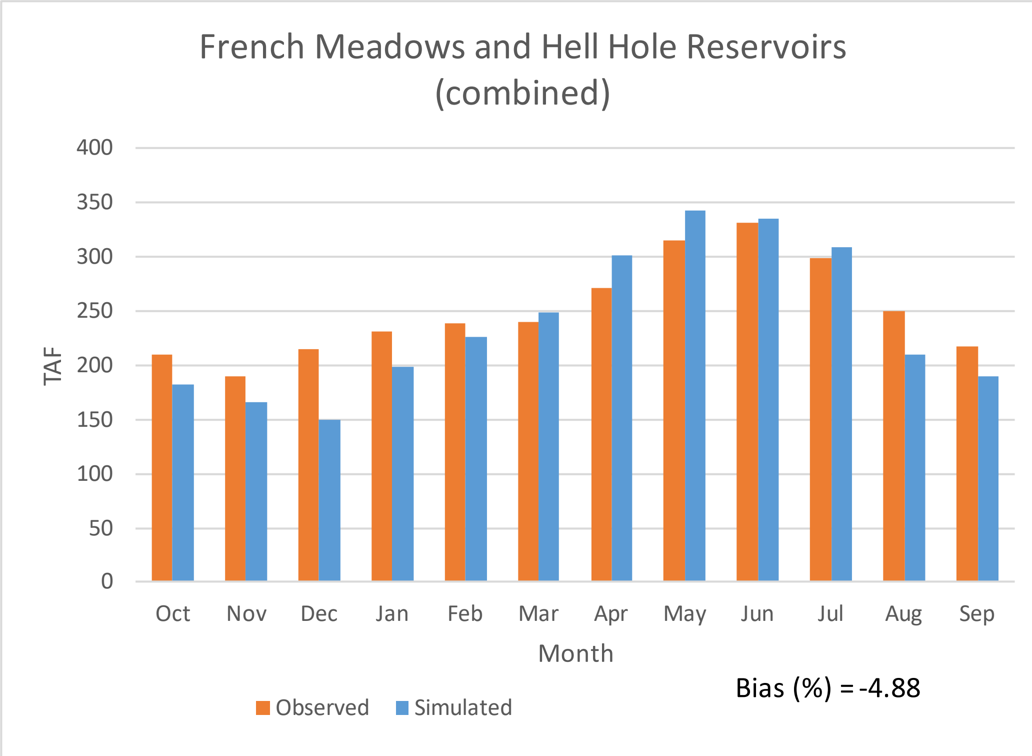


Figure A.9.12e. French Meadows and Hell Hole Reservoirs (combined), Average Monthly (Wet)

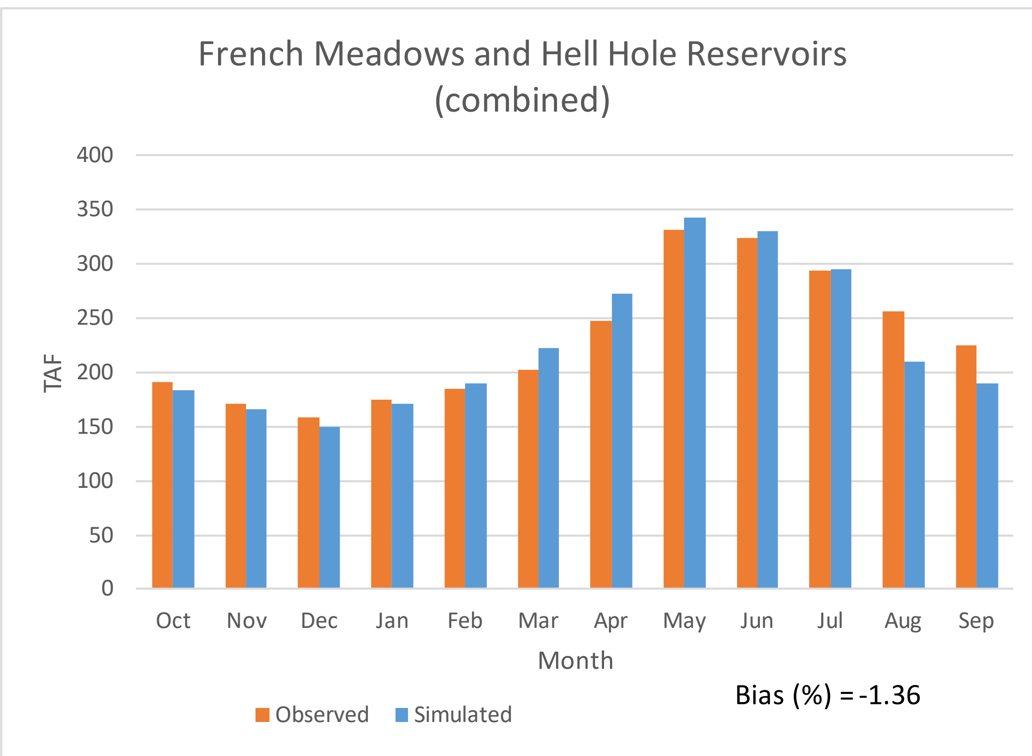


Figure A.9.12f. French Meadows and Hell Hole Reservoirs (combined), Average Monthly (Above Normal)

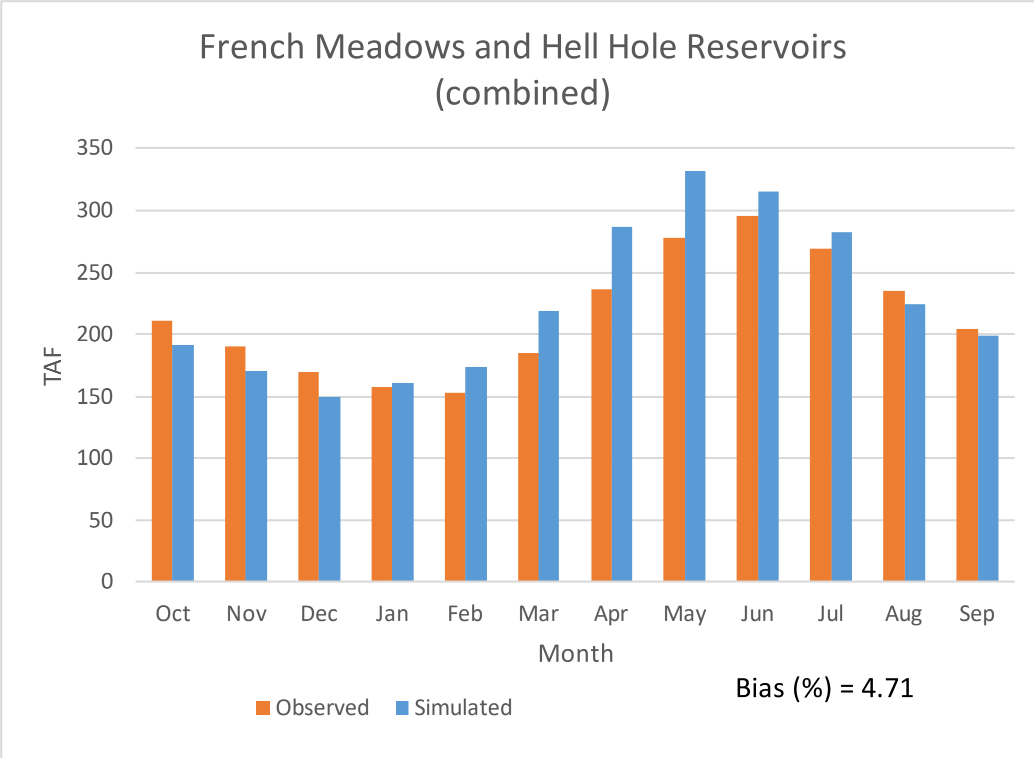


Figure A.9.12g. French Meadows and Hell Hole Reservoirs (combined), Average Monthly (Below Normal)

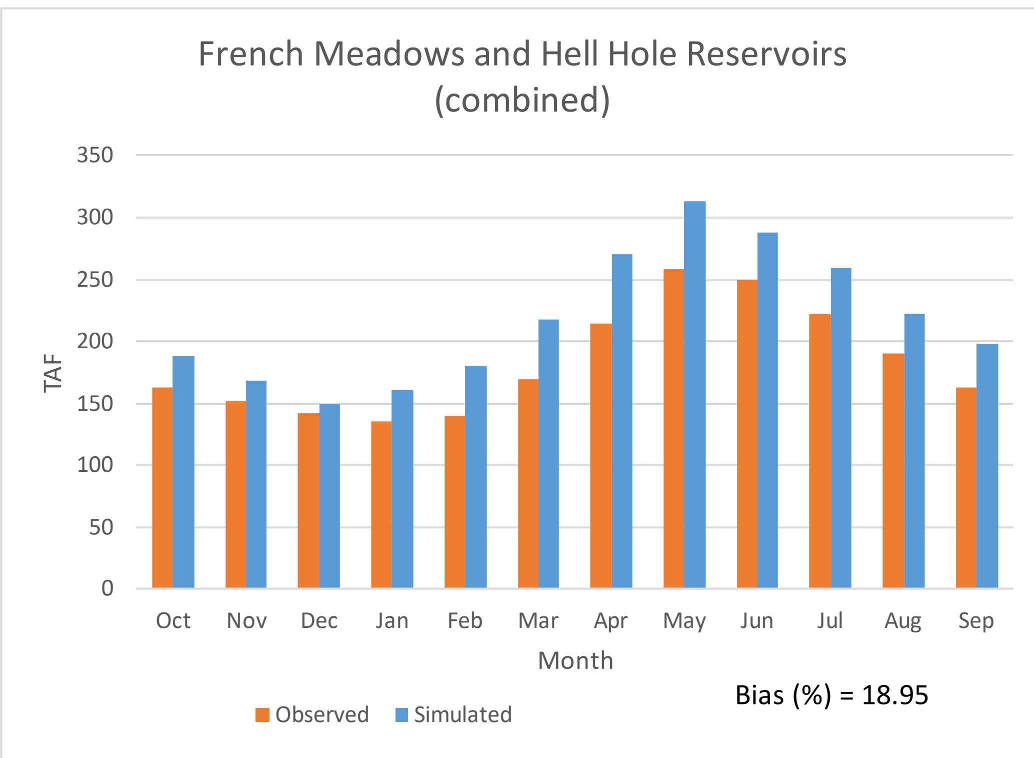


Figure A.9.12h. French Meadows and Hell Hole Reservoirs (combined), Average Monthly (Dry)

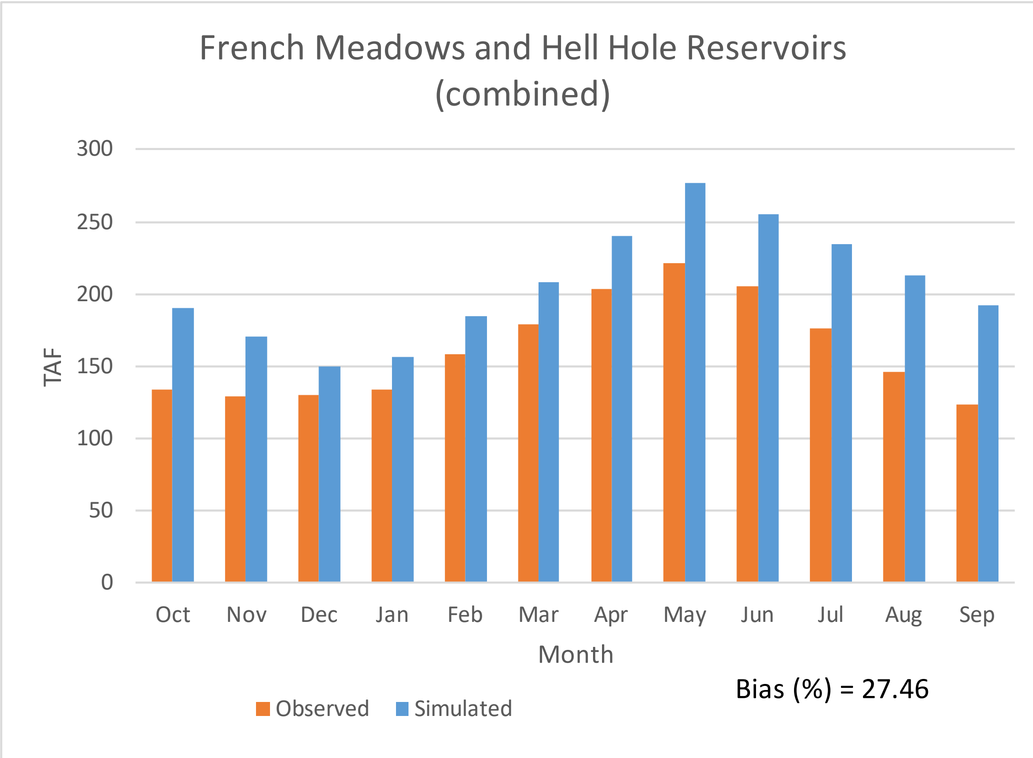


Figure A.9.12i. French Meadows and Hell Hole Reservoirs (combined), Average Monthly (Critical)

A.9.13 Ice House, Loon Lake and Union Valley (combined)

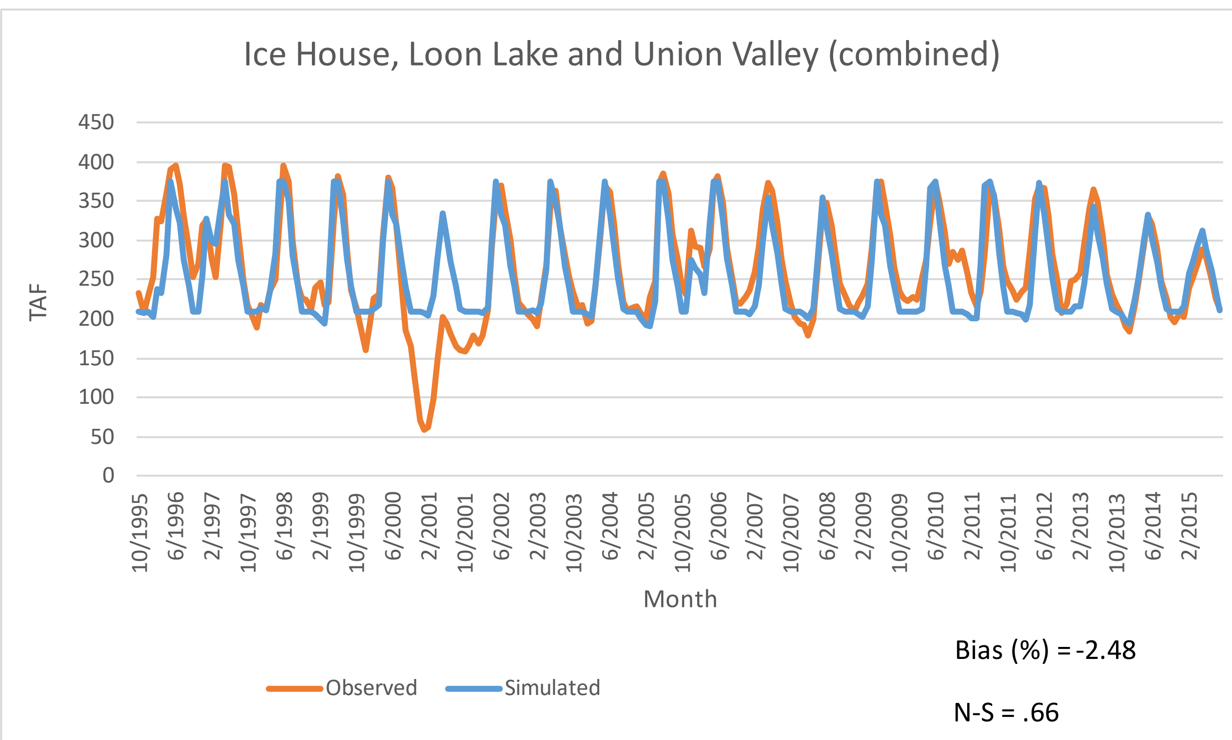


Figure A.9.13a. Ice House, Loon Lake and Union Valley (combined), Monthly 1996 to 2015

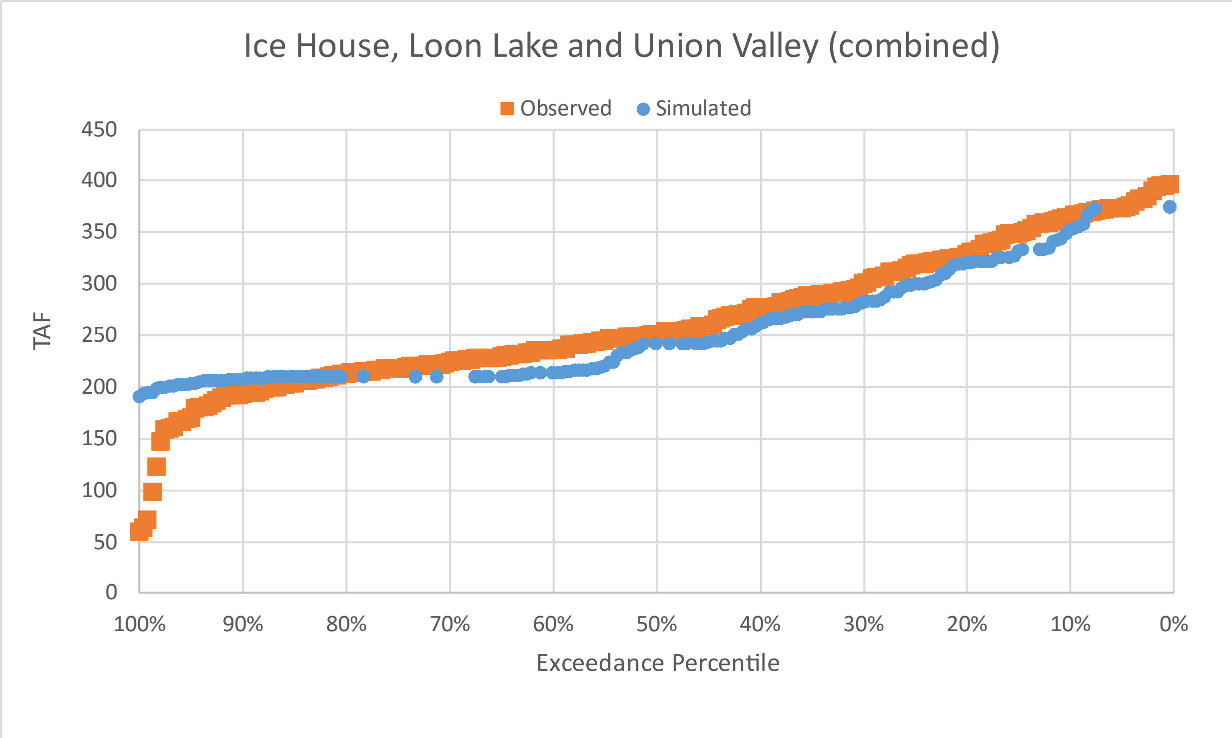


Figure A.9.13b. Ice House, Loon Lake and Union Valley (combined), Exceedance

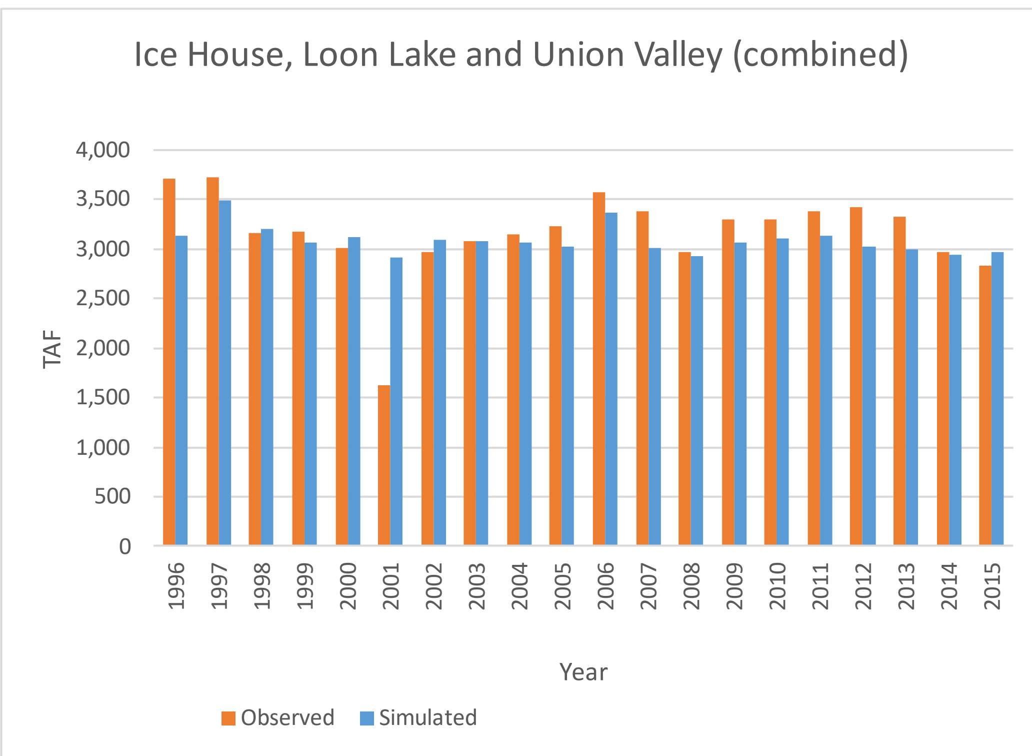


Figure A.9.13c. Ice House, Loon Lake and Union Valley (combined), Annual 1996 to 2015

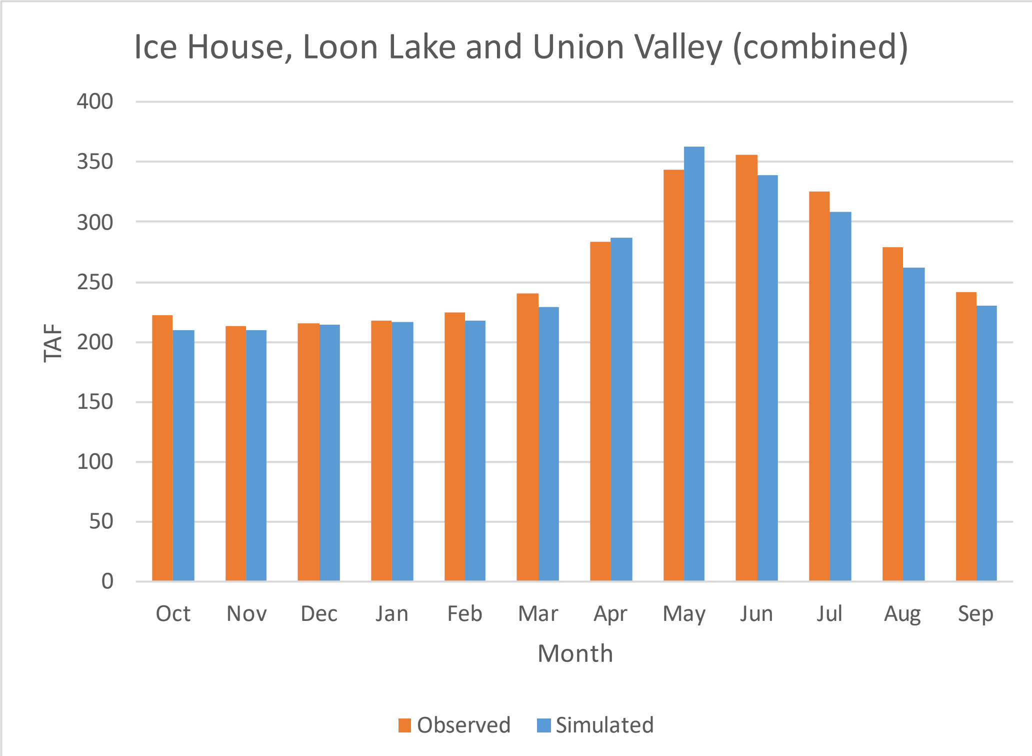


Figure A.9.13d. Ice House, Loon Lake and Union Valley (combined), Average Monthly

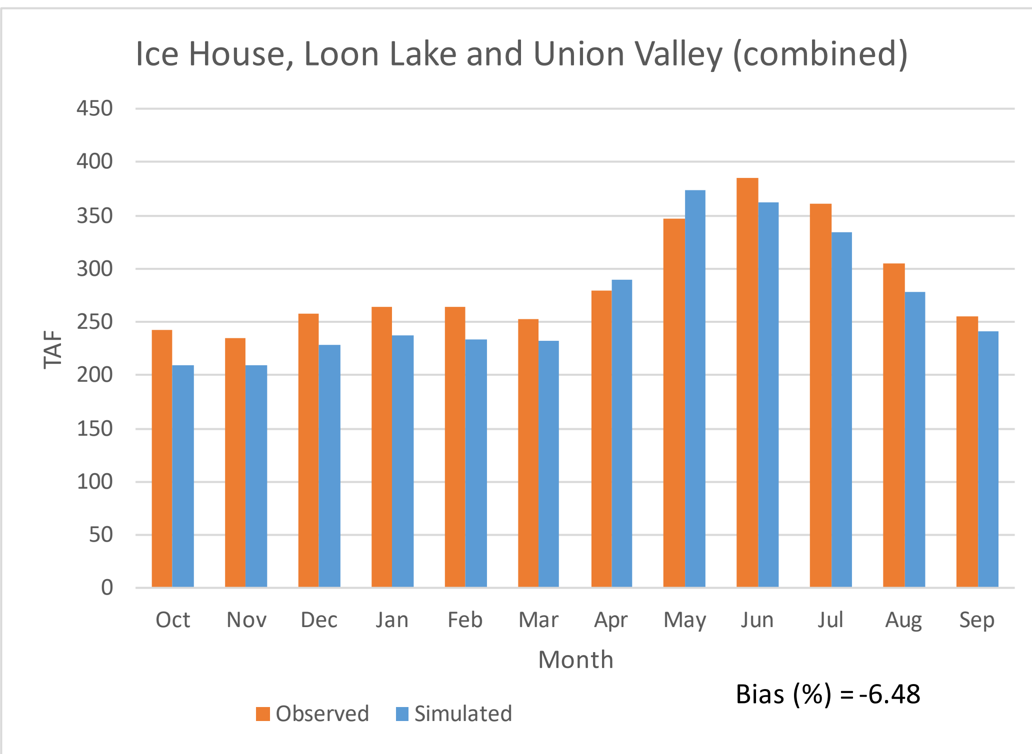


Figure A.9.13e. Ice House, Loon Lake and Union Valley (combined), Average Monthly (Wet)

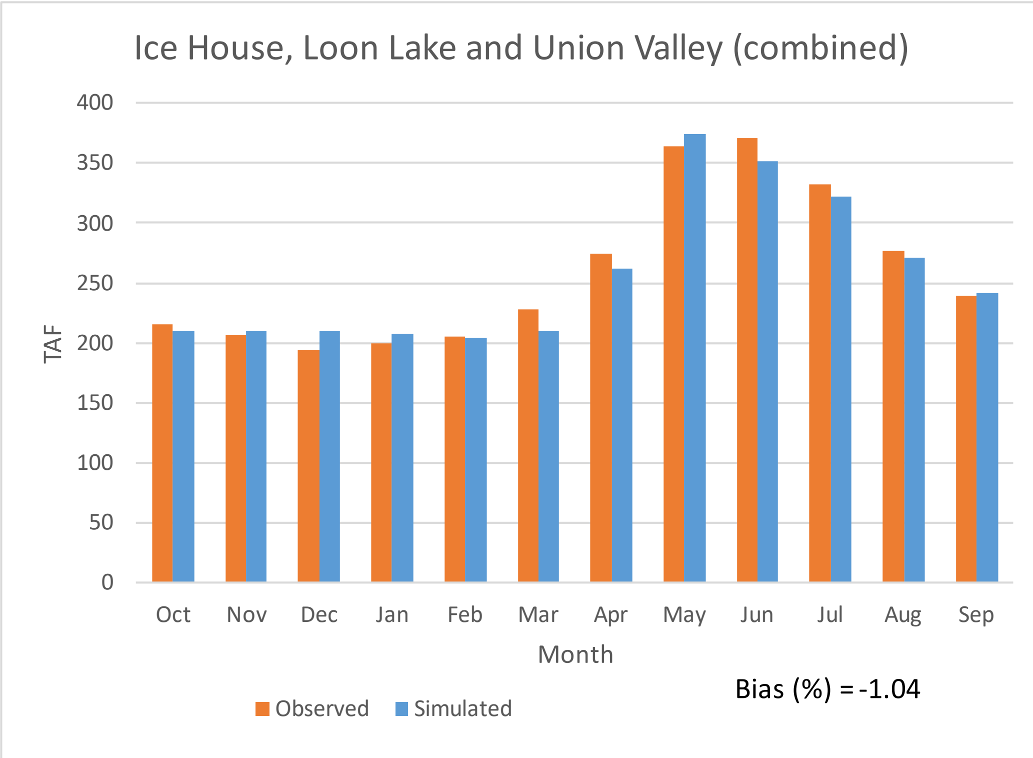


Figure A.9.13f. Ice House, Loon Lake and Union Valley (combined), Average Monthly (Above Normal)

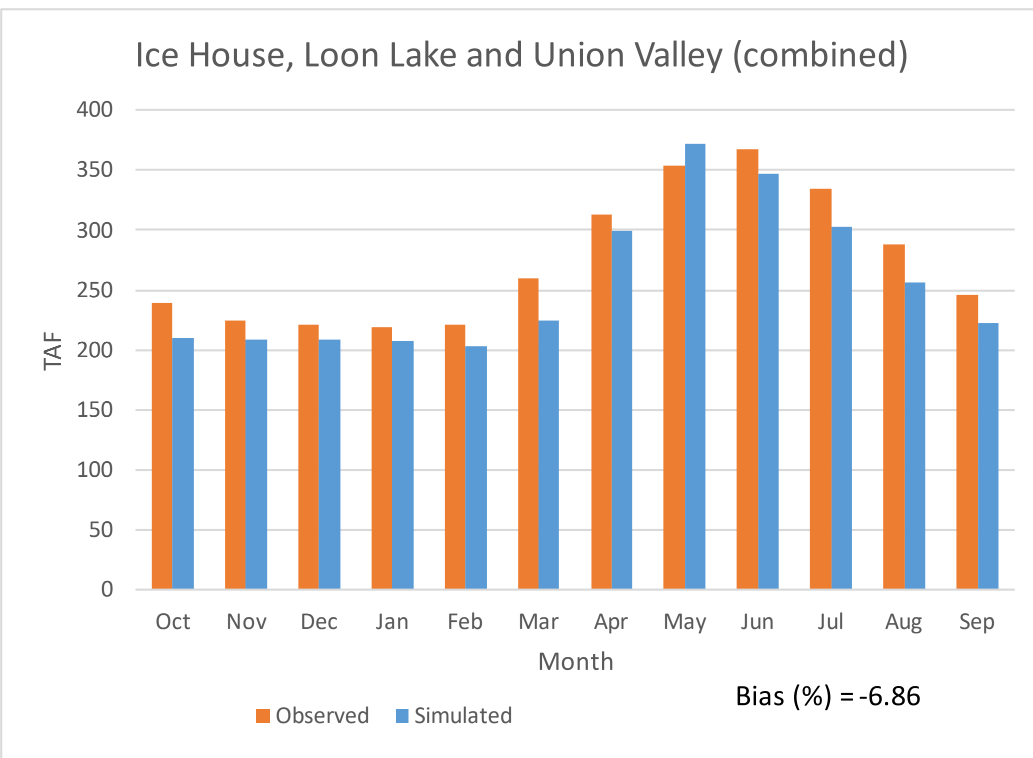


Figure A.9.13g. Ice House, Loon Lake and Union Valley (combined), Average Monthly (Below Normal)

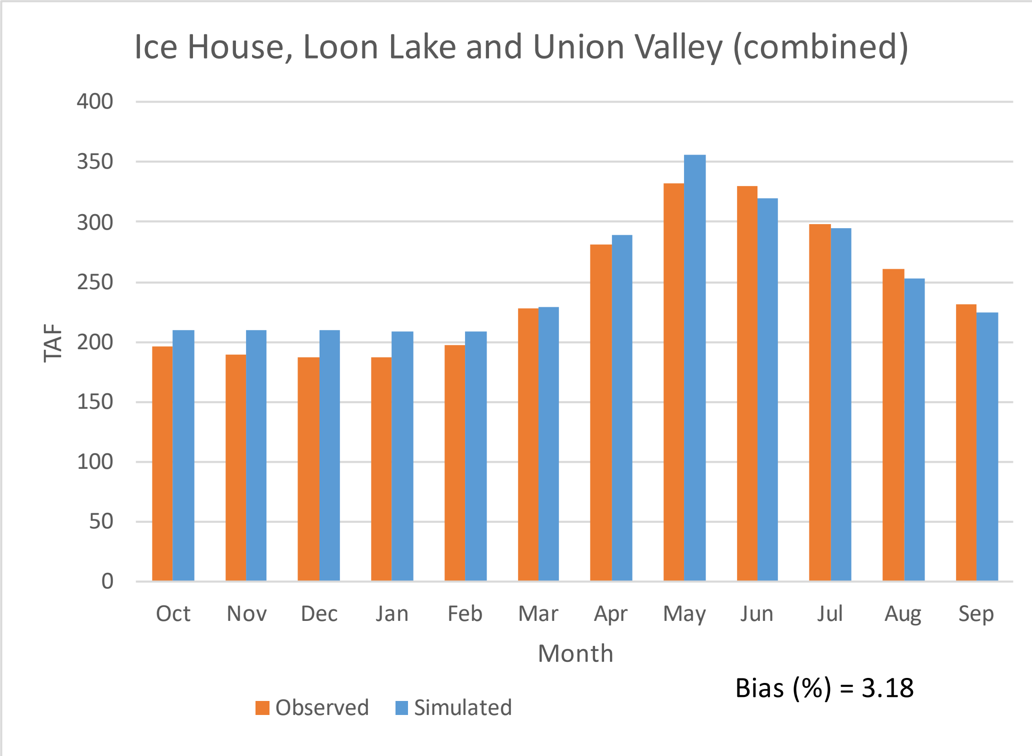


Figure A.9.13h. Ice House, Loon Lake and Union Valley (combined), Average Monthly (Dry)

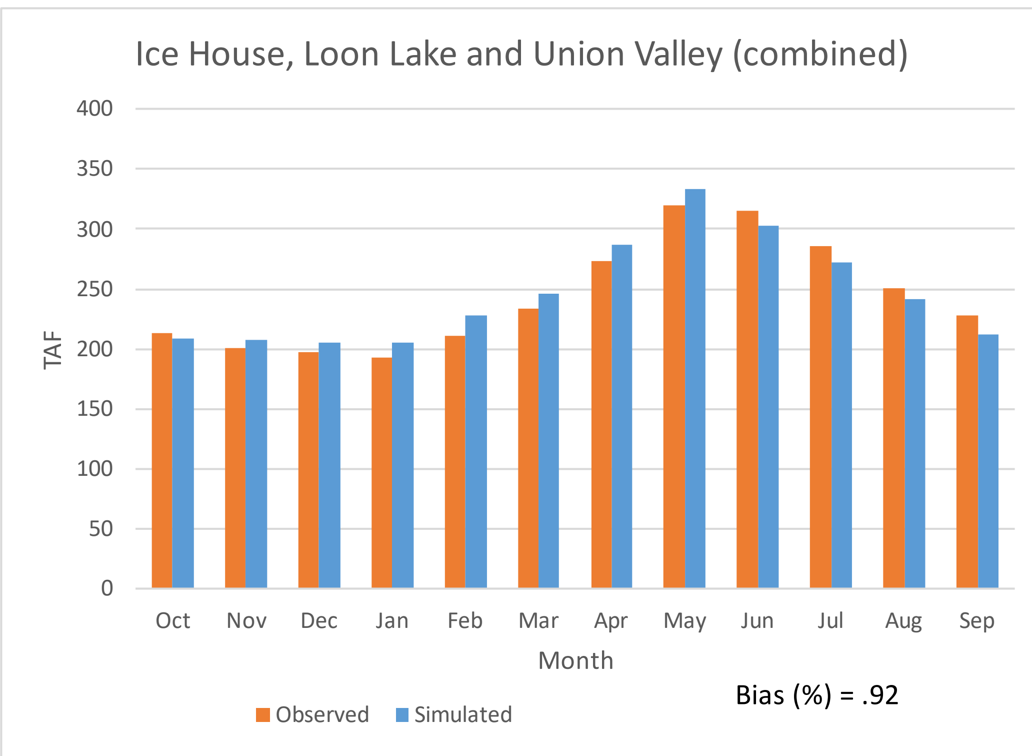


Figure A.9.13i. Ice House, Loon Lake and Union Valley (combined), Average Monthly (Critical)

A.10 Model Sensitivity Analysis

Model sensitivity analysis was undertaken using SacWAM version 1.05 on the recommendation of the peer review panel. In particular the panel recommended that the sensitivity of model flows and storage to assumed flows on the San Joaquin River at Vernalis be tested. In addition to that test, the model development team opted to compute the sensitivity of model results to the specified ET rates as there is uncertainty in this estimate due to uncertainty in cultivation timing, exact crop coefficients, and the degree to which a crop field transpires at the potential rate. Sensitivity tests were conducted by running the model with additional factors the increased or decreased the parameter of interest by a fixed percentage.

A.10.1 Evapotranspiration Analysis

The sensitivity analysis on evapotranspiration was done by increasing and decreasing the basal crop coefficients found in the *Crop Library* by +/- 5% for water years 2000-2015. This included the crop coefficients for all crops as well as the Native Vegetation and Wetlands land classes. Analysis of flows in the Delta region and combined CVP/SWP storage show that the model results change as expected, with an increase in ET resulting in less flow into the Delta and less storage and the opposite for a decrease in ET. Overall, the results are not very sensitive to changes of +/-5% in ET. The largest changes are for combined storage and at maximum are 1.8% and -1.9% for the critical years. Changes in Delta inflows, Delta outflow, and Delta exports are smaller as a percentage of the base case.

Table A-10.1. Sensitivity of Model Results to +/-5% change in ET

	Year Type					
	All	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
	Delta Inflow					
+5%	-79 (-0.4%)	-86 (-0.2%)	-113 (-0.5%)	-51 (-0.3%)	-106 (-0.8%)	-44 (-0.5%)
-5%	76 (0.4%)	112 (0.3%)	74 (0.3%)	78 (0.5%)	81 (0.6%)	37 (0.4%)
	Delta Outflow					
+5%	-49 (-0.3%)	-92 (-0.3%)	-97 (-0.6%)	-32 (-0.3%)	-18 (-0.2%)	-9 (-0.2%)
-5%	59 (0.4%)	91 (0.3%)	62 (0.4%)	56 (0.5%)	34 (0.4%)	42 (0.4%)
	Delta Exports					
+5%	-21 (-0.4%)	1 (0.0%)	-10 (-0.2%)	-16 (-0.3%)	-56 (-1.3%)	-29 (-1.0%)
-5%	19 (0.4%)	20 (0.3%)	11 (0.2%)	17 (0.3%)	50 (1.1%)	2 (0.1%)
	Combined CVP SWP Storage					
+5%	-62 (-0.7%)	-28 (-0.3%)	-45 (-0.5%)	-39 (-0.4%)	-59 (-0.7%)	-120 (-1.9%)
-5%	69 (0.8%)	24 (0.2%)	47 (0.5%)	68 (0.7%)	90 (1.1%)	111 (1.8%)

A.10.2 Vernalis Inflow Analysis

The sensitivity of model results to changes in the specified San Joaquin flows at Vernalis for water years 2000-2015 was tested by running the model with plus and minus 10% flow. The results shown in Table A-10.2 indicate that Delta inflow, Delta outflow and combined CVP/SWP storage all change less than 2% for all water year types. The most sensitive result is the Delta exports which changed by up to 2.6% in critical years when the Vernalis inflow was increased by 10%.

Table A-10.2 Sensitivity of Model Results to +/-10% Change in Vernalis Inflow

	Year Type					
	All	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
			Delta Inflow			
-10%	-297 (-1.4%)	-549 (-1.6%)	-302 (-1.3%)	-219 (-1.3%)	-163 (-1.3%)	-96 (-1.0%)
+10%	297 (1.4%)	549 (1.6%)	276 (1.2%)	231 (1.4%)	158 (1.2%)	114 (1.2%)
			Delta Outflow			
-10%	-199 (-1.3%)	-427 (-1.5%)	-206 (-1.2%)	-138 (-1.3%)	-63 (-0.8%)	-25 (-0.5%)
+10%	199 (1.3%)	445 (1.5%)	171 (1.0%)	132 (1.3%)	59 (0.8%)	35 (0.7%)
			Delta Exports			
-10%	-97 (-1.9%)	-122 (-2.0%)	-95 (-1.7%)	-80 (-1.5%)	-99 (-2.2%)	-68 (-2.2%)
+10%	97 (1.9%)	104 (1.7%)	105 (1.9%)	98 (1.9%)	98 (2.2%)	78 (2.6%)
			Combined CVP SWP Storage			
-10%	-67 (-0.7%)	-67 (-0.7%)	-32 (-0.3%)	-67 (-0.7%)	-75 (-0.9%)	-86 (-1.3%)
+10%	79 (0.9%)	55 (0.5%)	59 (0.6%)	81 (0.9%)	108 (1.3%)	96 (1.5%)

A.11 Data Directory

Referenced Name	File Name	File Location
ET calibration	ET Calibration.xlsx	Data\Demand_Sites_and_Catchments\Agricultural_Catchments\Land_Use
rainfall runoff calibration	Rainfall Runoff Calibration.xlsb	Other_Assumptions\Valley Floor Hydrology\SCS Curve Number

A.12 References

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper 56, Rome. www.fao.org/docrep/x0490e/x0490e00.htm . Accessed July 2016.

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