

A Simulation Tool for the Bay-Delta Water Quality Control Plan

**SacWAM, Peer Review Briefing
October 19, 2016**



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Acknowledgements

- State Water Resources Control Board
 - Karen Niiya, Scott Ligare, Matt Holland, Yongxuan Gao, Vadim Demchuk, David Altare, Eleanor Bartolomeo
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Acknowledgements

- Jim Byer, Sunset Technology
- DWR Bay Delta Office

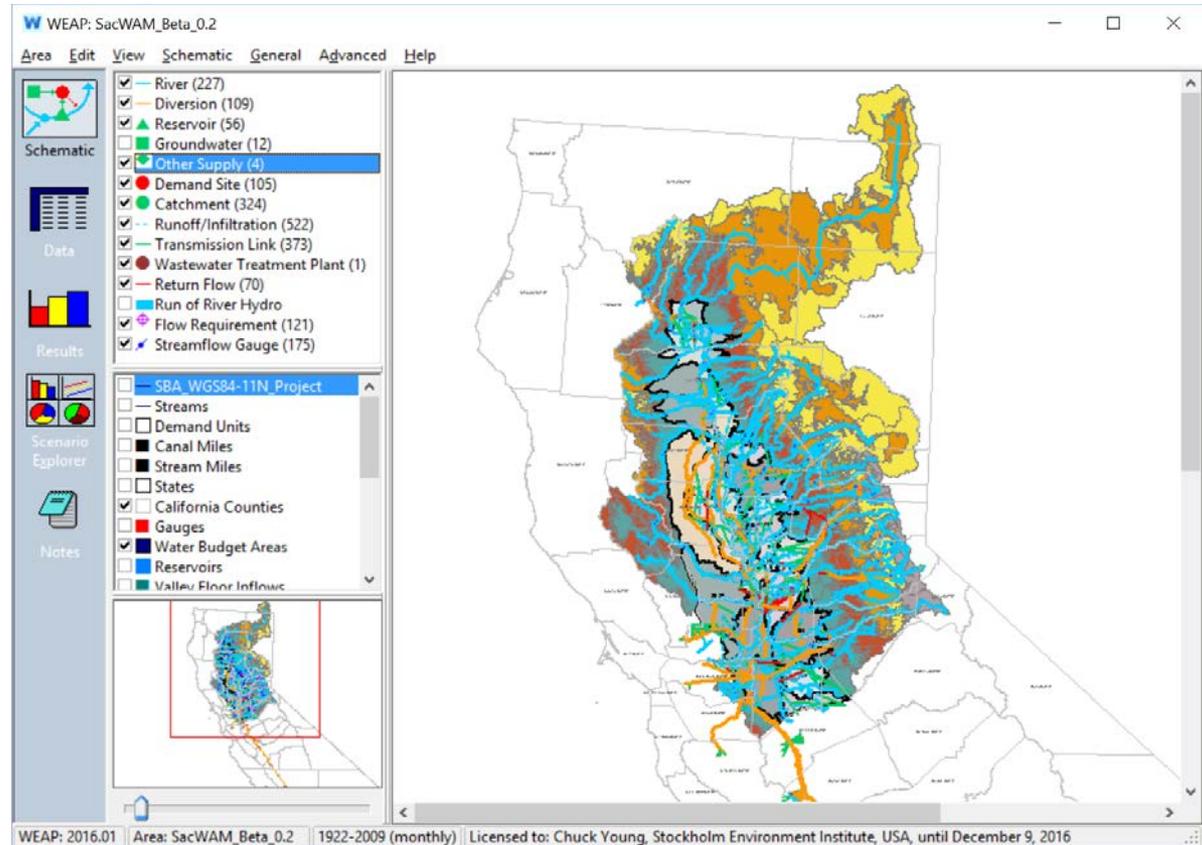


Some Features

- Comprehensive accounting of water resources system
 - represents the rainfall runoff and snow processes
 - represents infrastructure such as dams, canals, diversions, etc
 - represents operations rules
- Objects are pre-built which simplifies model construction
- Several options are available for the representation of demands and supplies

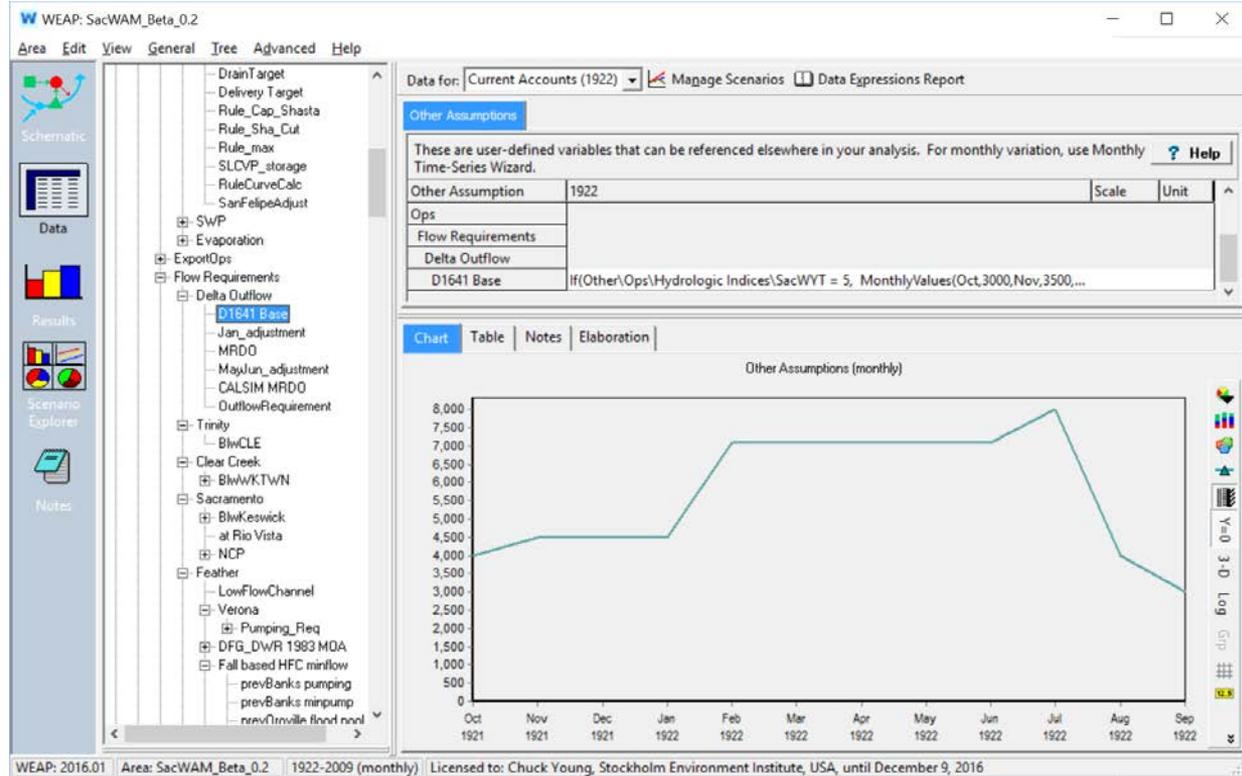
WEAP

Well developed graphical user interface



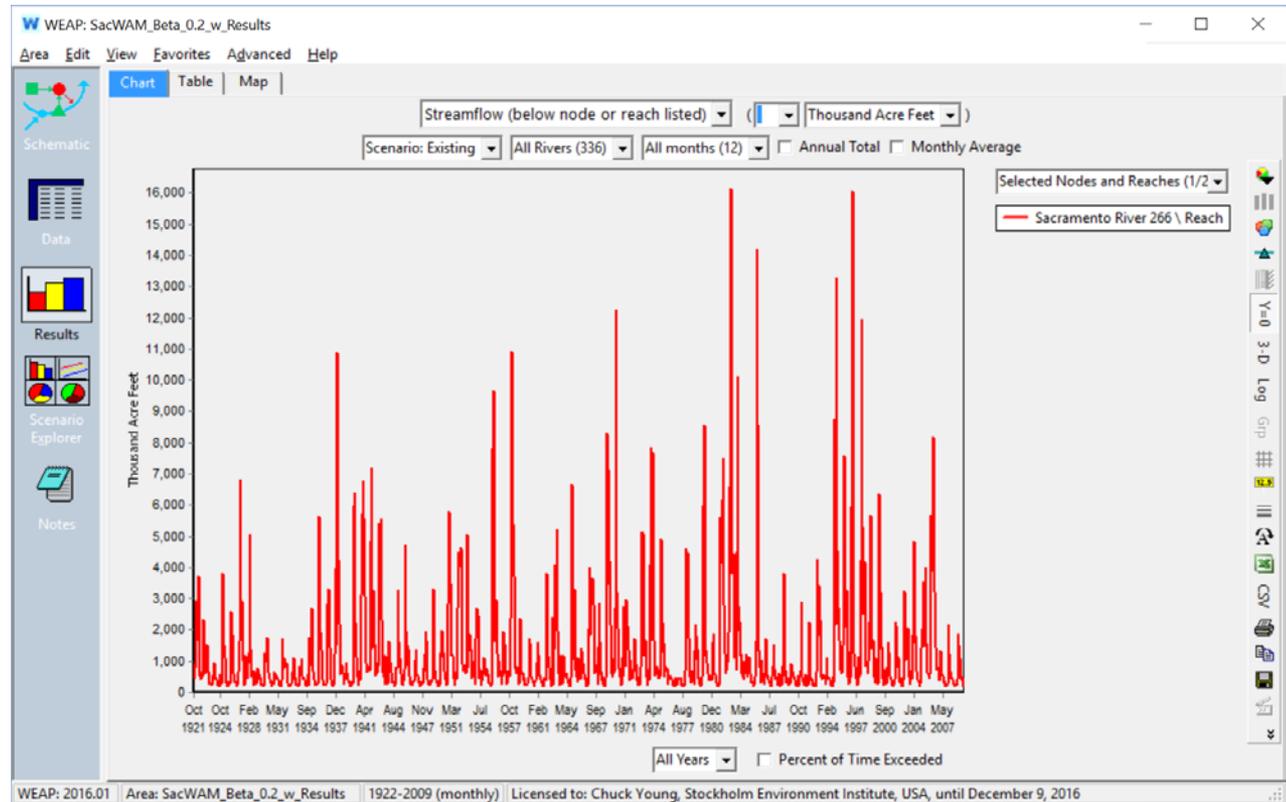
Data View

All model parameters are easily accessed through a “data tree”



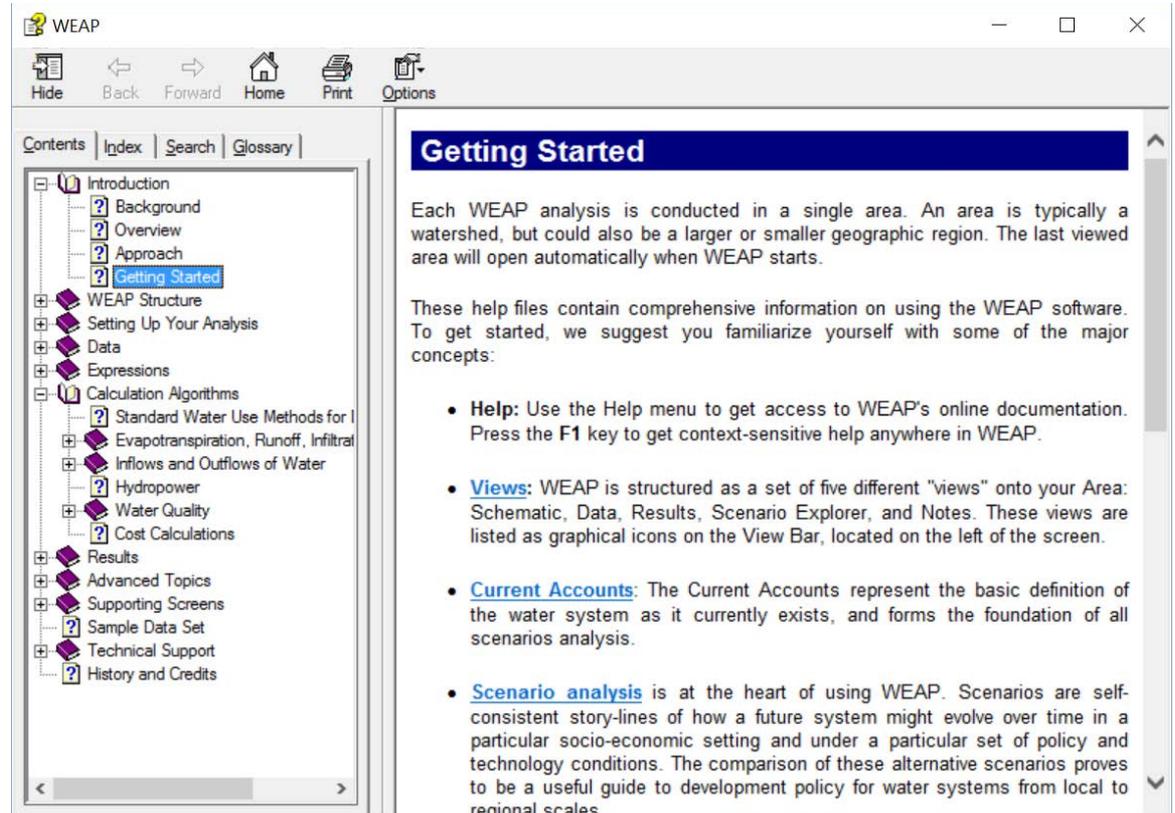
Results View

Results can be shown as graphs



Help Screen

Help is available!



The screenshot shows the WEAP software help interface. The window title is "WEAP". The top navigation bar includes "Hide", "Back", "Forward", "Home", "Print", and "Options". The left sidebar contains a "Contents" pane with a tree view of topics. The "Getting Started" topic is selected and highlighted in blue. The main content area displays the "Getting Started" page, which includes an introductory paragraph, a list of help files, and a list of key concepts.

Getting Started

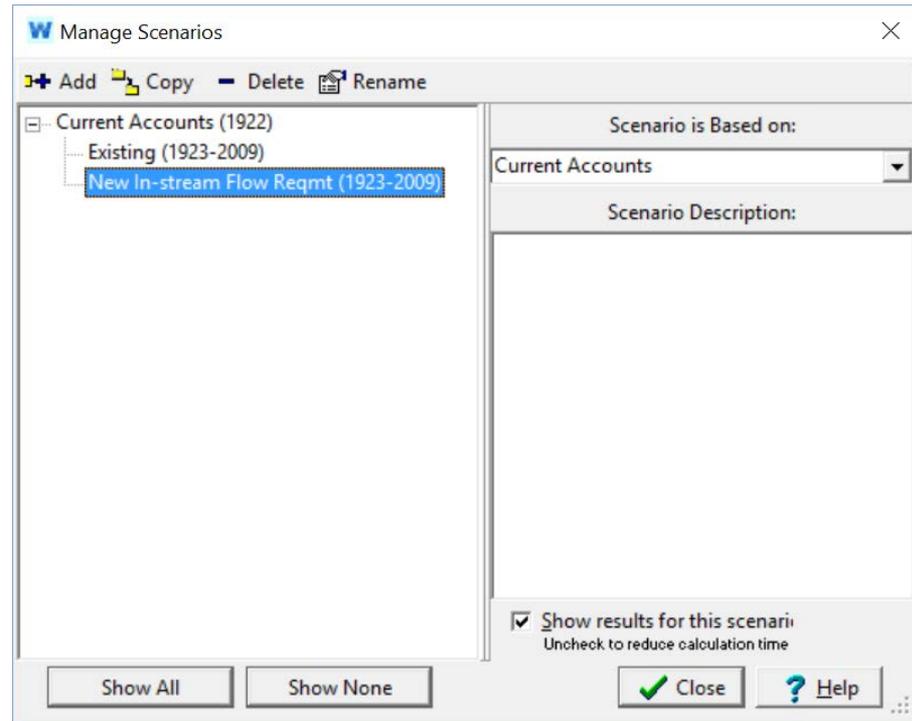
Each WEAP analysis is conducted in a single area. An area is typically a watershed, but could also be a larger or smaller geographic region. The last viewed area will open automatically when WEAP starts.

These help files contain comprehensive information on using the WEAP software. To get started, we suggest you familiarize yourself with some of the major concepts:

- **Help:** Use the Help menu to get access to WEAP's online documentation. Press the F1 key to get context-sensitive help anywhere in WEAP.
- **Views:** WEAP is structured as a set of five different "views" onto your Area: Schematic, Data, Results, Scenario Explorer, and Notes. These views are listed as graphical icons on the View Bar, located on the left of the screen.
- **Current Accounts:** The Current Accounts represent the basic definition of the water system as it currently exists, and forms the foundation of all scenarios analysis.
- **Scenario analysis** is at the heart of using WEAP. Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. The comparison of these alternative scenarios proves to be a useful guide to development policy for water systems from local to regional scales.

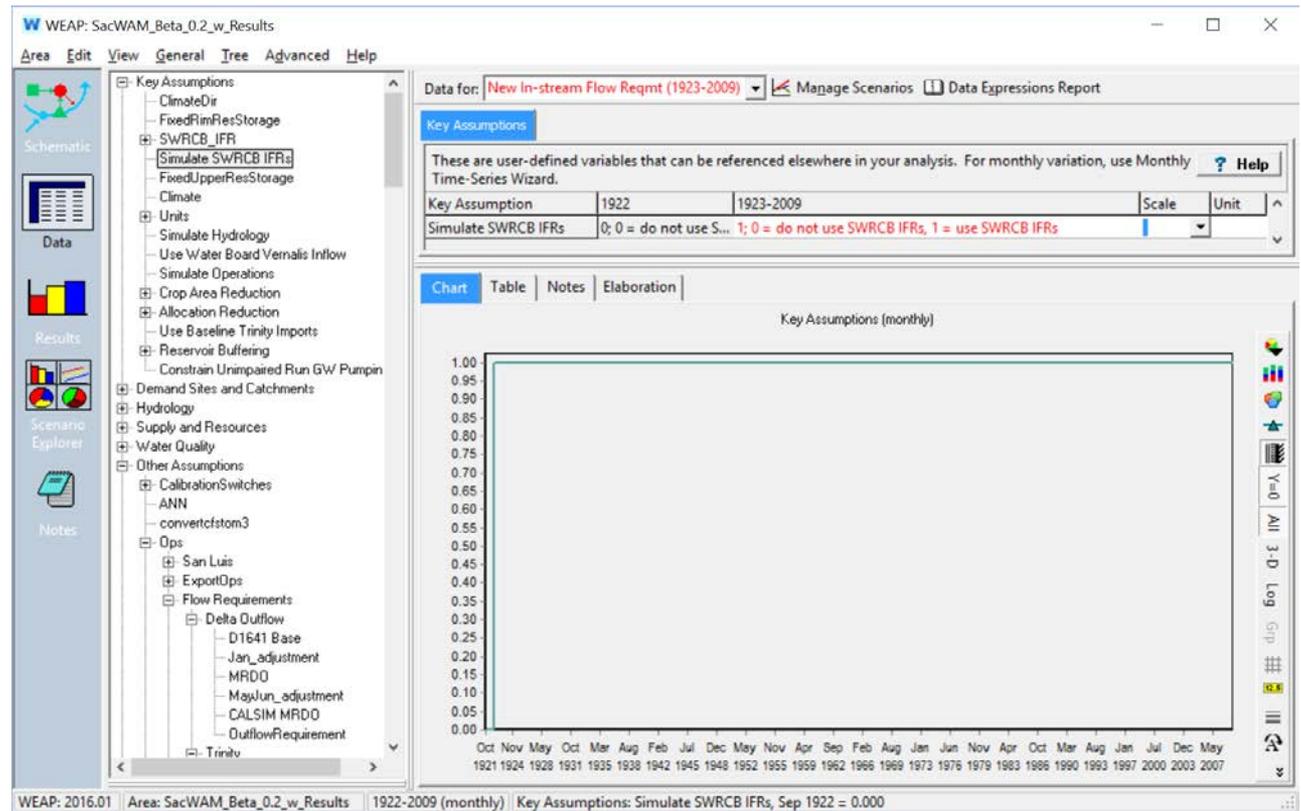
Scenarios

Scenarios are easily created



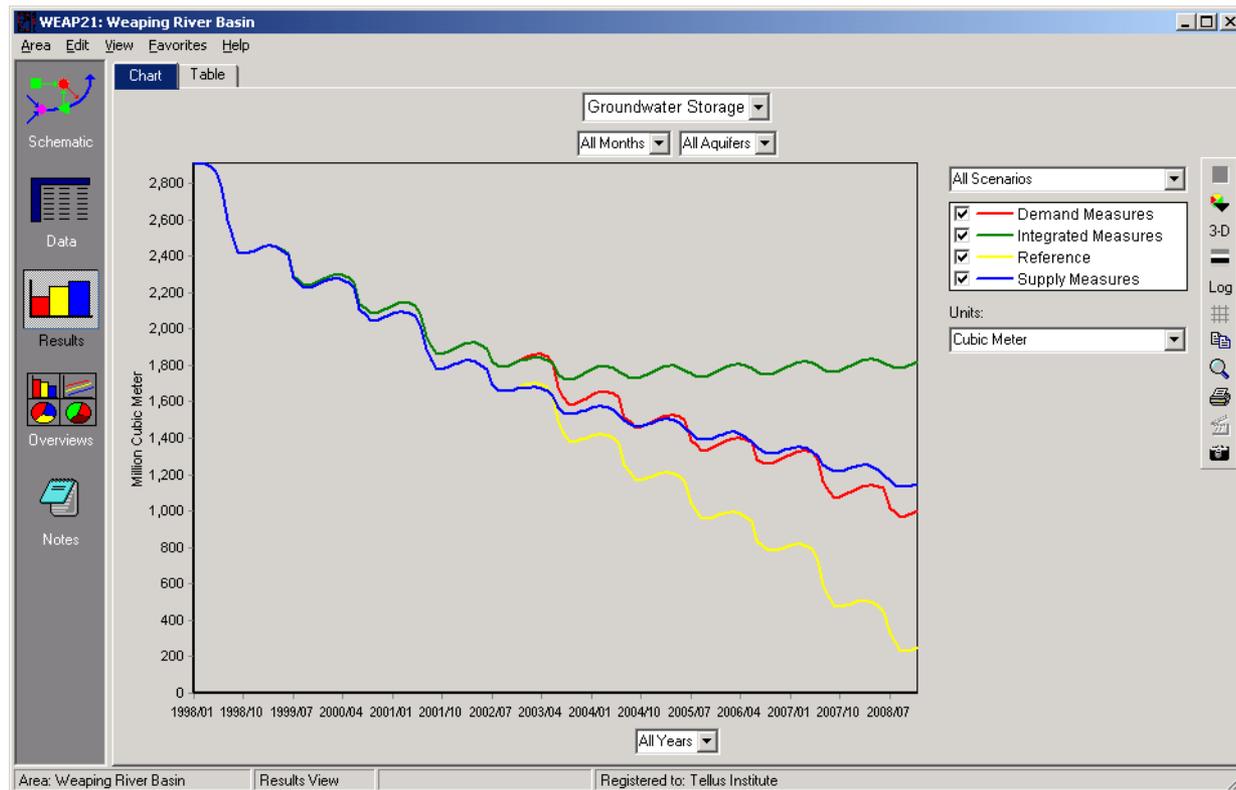
Scenarios

WEAP tracks parameters in each scenario

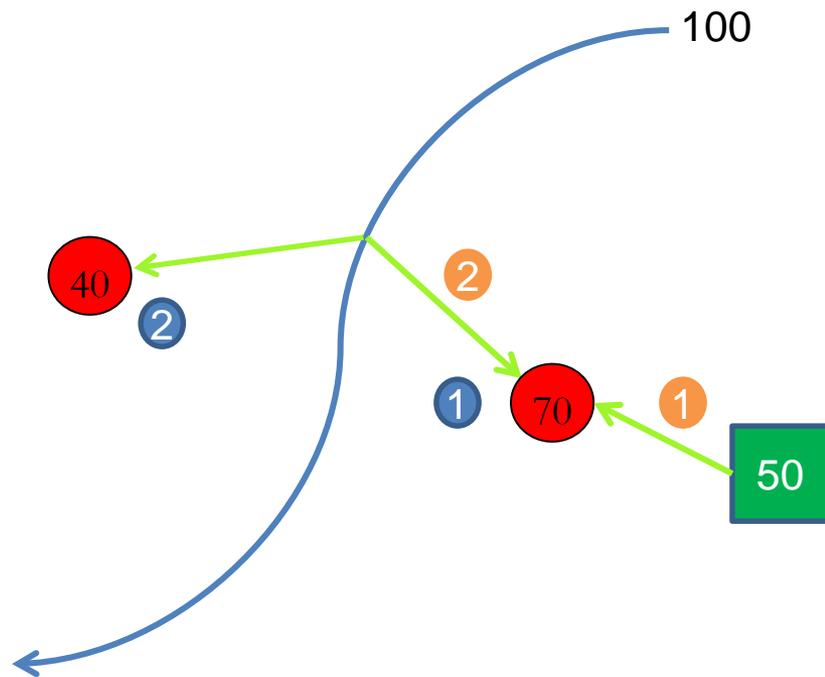


Scenarios

- Results from each scenario can be displayed simultaneously

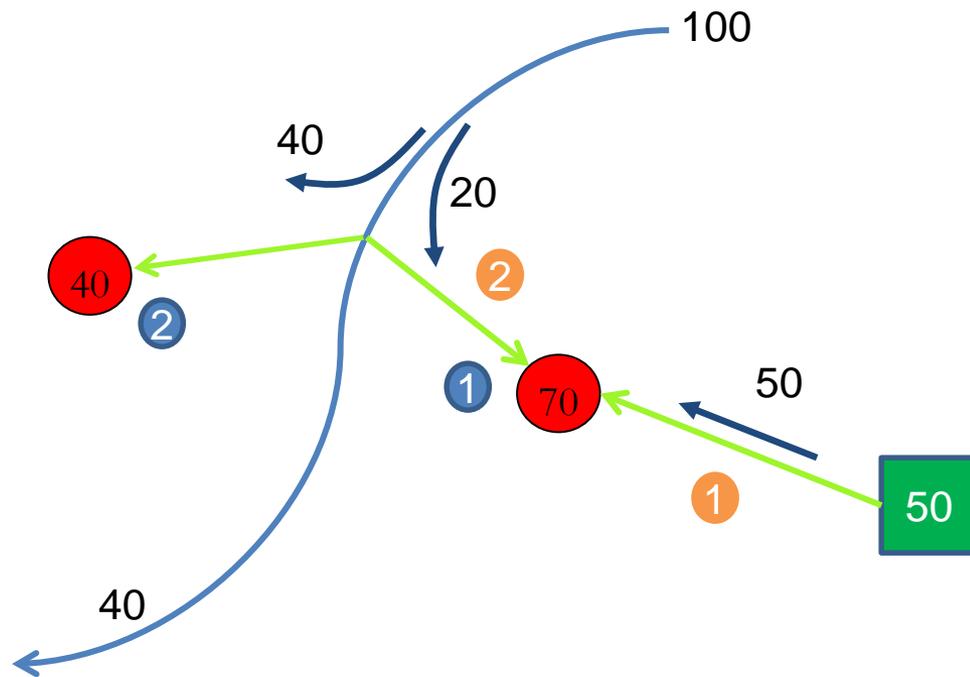


Water Allocation



- Solved within each time step
- Solved using a Linear Program (LP)
- Demands are assigned a “priority”
- Sources are assigned a “preference”
- Problem is solved using “allocation order”

Different Supply Preferences



The large demand (70 units) has higher priority for river water, but has a greater preference for groundwater.

WEAP Licensing...

SacWAM Users

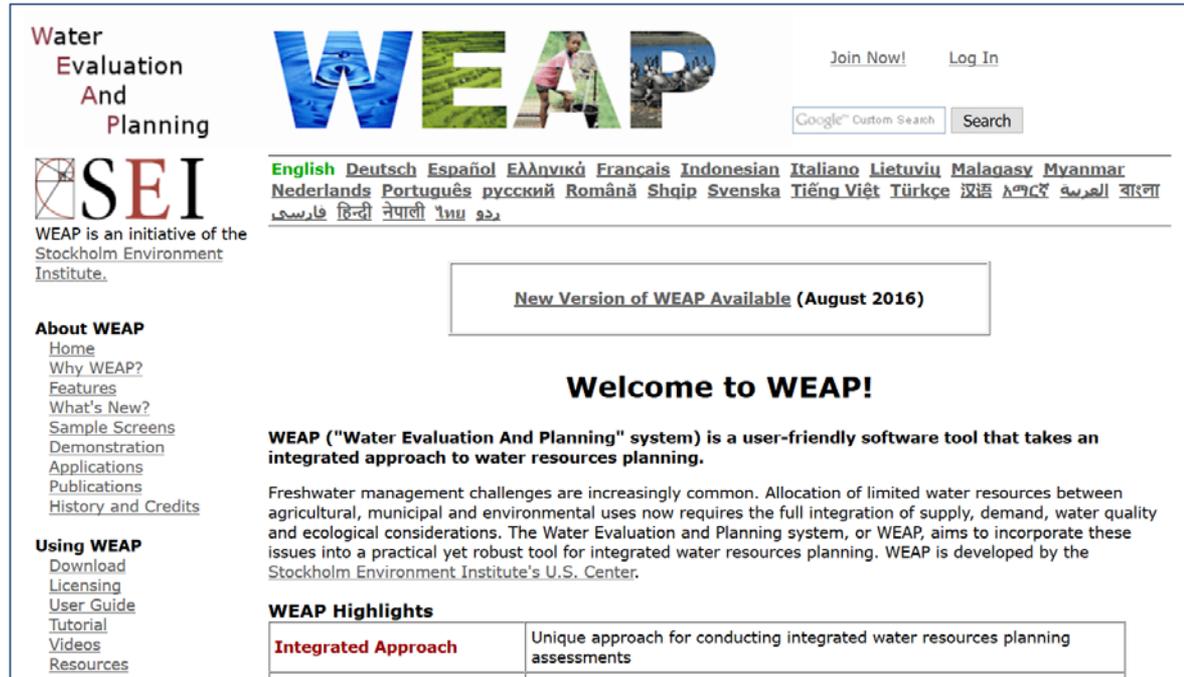
- CA public agencies – **Free**
 - This includes irrigation districts, flood control districts, water agencies, etc.
- University students – **Free**
- Academic institutions – **Free**
- Federal Gov/Non-Profits/etc. – **Free**
- Consultants
 - Single project – **\$3,000**
 - Enterprise – **\$10,000**

Note: the unlicensed version can be used to explore a model

Web site...

www.weap21.org

- Licensing
- Downloads
- Tutorial
- Training videos



The screenshot shows the WEAP website homepage. At the top left is the logo "Water Evaluation And Planning". To its right is the large "WEAP" logo with a water drop and a person. Further right are "Join Now!" and "Log In" links, and a Google Custom Search box. Below the logo is a list of languages: English, Deutsch, Español, Ελληνικό, Français, Indonesian, Italiano, Lietuvių, Malagasy, Myanmar, Nederlands, Português, русский, Română, Shqip, Svenska, Tiếng Việt, Türkçe, 汉语, አማርኛ, العربية, বাংলা, فارسی, हिन्दी, नेपाली, ལྷན་སྐད་.

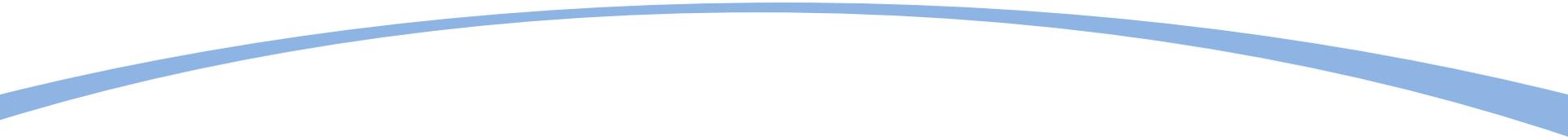
Below the language list is a box that says "New Version of WEAP Available (August 2016)".

The main heading is "Welcome to WEAP!". Below it is a paragraph: "WEAP ("Water Evaluation And Planning" system) is a user-friendly software tool that takes an integrated approach to water resources planning." This is followed by a longer paragraph about freshwater management challenges.

On the left side, there are two menu sections: "About WEAP" with links for Home, Why WEAP?, Features, What's New?, Sample Screens, Demonstration, Applications, Publications, and History and Credits; and "Using WEAP" with links for Download, Licensing, User Guide, Tutorial, Videos, and Resources.

At the bottom right, there is a "WEAP Highlights" section with a table:

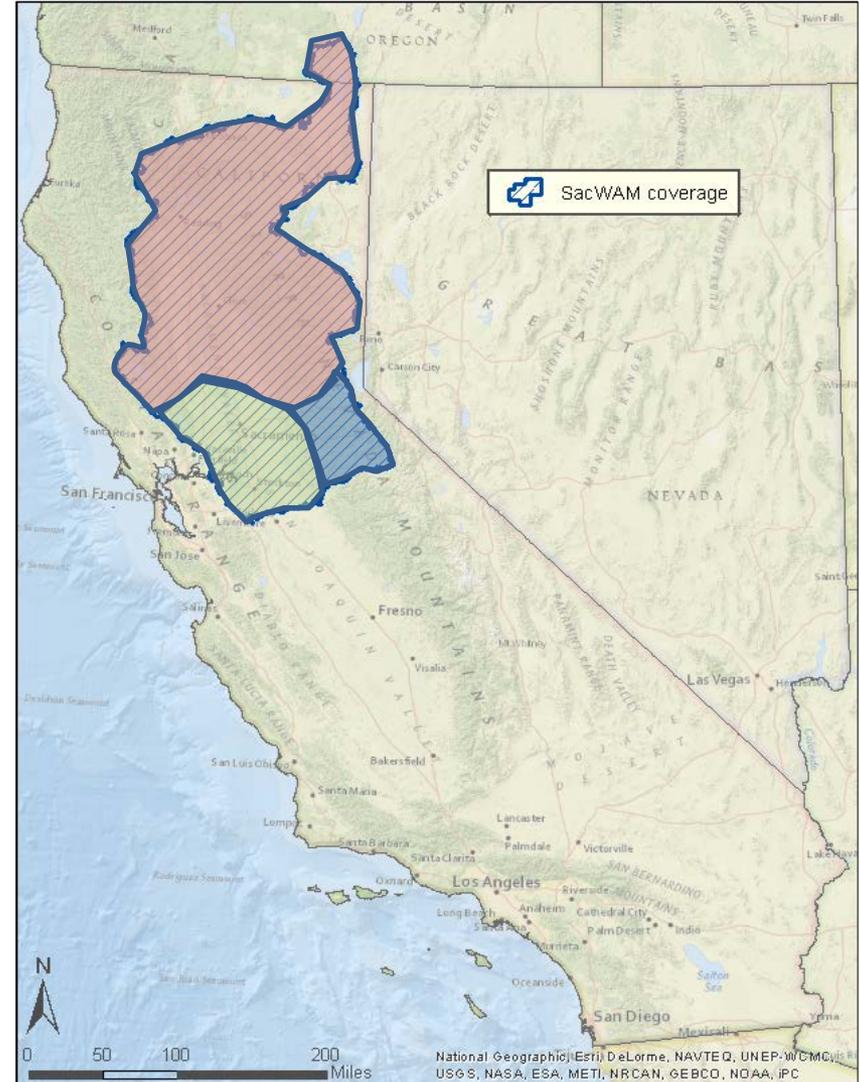
WEAP Highlights	
Integrated Approach	Unique approach for conducting integrated water resources planning assessments



AN INTRODUCTION TO SACWAM

Model Extent

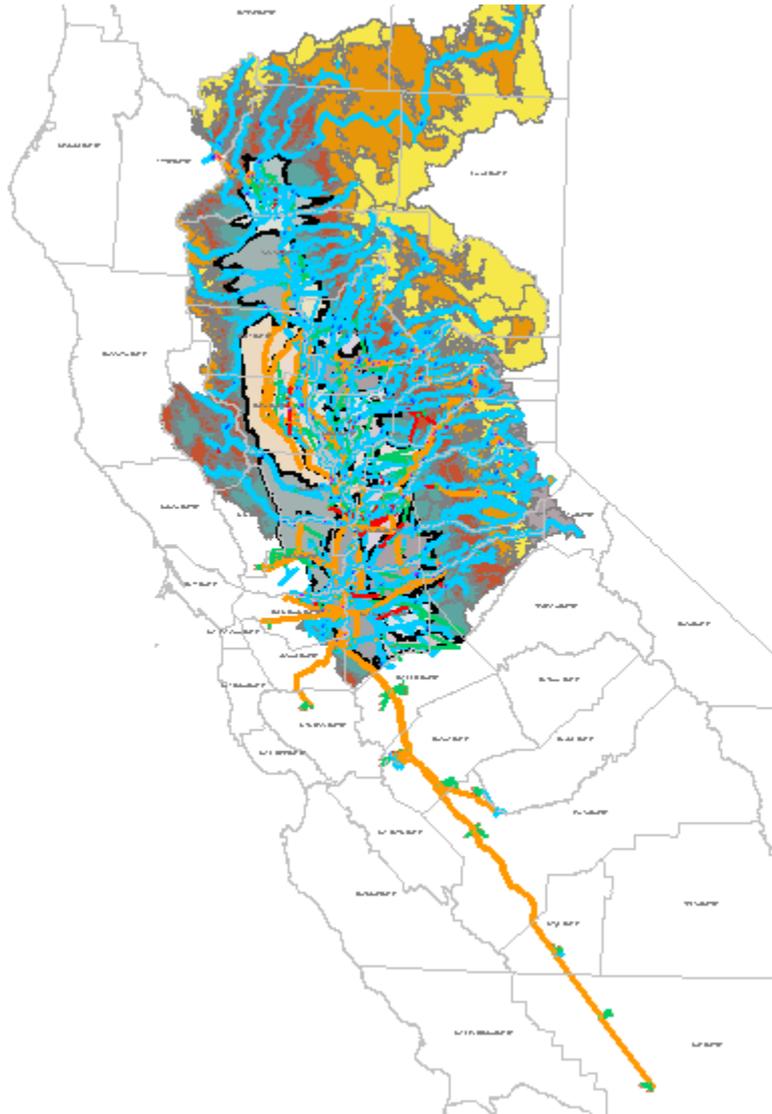
- Sacramento Basin and Trinity Imports
- East Side Streams
- Delta
- South of Delta



Model Features

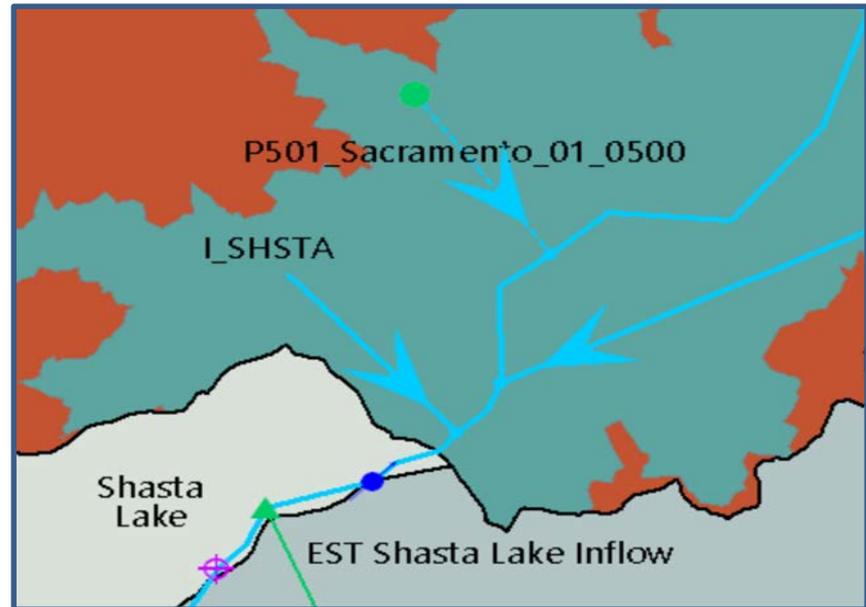
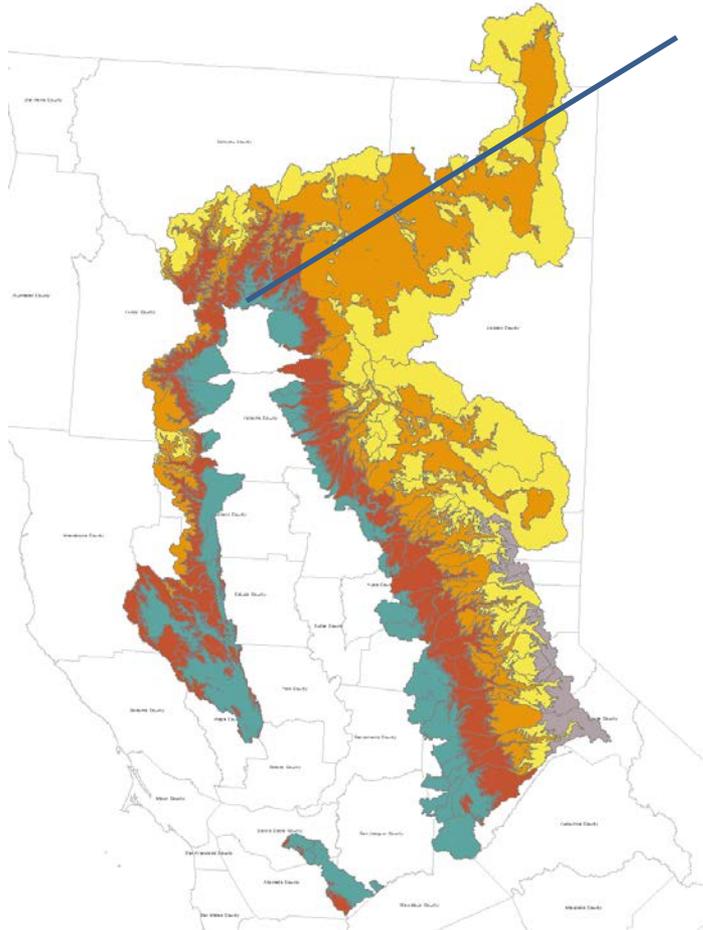
1. Current period of simulation 1922 – 2009
2. Monthly time step
3. Simulation of:
 1. upper watershed hydrology (optional)
 2. upper watershed operations
 3. unimpaired flows
 4. agricultural, urban, and refuge water use
 5. stream flows at points of interest to SWRCB
 6. Delta flows and salinity
 7. CVP/SWP operations
 8. Local project operations

Model Schematic



South of Delta has a simplified representation of San Luis Reservoir, Delta Mendota Canal, and the California Aqueduct

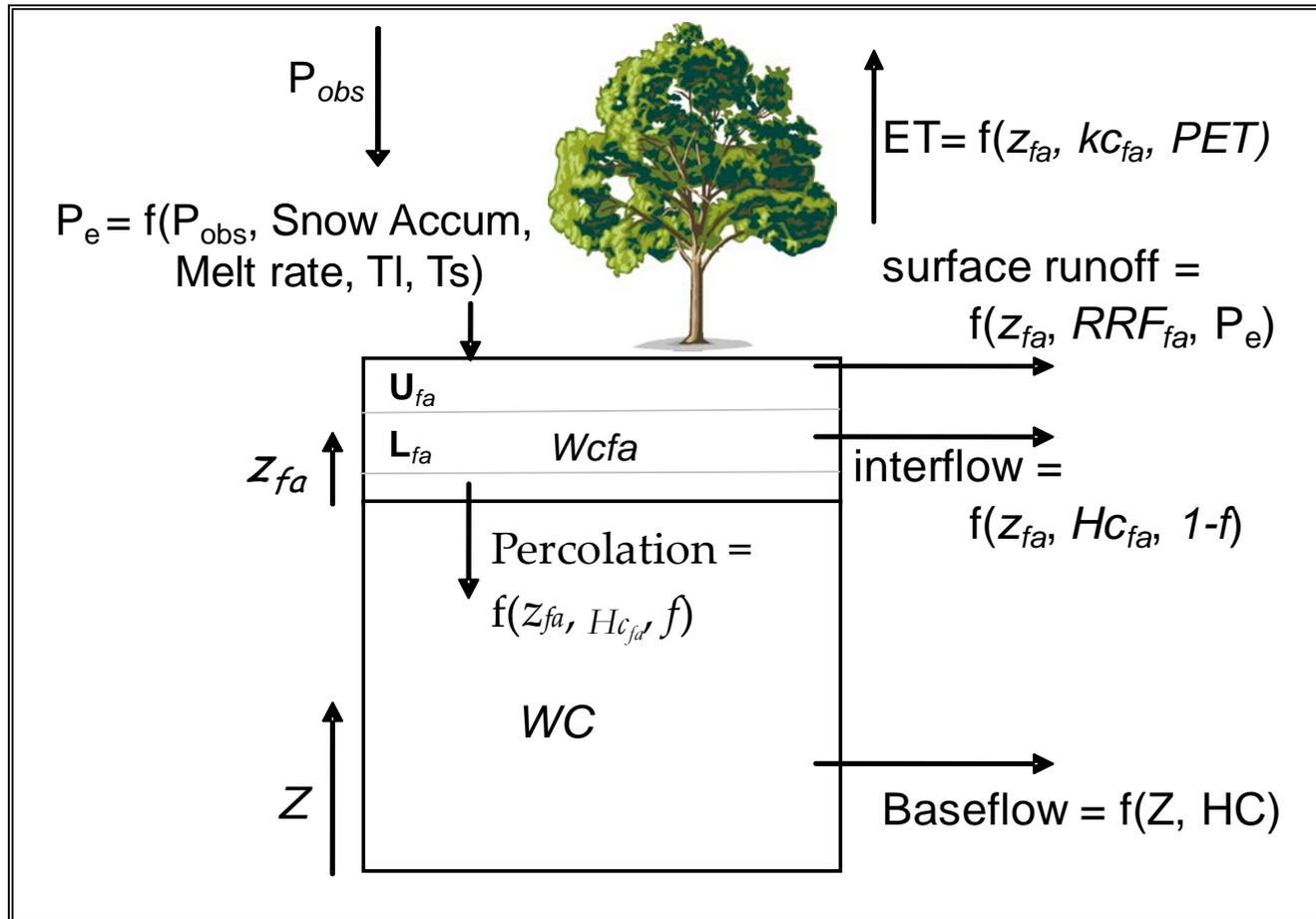
Upper Watersheds



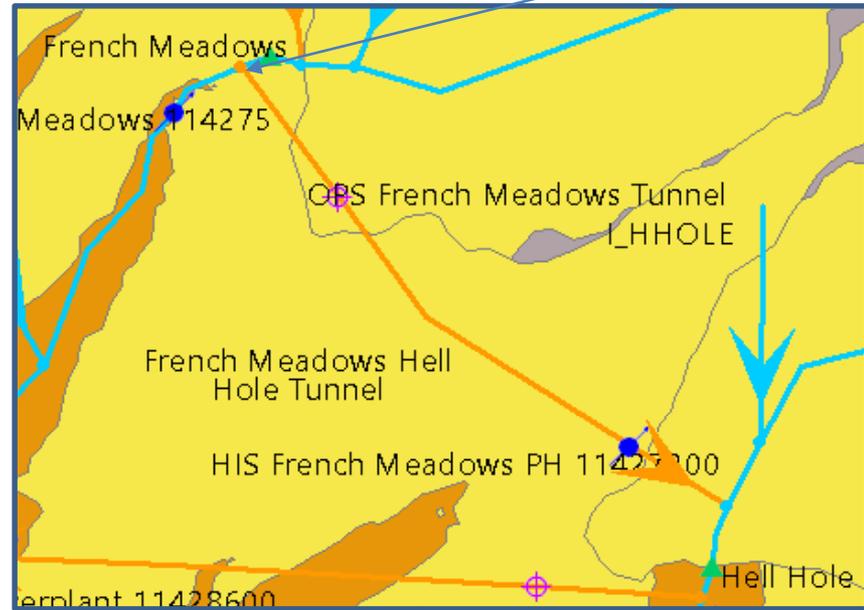
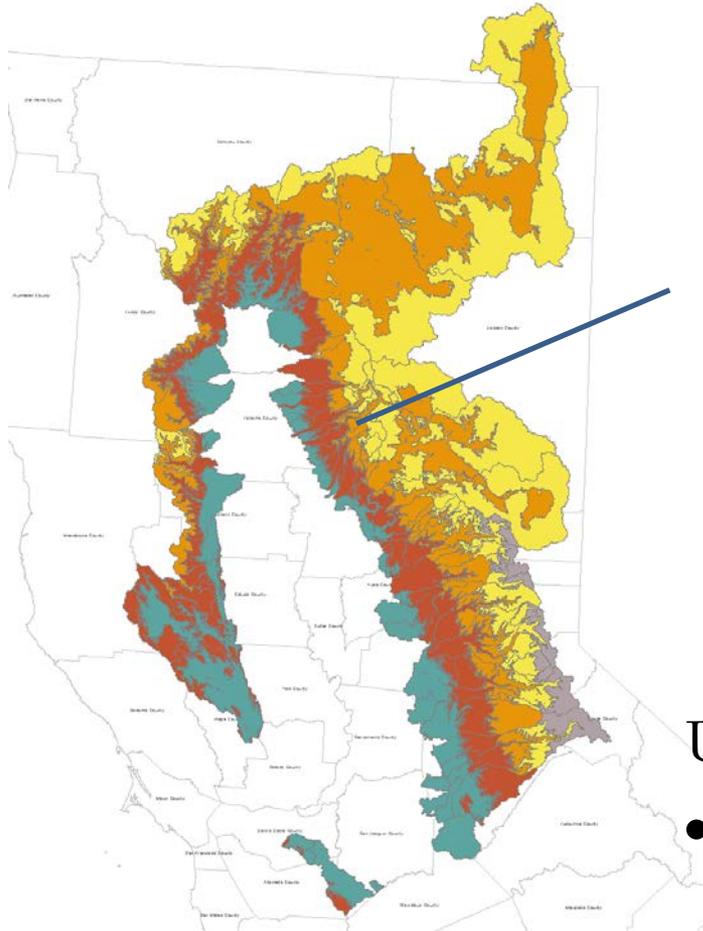
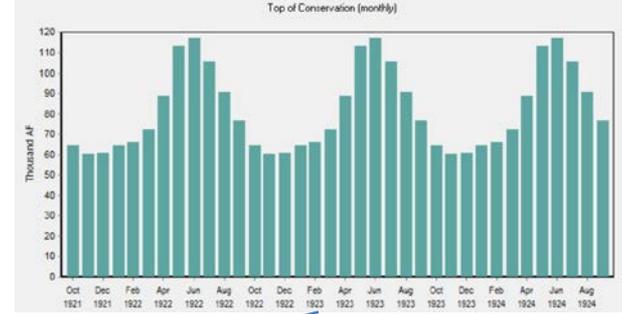
Two simulation options:

1. Specified inflows
2. Catchments

Upper Watershed Hydrology



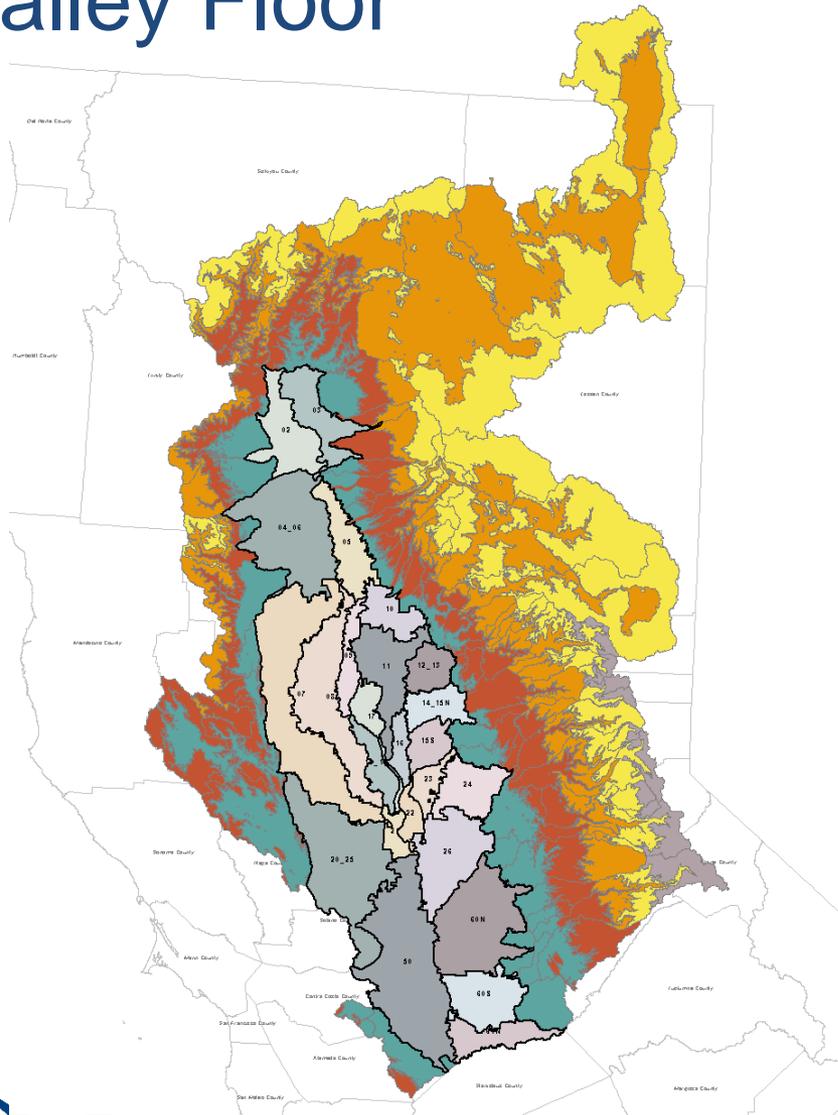
Upper Watersheds



Upper watershed operations

- based on average monthly historical operations
- will soon be refined

Valley Floor



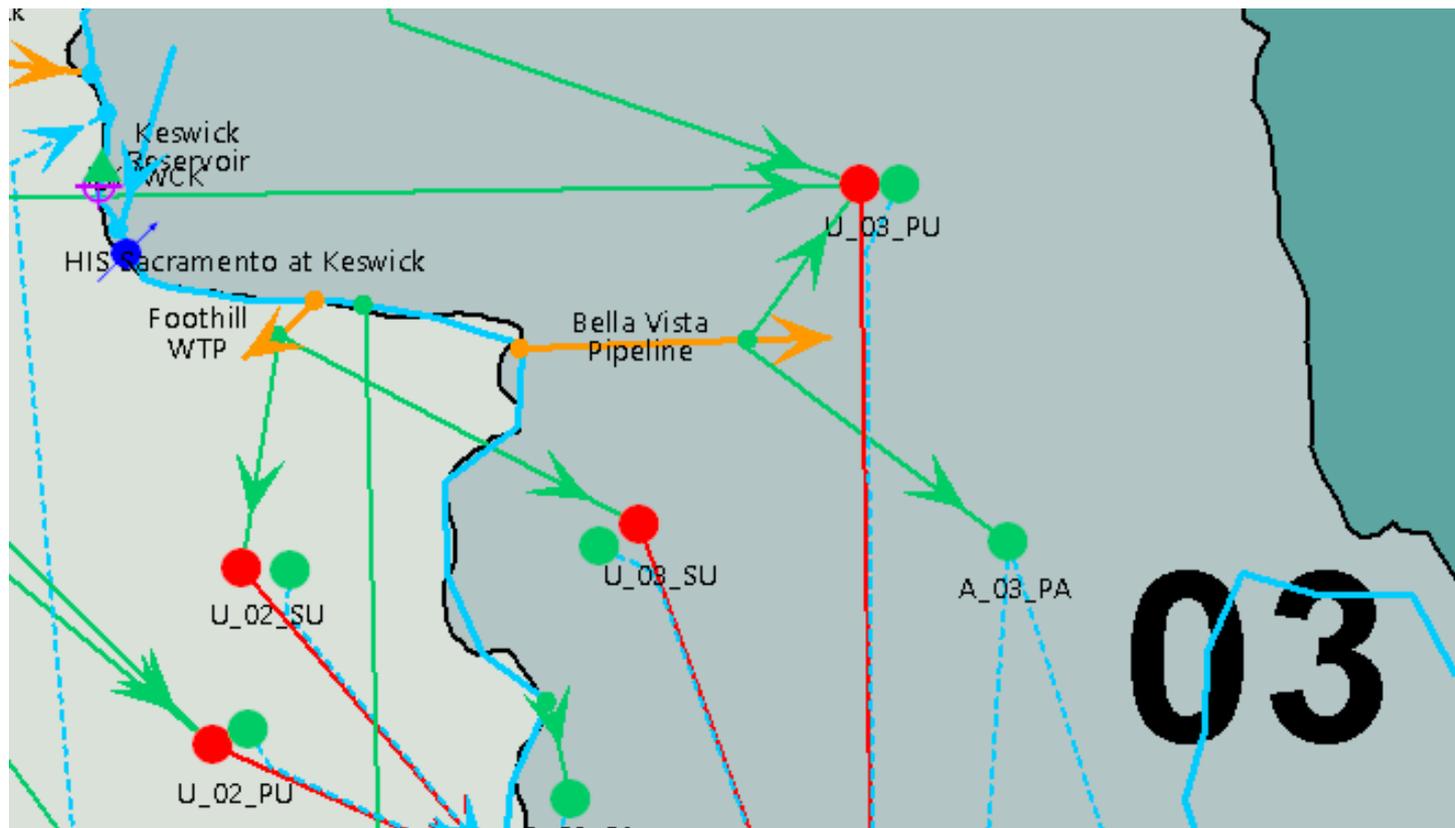
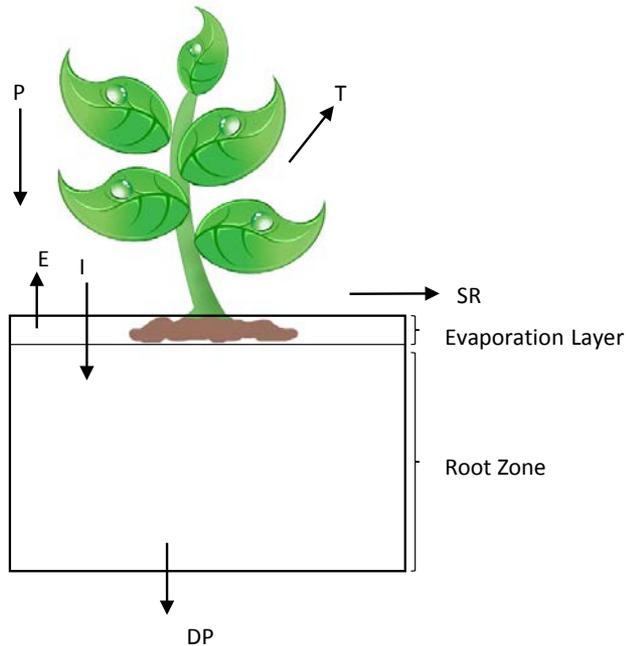


Table 4-2. Agricultural Demand Units in Sacramento River Hydrologic Region

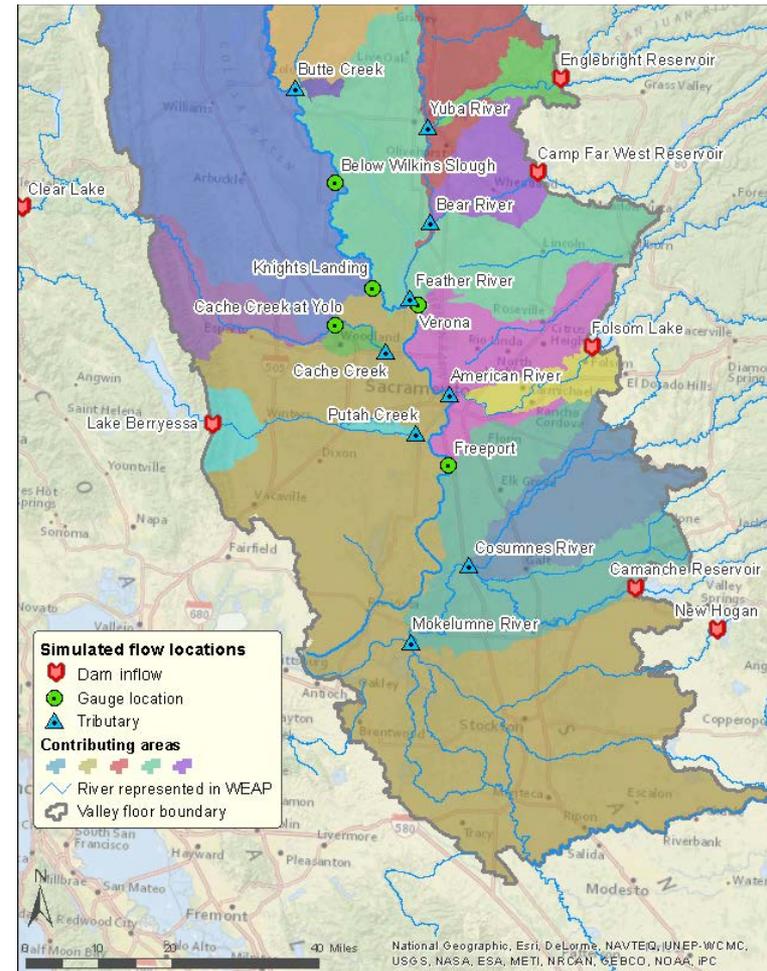
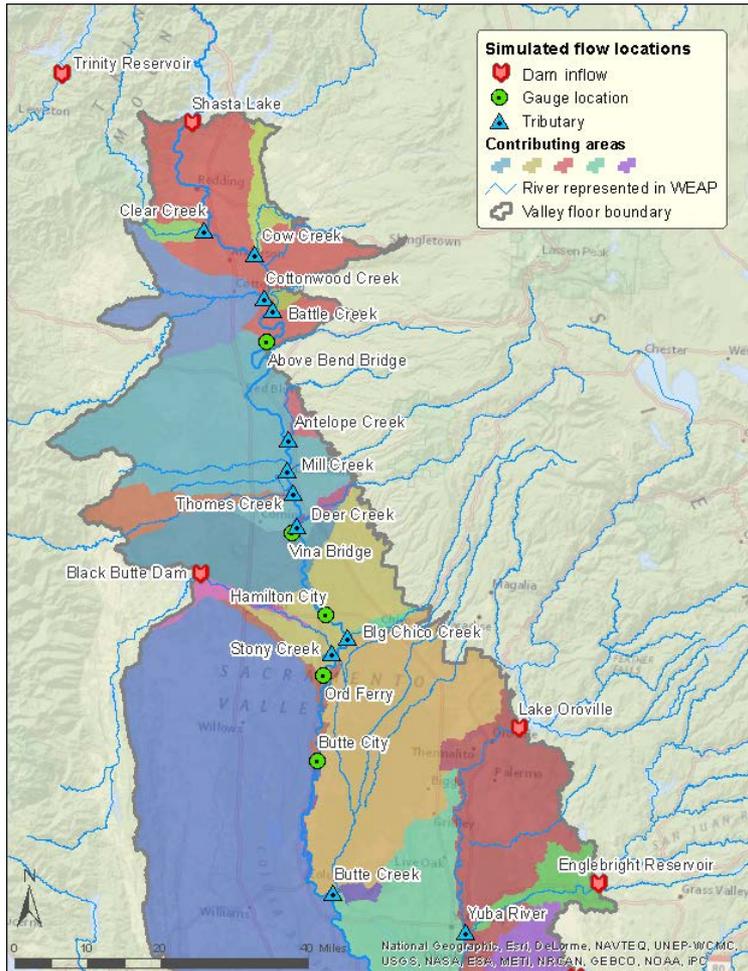
WBA	Demand Unit	Water District or Agency	Water Provider
02	A_02_NA	Non-district	N/A
	A_02_PA	Clear Creek CSD	CVP
	A_02_SA	Anderson-Cottonwood ID Misc. settlement contractors	CVP
03	A_03_NA	Non-district	N/A
	A_03_PA	Bella Vista WD	CVP
	A_03_SA	Anderson-Cottonwood ID Misc. settlement contractors	CVP

Valley Floor Hydrology

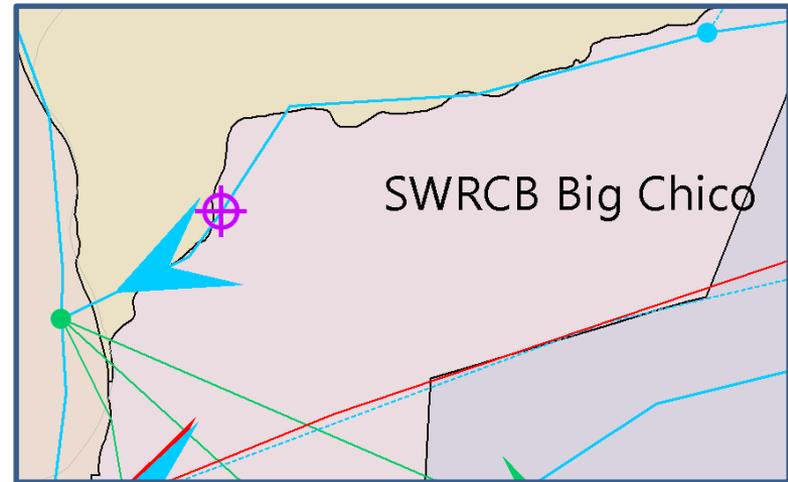
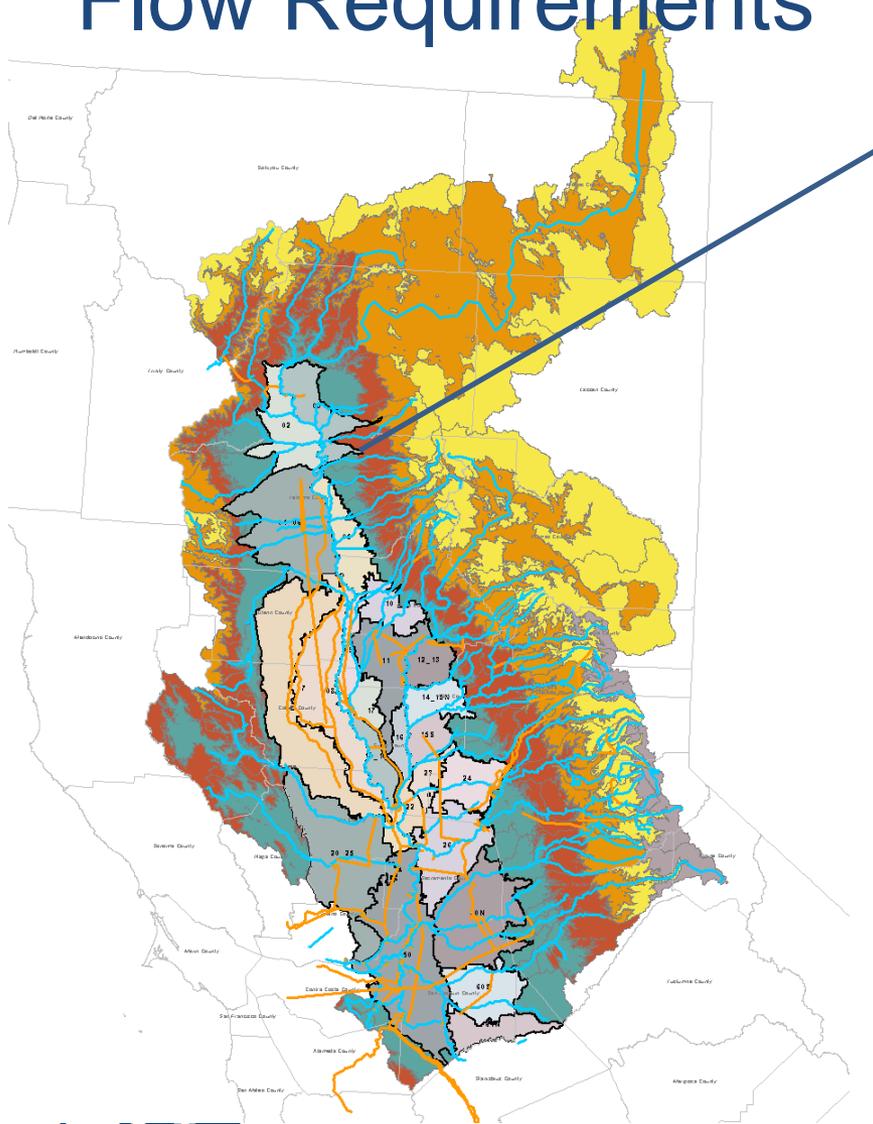


- Daily model (MABIA)
- Infiltration is based on a curve number approach
- ET is based on the dual crop coefficient approach in FAO 56
- ET was calibrated to DWR CUP (SIMETAW) model for consistency

Streamflow Simulation

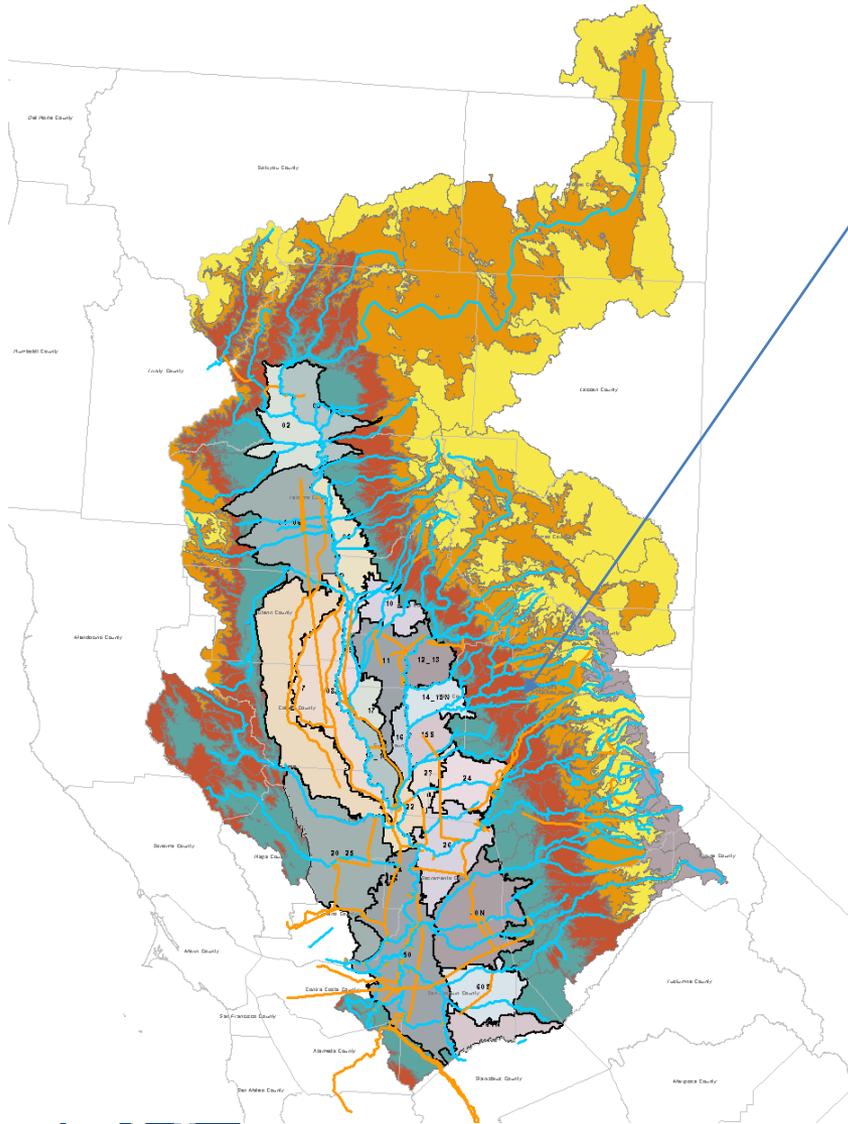


Flow Requirements



New flow requirements are easily added. Currently they exist at the mouth of each stream, below the main reservoirs, and at important locations on the Sacramento River.

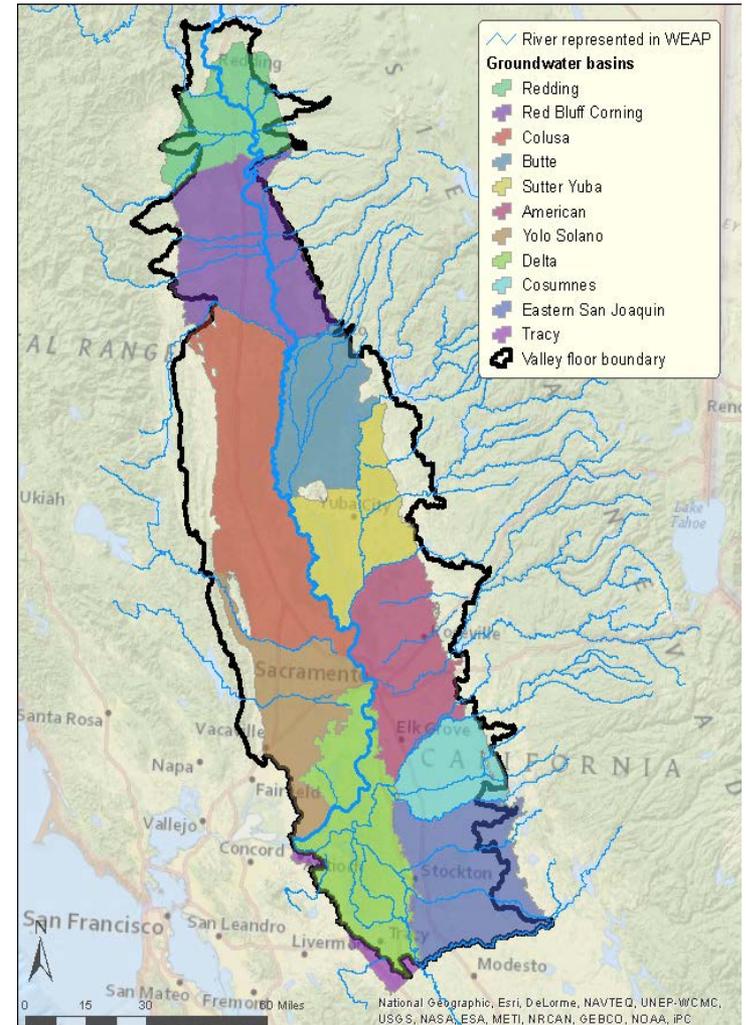
Stream Gauges



- 173 streamflow gauges provide points of comparison.
- HIS – historical data
- EST – estimated data
- FNF – full natural flow gauges represent historical flows with effects of upstream operations removed

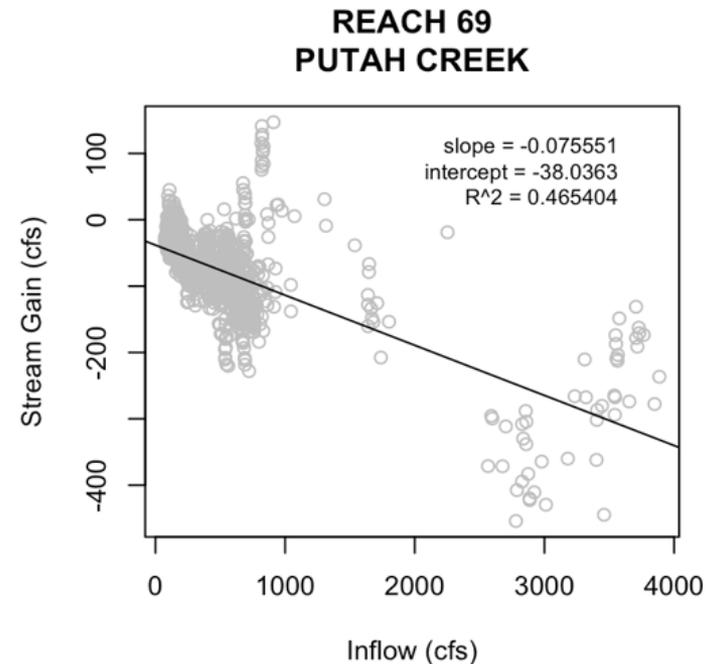
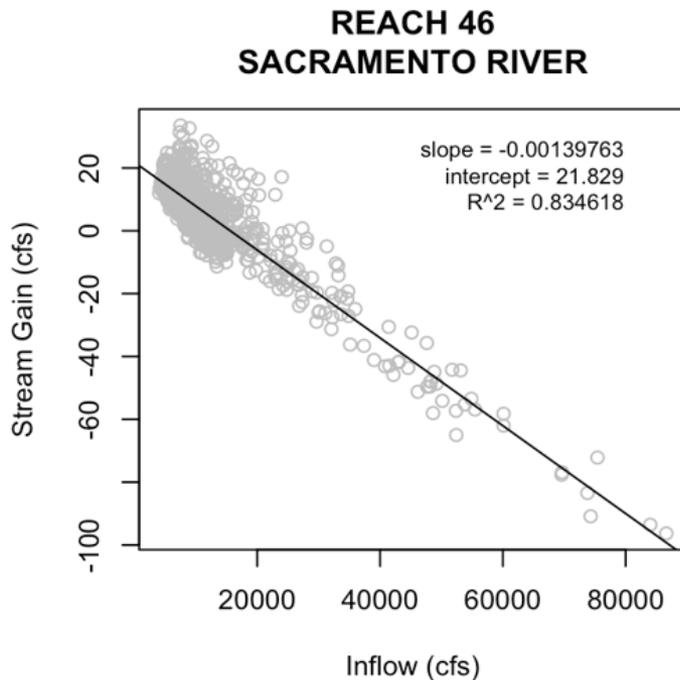
Groundwater Simulation

- Eleven groundwater basins based on Bulletin 118.
- Interactions include:
 - Areal recharge
 - Canal losses
 - Groundwater pumping
 - Stream-aquifer interactions

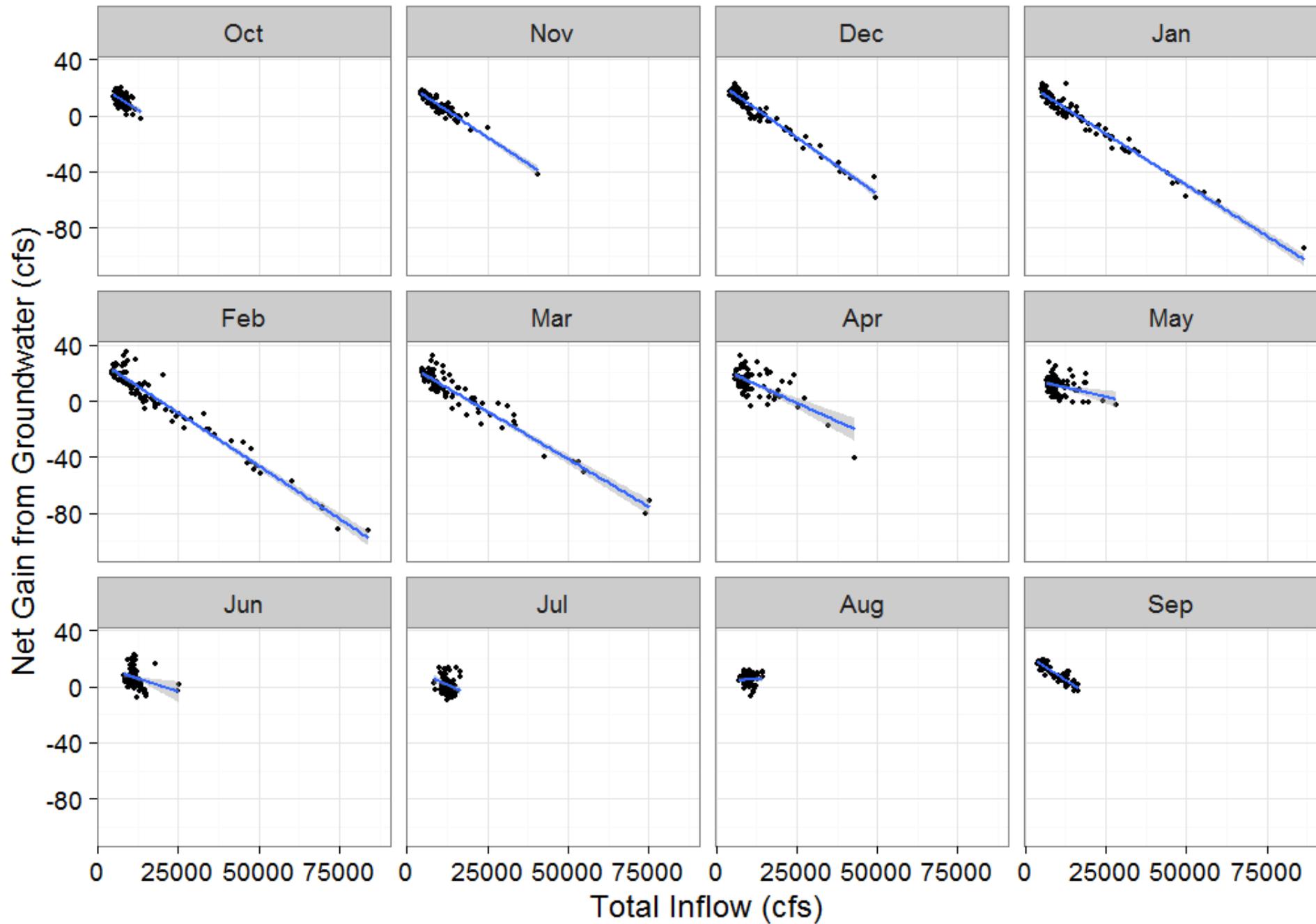


Groundwater Simulation

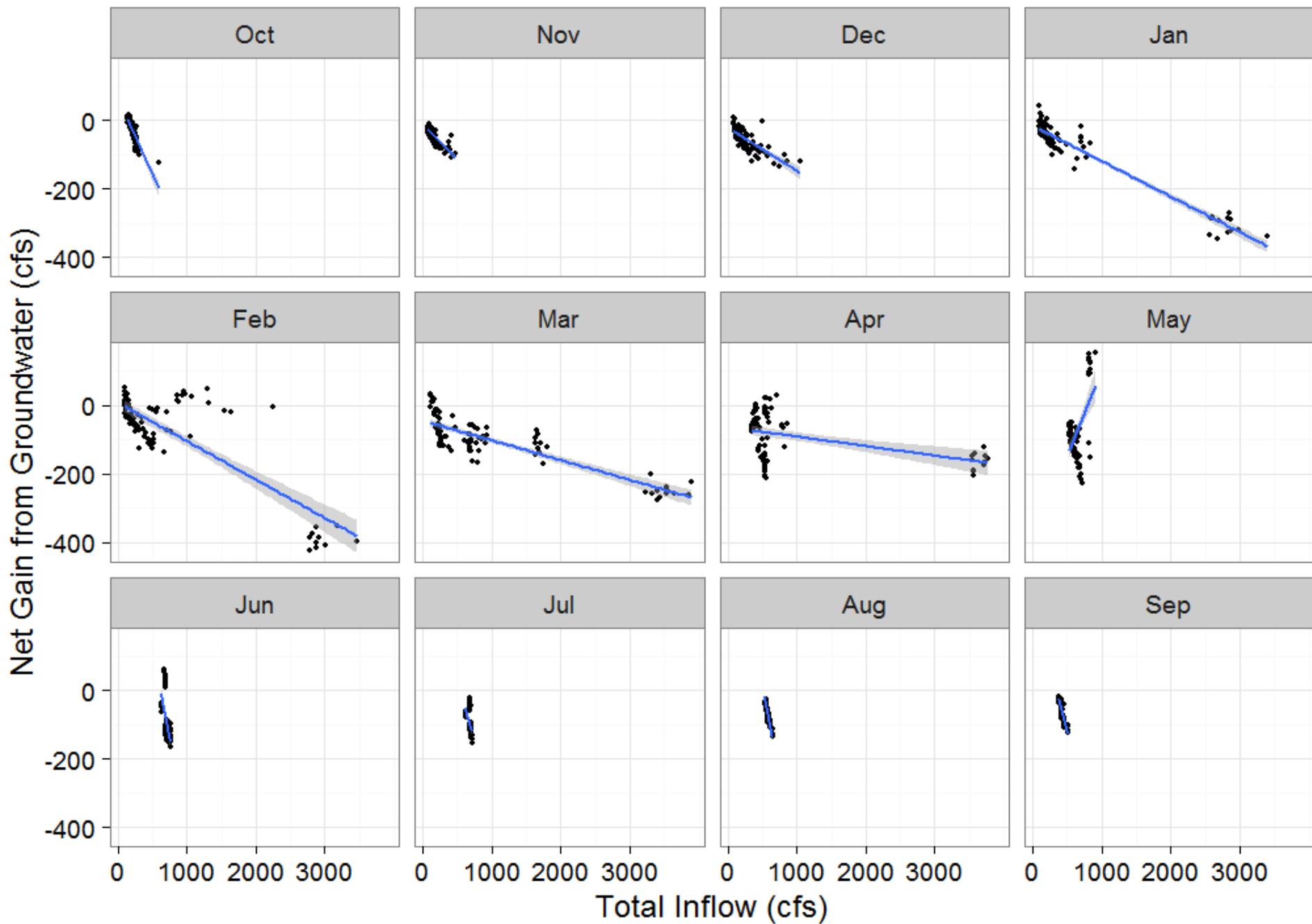
- Stream aquifer interactions are based on a linear approximation of C2VSim



Sacramento River below Thomes Creek



Putah Creek below Diversion Dam



SACWAM

VALIDATION OF SIMULATED OPERATIONS

COMPARISON WITH HISTORICAL DATA

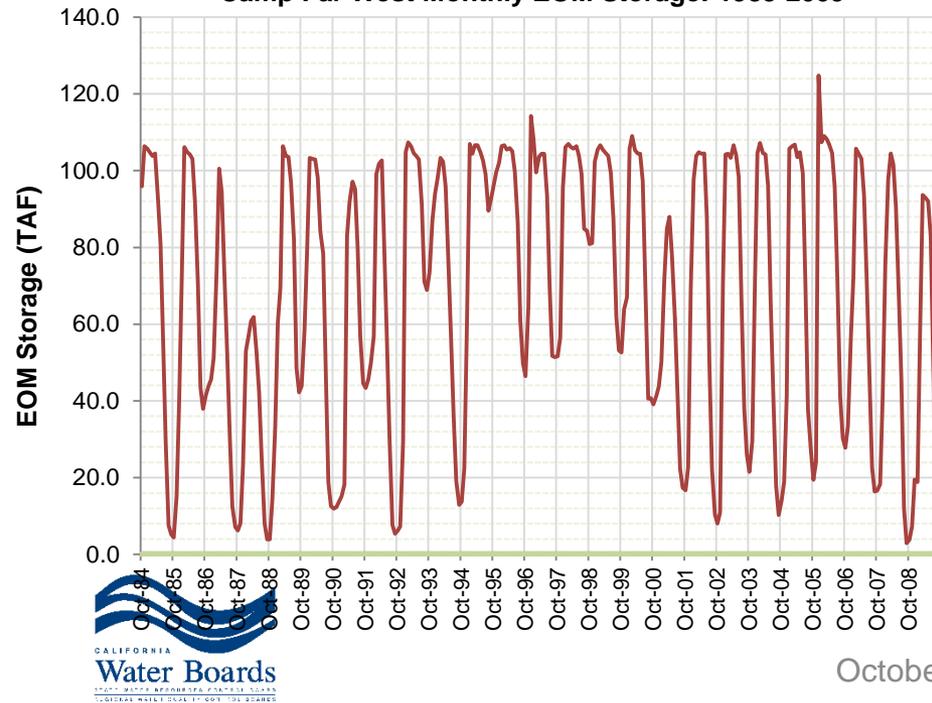


SacWAM Reservoir Operations

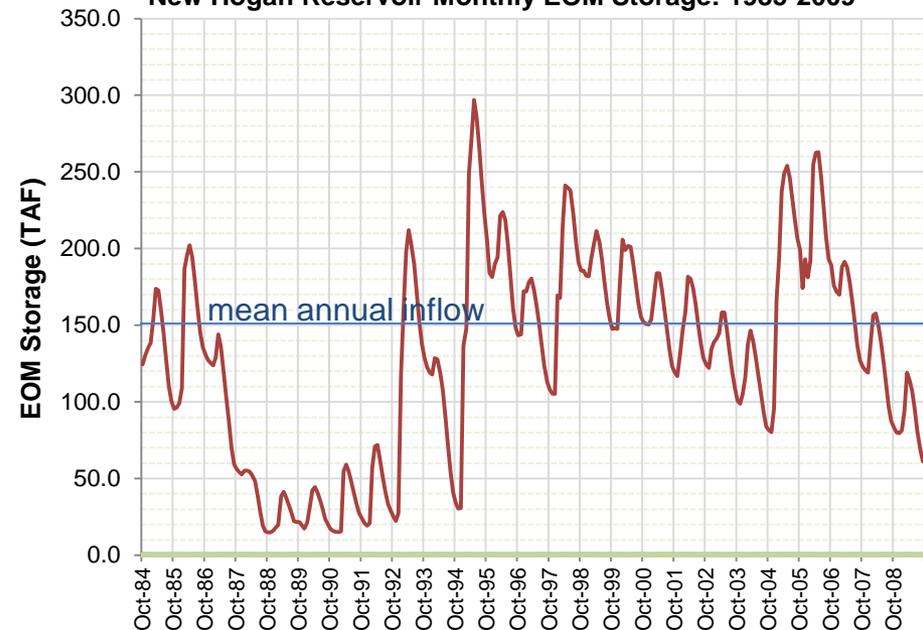
- Reservoir types

- mean annual inflow/storage capacity > 1
- mean annual inflow/storage capacity < 1

Camp Far West Monthly EOM Storage: 1985-2009



New Hogan Reservoir Monthly EOM Storage: 1985-2009



Reservoir Operations

- Performance metrics
 - Storage (bias, RMSE, Nash-Sutcliffe)
 - Exercising reservoir for water supply
 - Annual storage range
 - Hedging
 - End-of-September carryover storage
- Validation Period
 - 25 yrs: 1985-2009 or 30 yrs: 1986-2015
 - 6-year drought, 1997 flood event, 1998 El Nino, 4-year drought
 - Water year types: 12 C, 4 D, 2 BN, 3 AN, 9 W
 - 4-River index 96% of 1922-2015 average

Reservoir Operational Adjustments

- High inflow/storage capacity
 - Downstream demands
 - Downstream stream seepage
- Low inflow/storage capacity
 - Allocation logic: delivery vs carryover

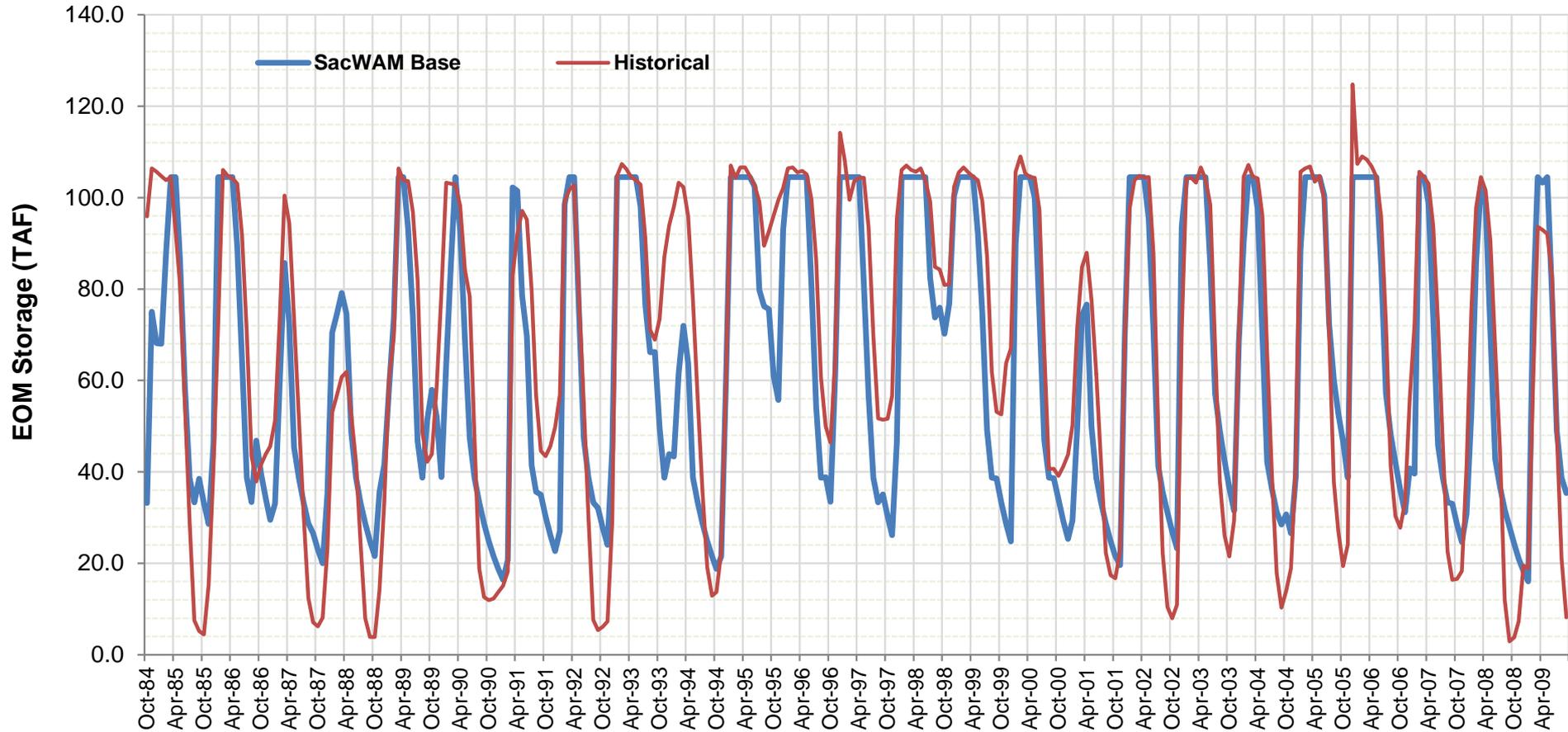
VALIDATION OF LOCAL OPERATIONS

COMPARISON WITH HISTORICAL DATA



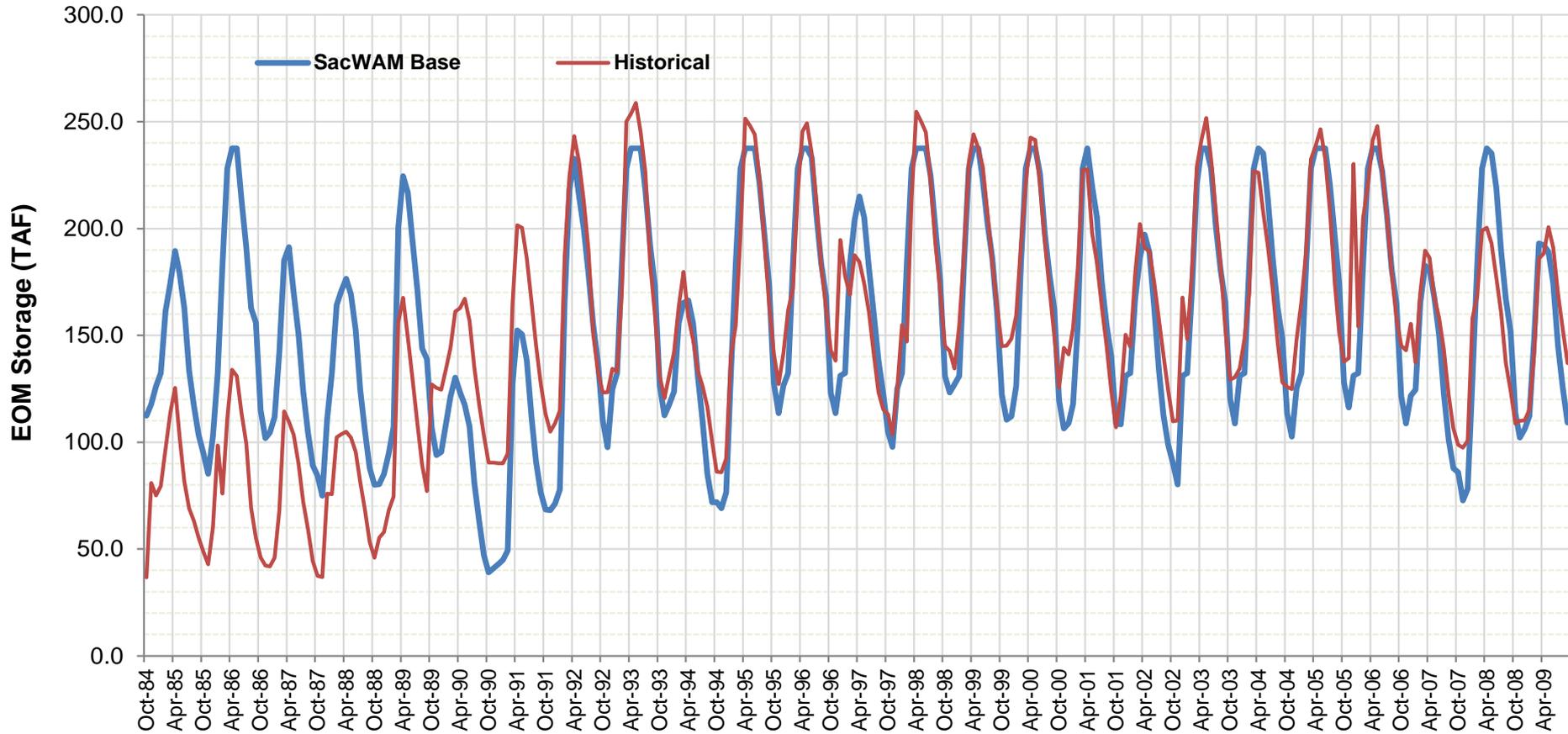
Camp Far West, Bear River

Camp Far West Monthly EOM Storage: 1985-2009



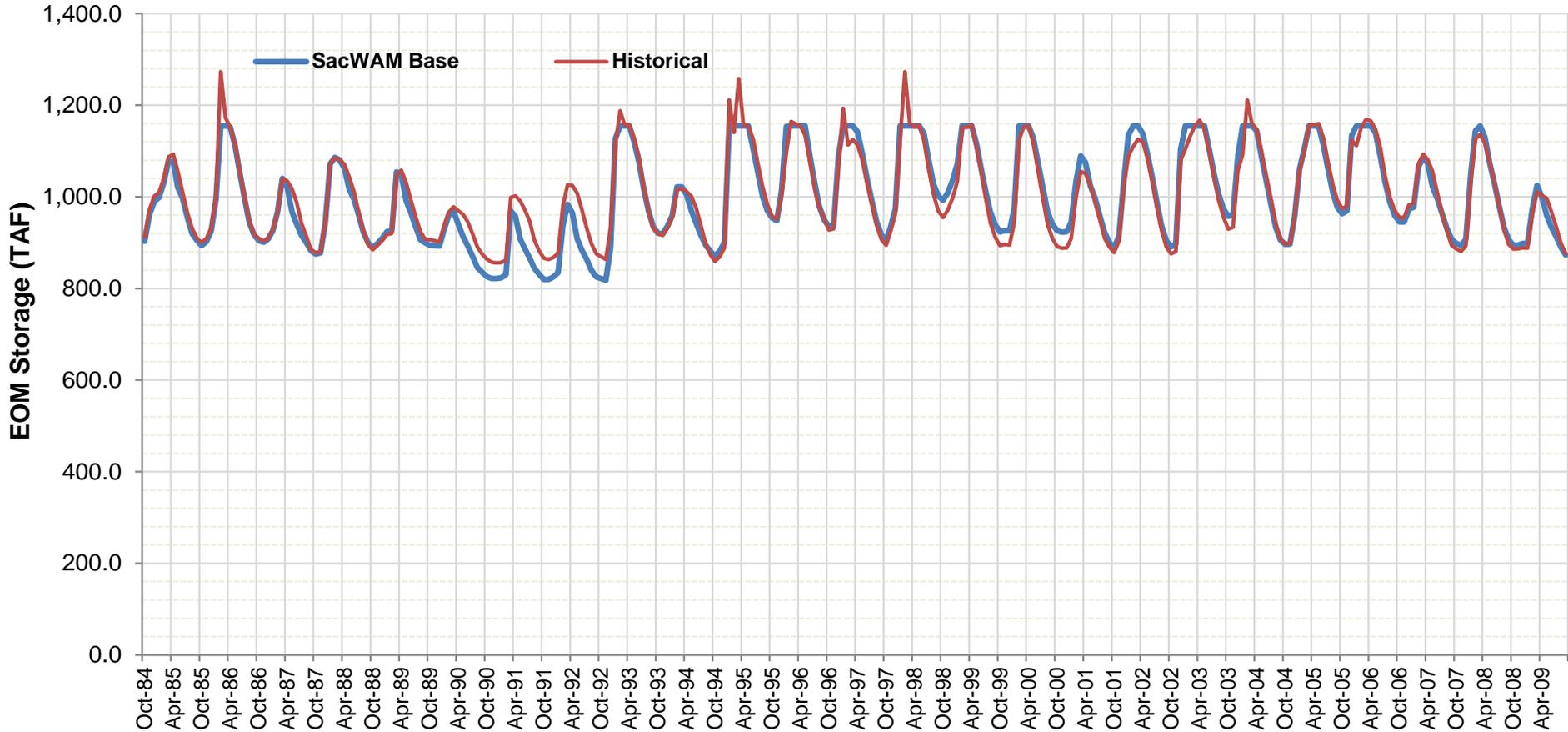
East Park, Stony Gorge, Black Butte, Stony Creek

Stony Creek Storage Monthly EOM Storage: 1985-2009



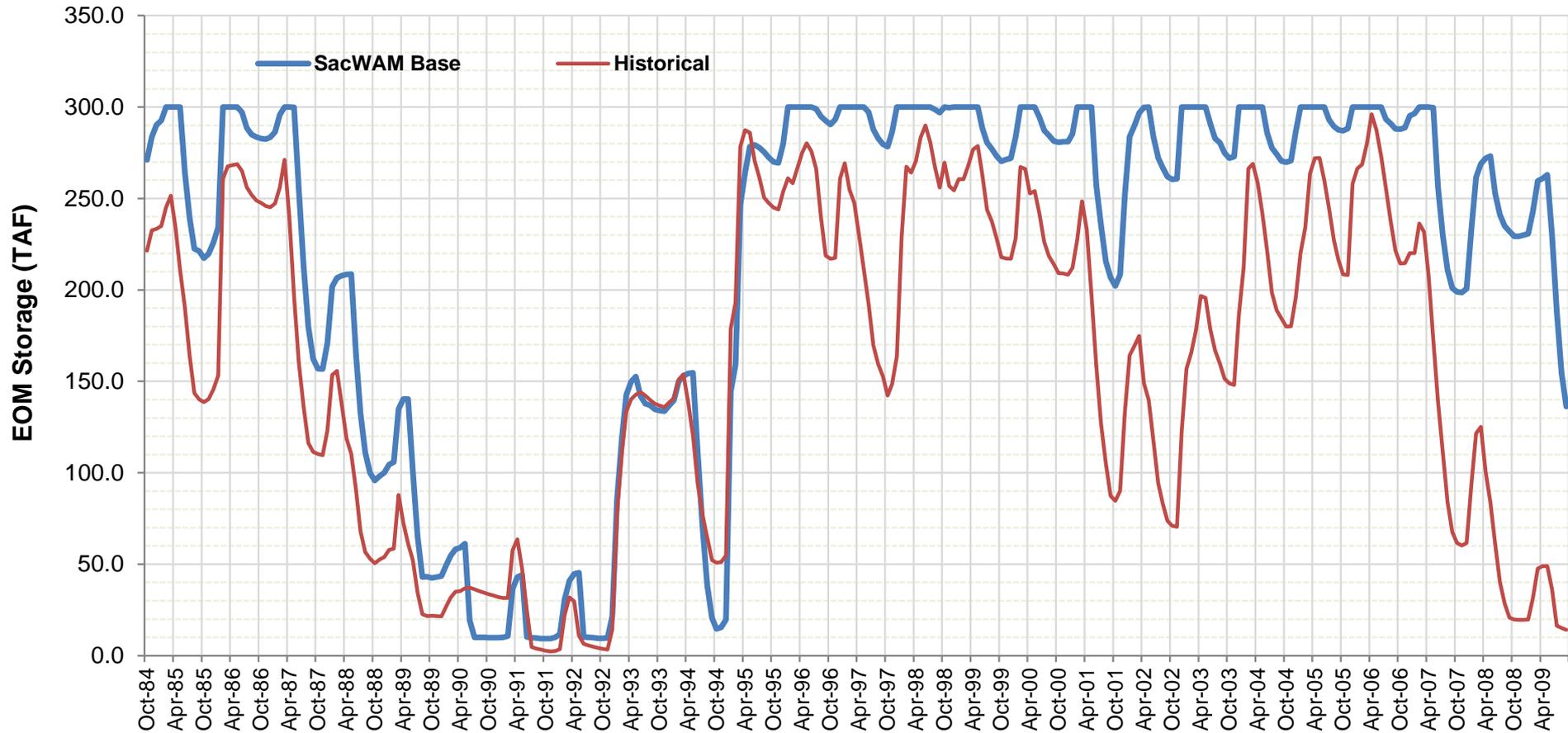
Clear Lake, Cache Creek

Clear Lake Monthly EOM Storage: 1985-2009

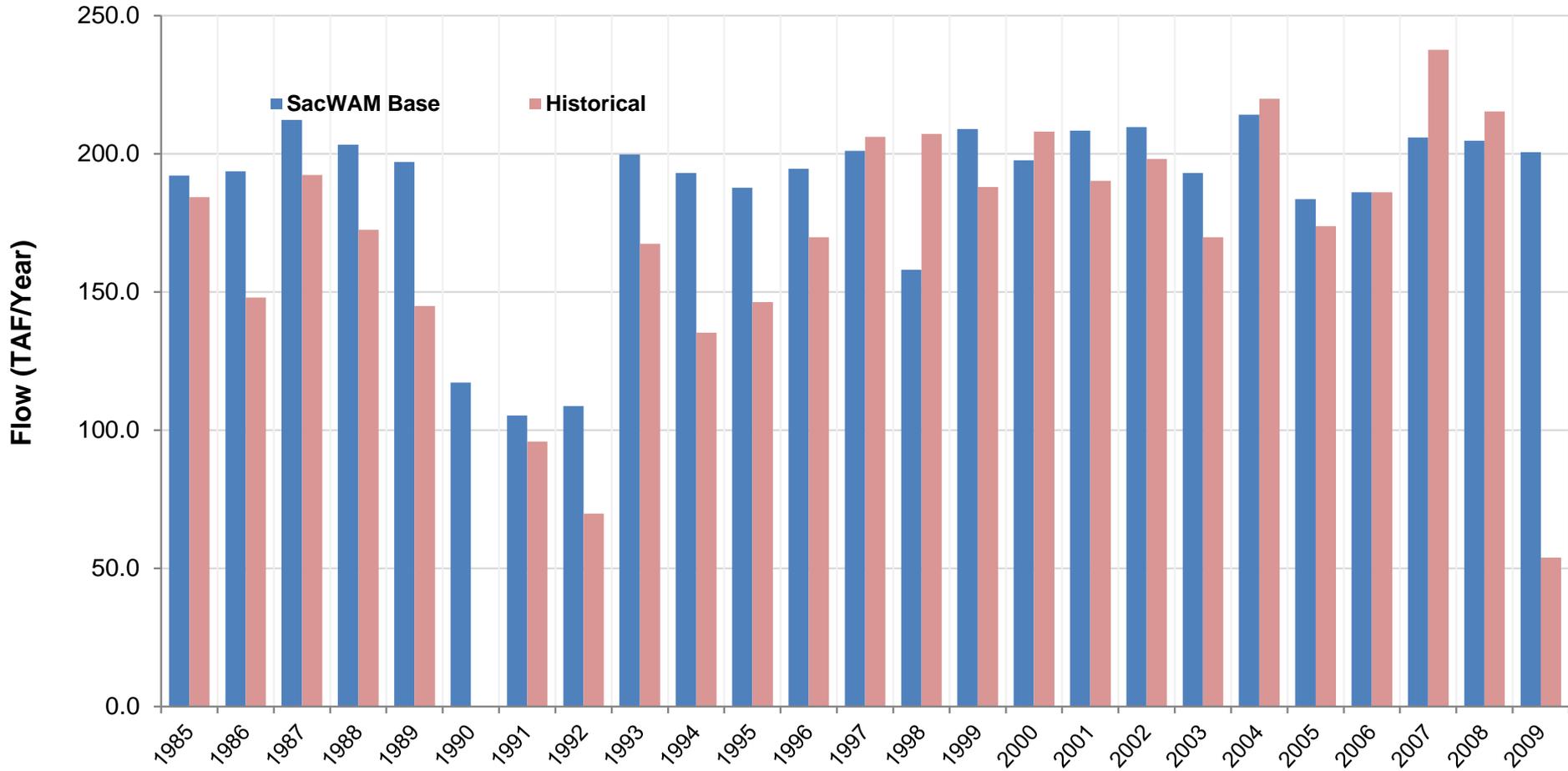


Indian Valley, NF Cache Creek

Indian Valley Reservoir Monthly EOM Storage: 1985-2009

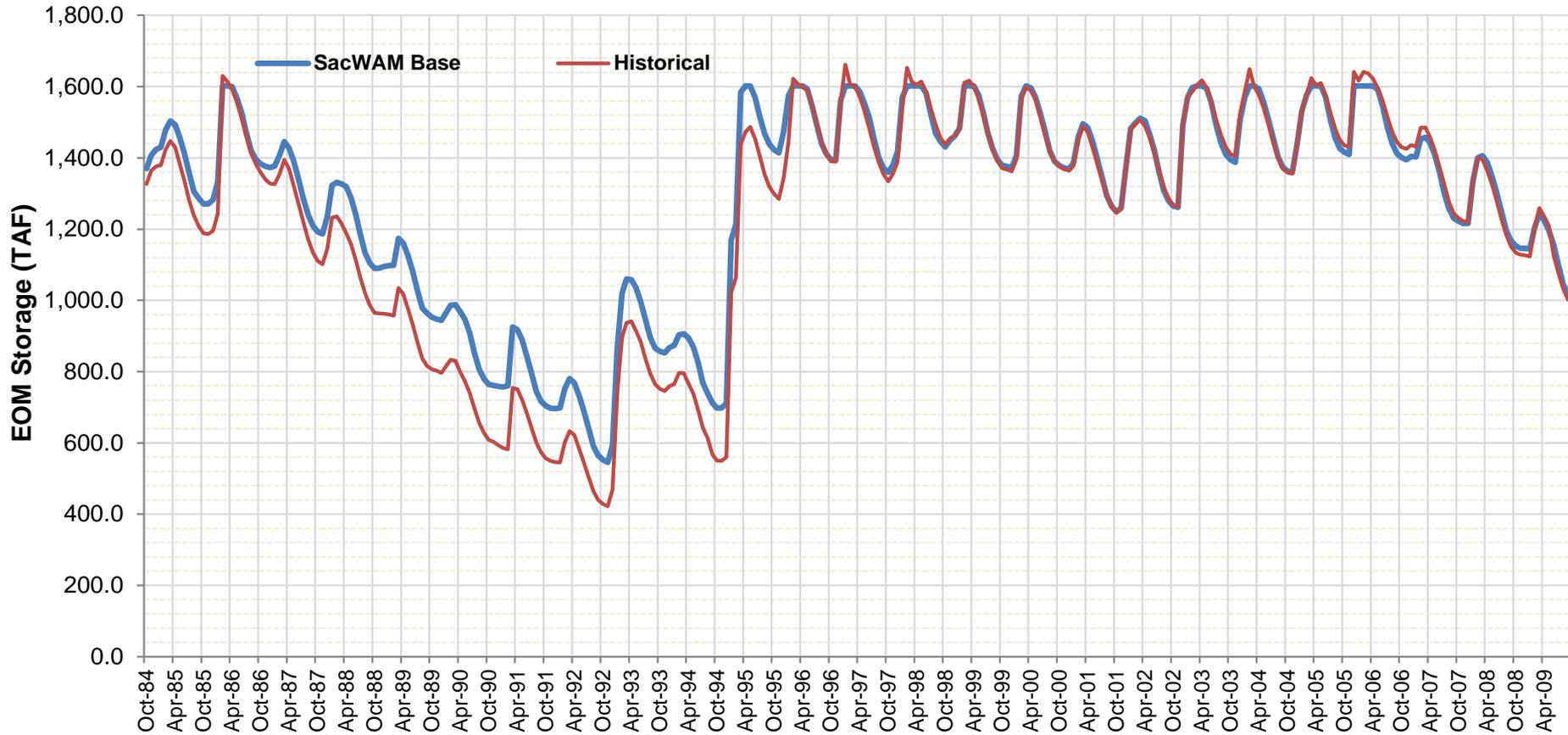


Yolo County FCWCD Deliveries



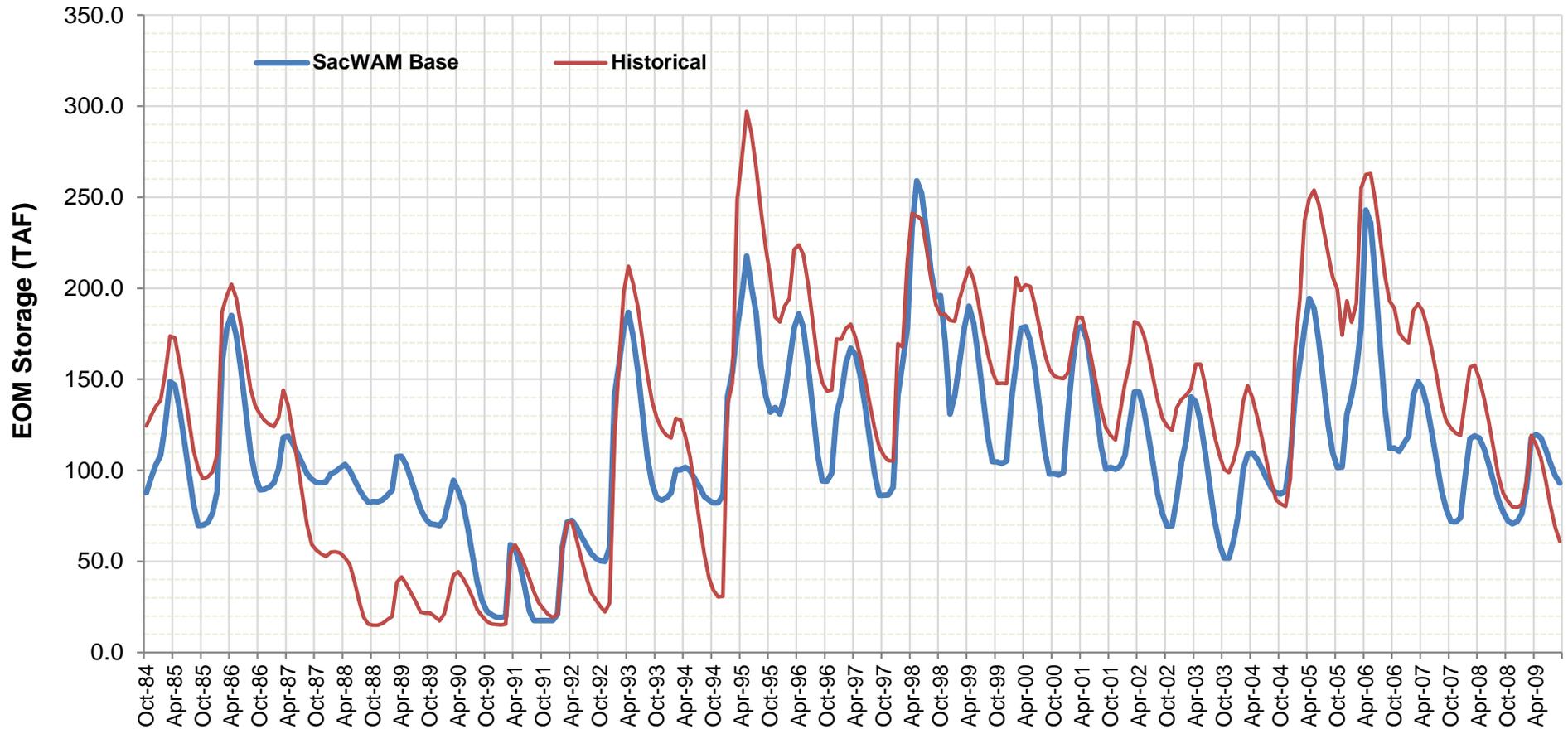
Lake Berryessa, Putah Creek

Lake Berryessa Monthly EOM Storage: 1985-2009



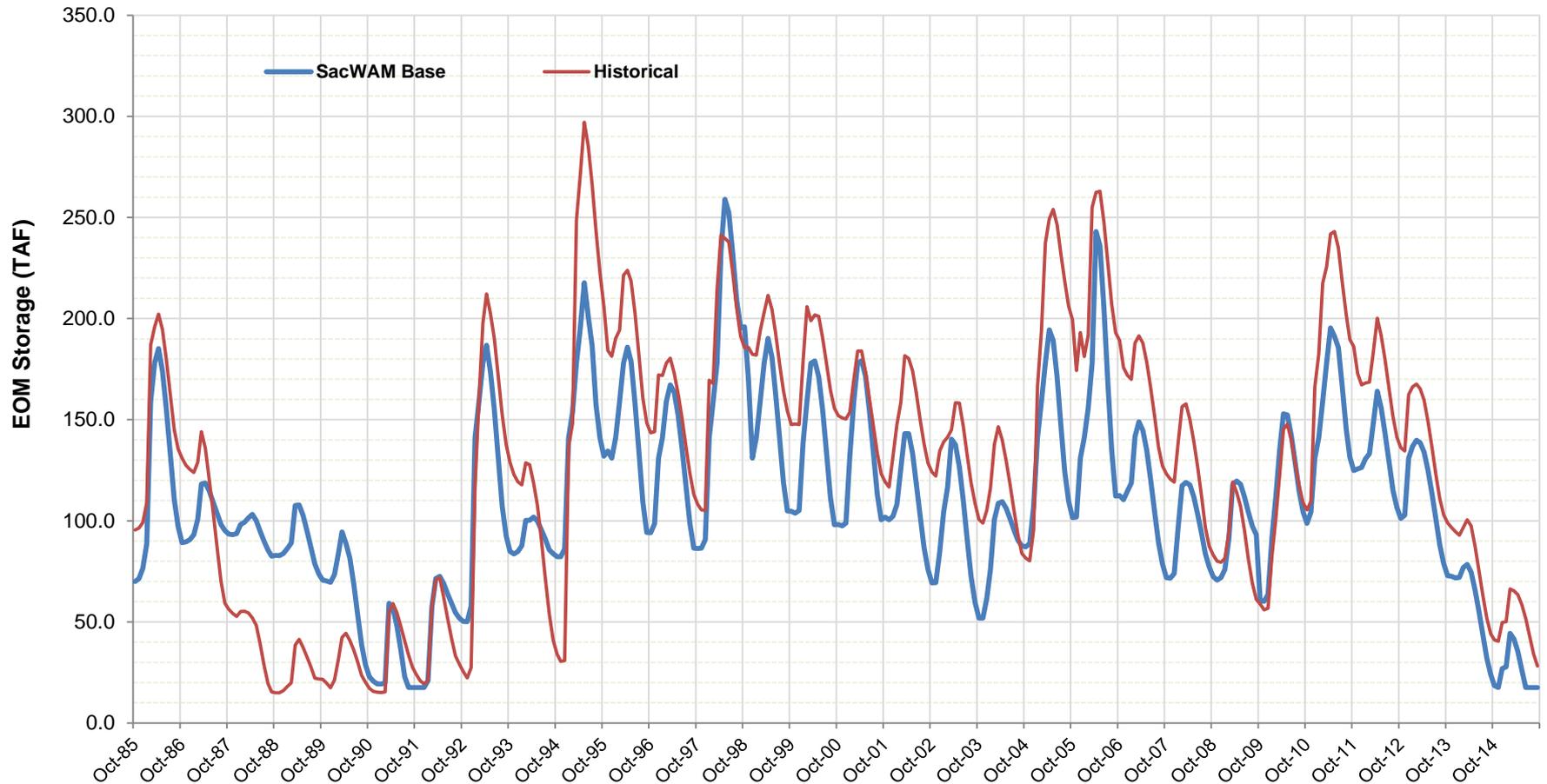
New Hogan, Calaveras River

New Hogan Reservoir Monthly EOM Storage: 1985-2009



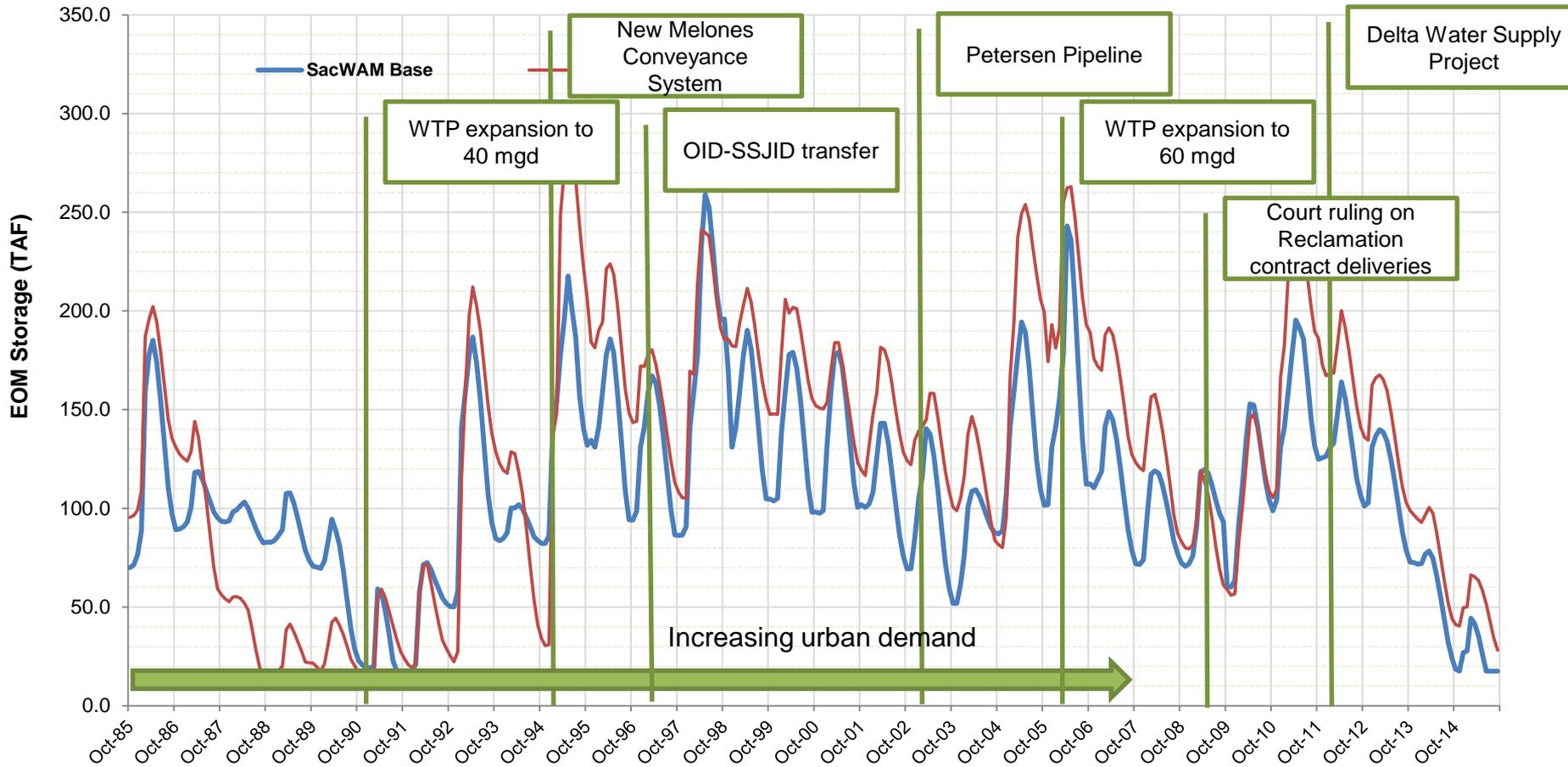
New Hogan, Calaveras River

New Hogan Reservoir Monthly EOM Storage: 1986-2015



Cautionary Note

New Hogan Reservoir Monthly EOM Storage: 1986-2015



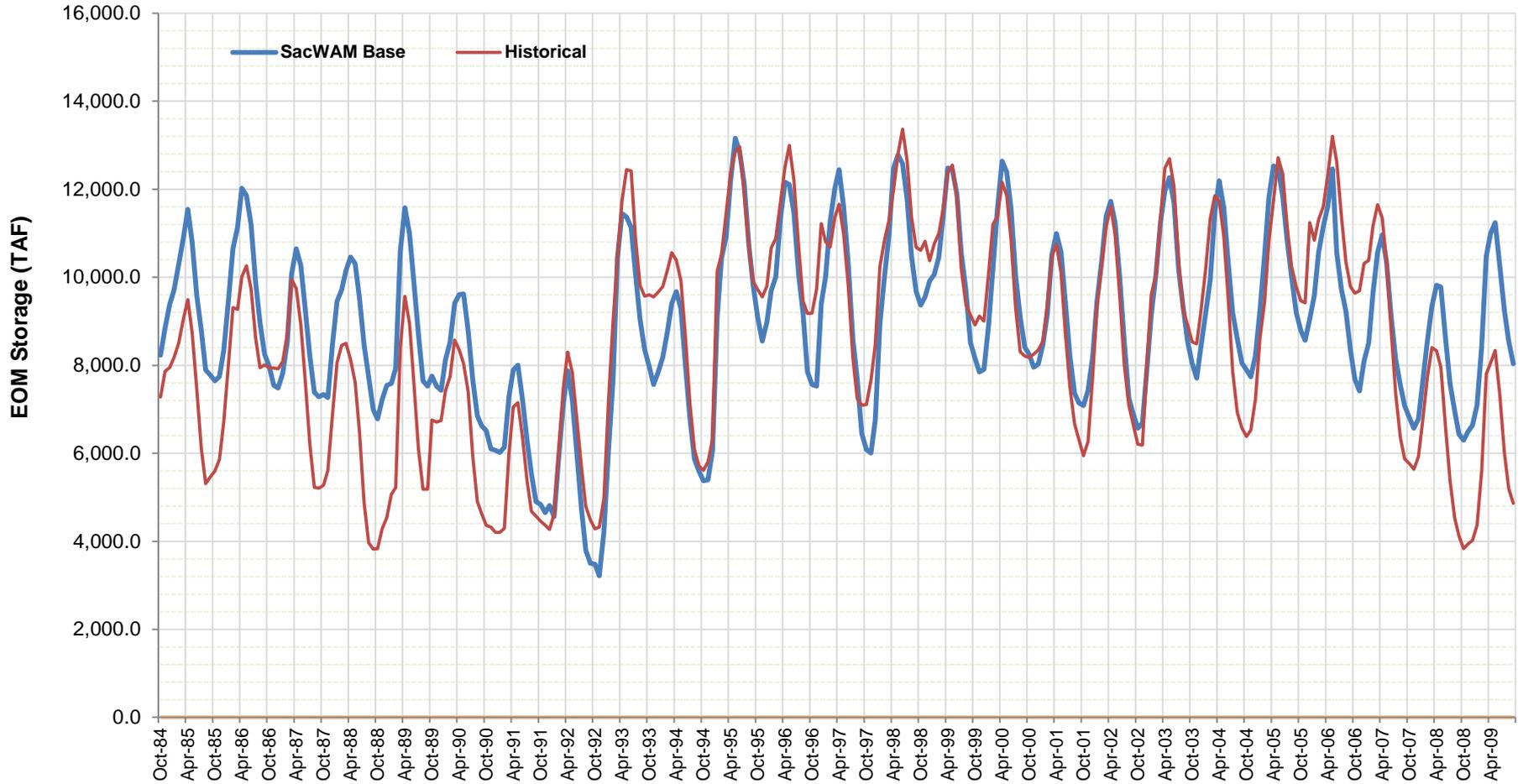
VALIDATION OF CVP-SWP OPERATIONS

COMPARISON WITH HISTORICAL DATA



Combined CVP-SWP Storage

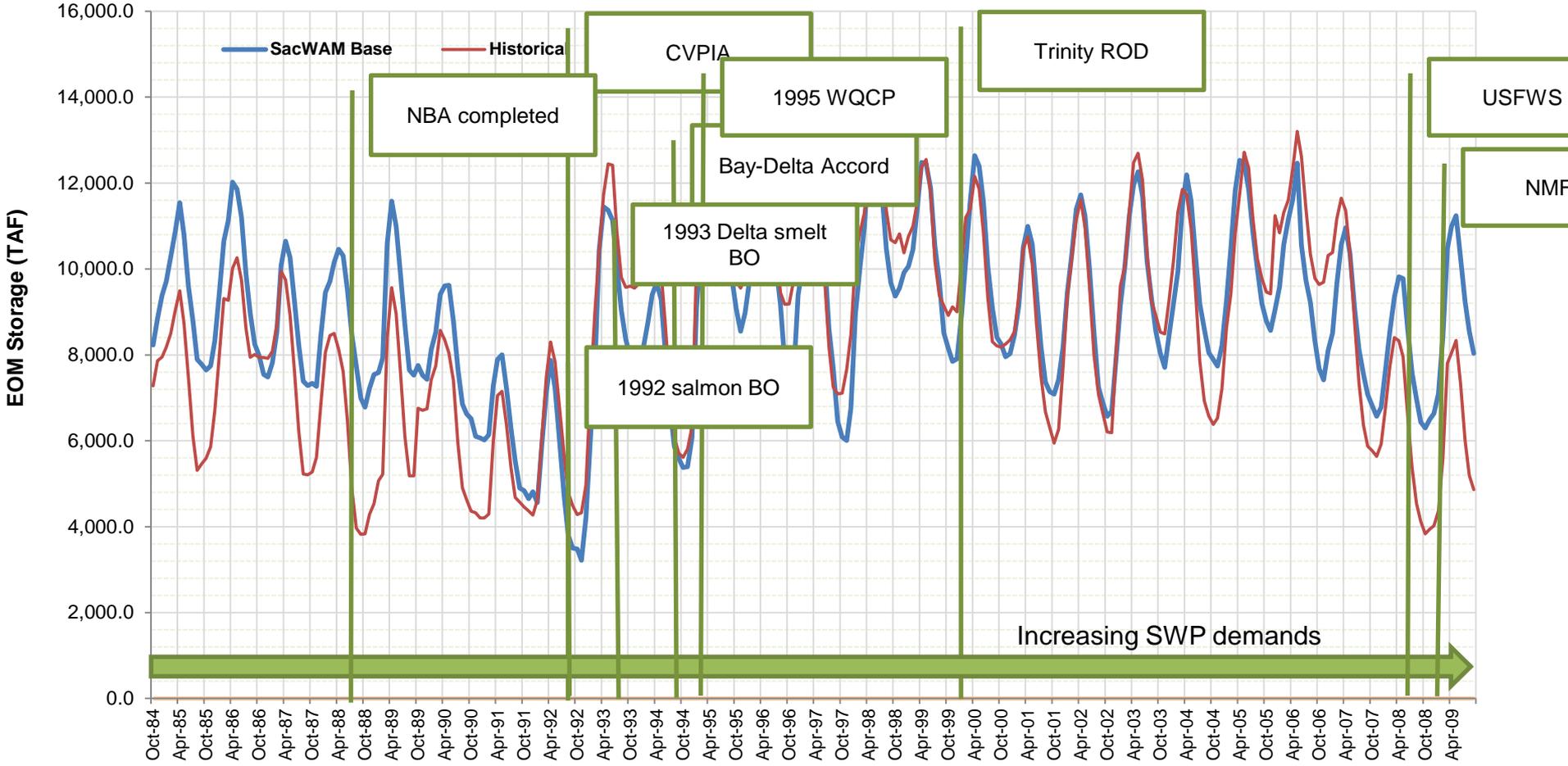
Combined CVP and SWP EOM Storage: 1985-2009



Cautionary Note

Combined CVP and SWP EOM Storage: 1985-2009

CA-DMC Intertie

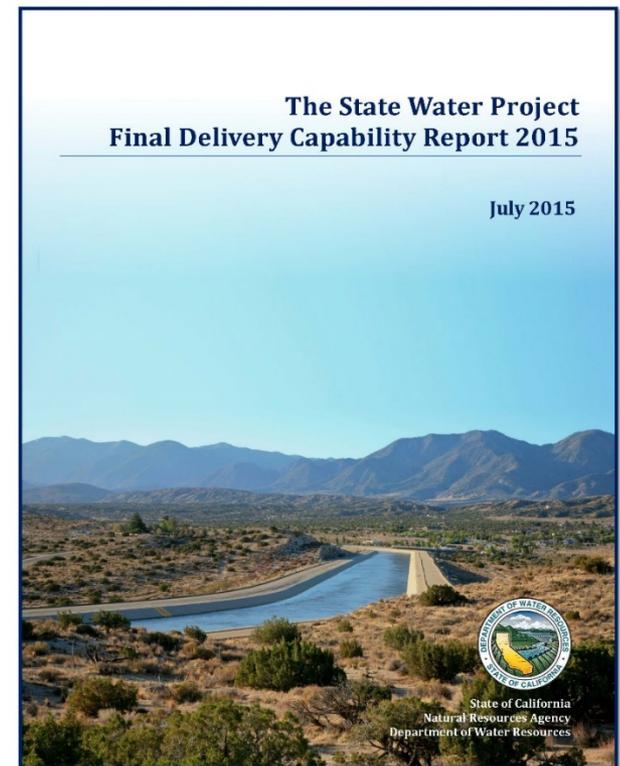


2009-2015

- Extend period of simulation to:
 - validate model performance post NMFS/USFWS BOs
 - During extreme drought

VALIDATION OF CVP-SWP OPERATIONS

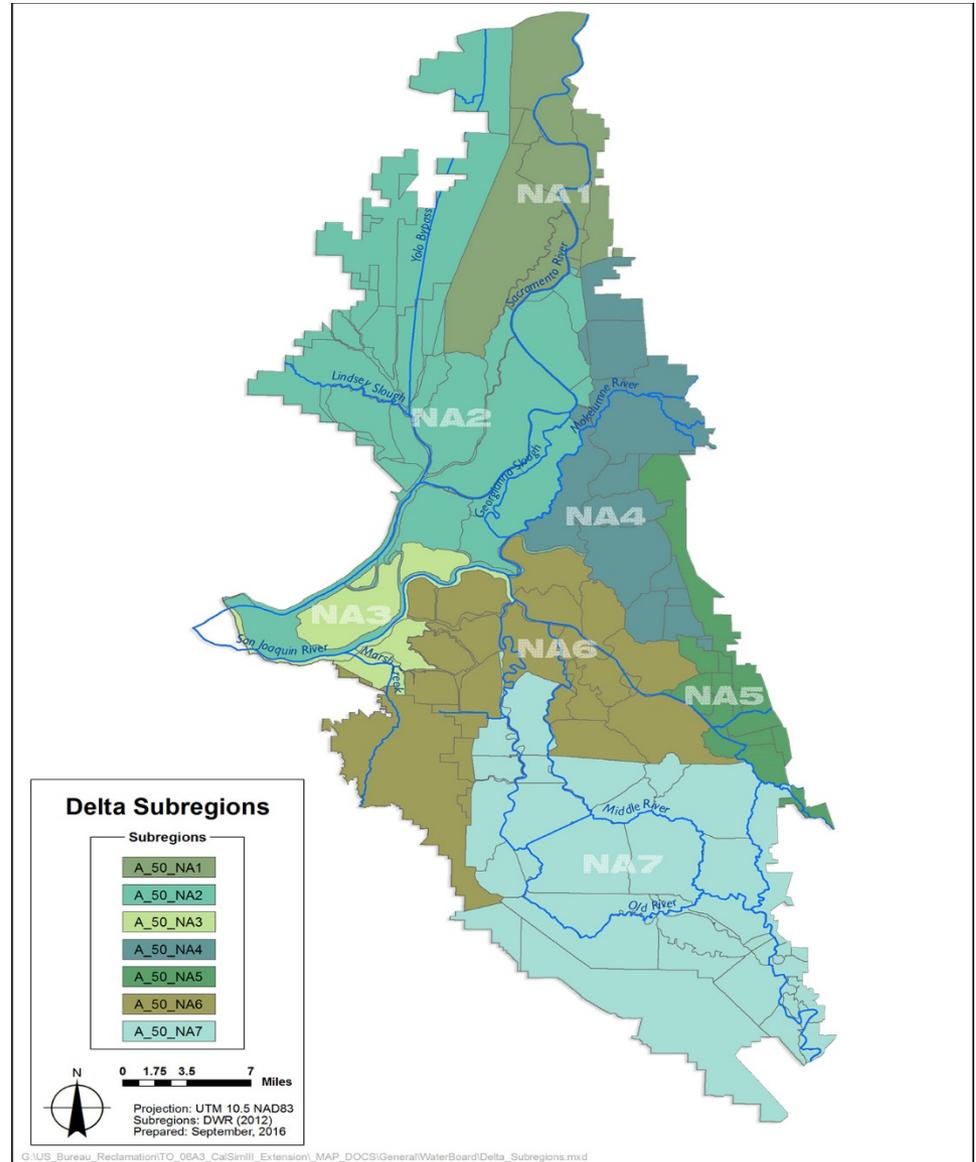
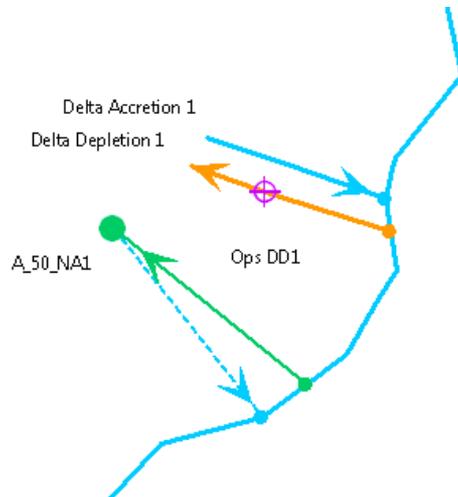
COMPARISON WITH CALSIM II



Hydrology Alignment

- For consistency with DSM2, Delta net channel depletions uses monthly time series of Delta inflows/outflows

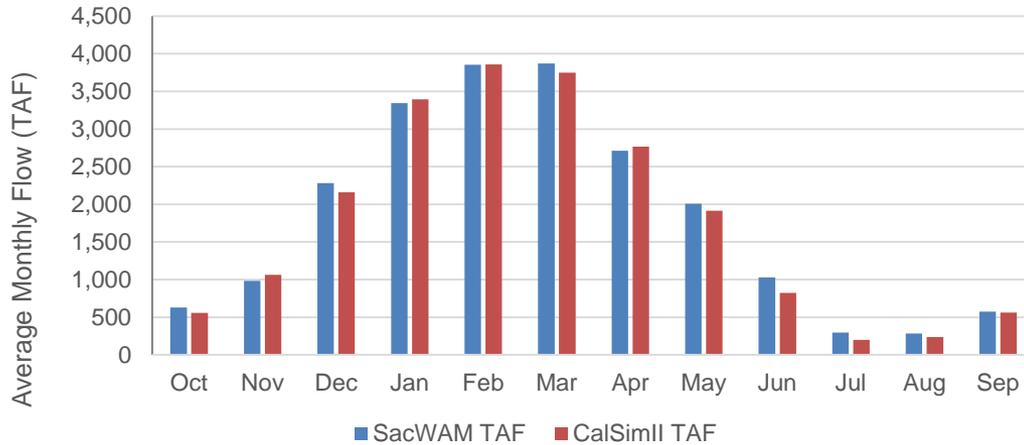
Delta Regions



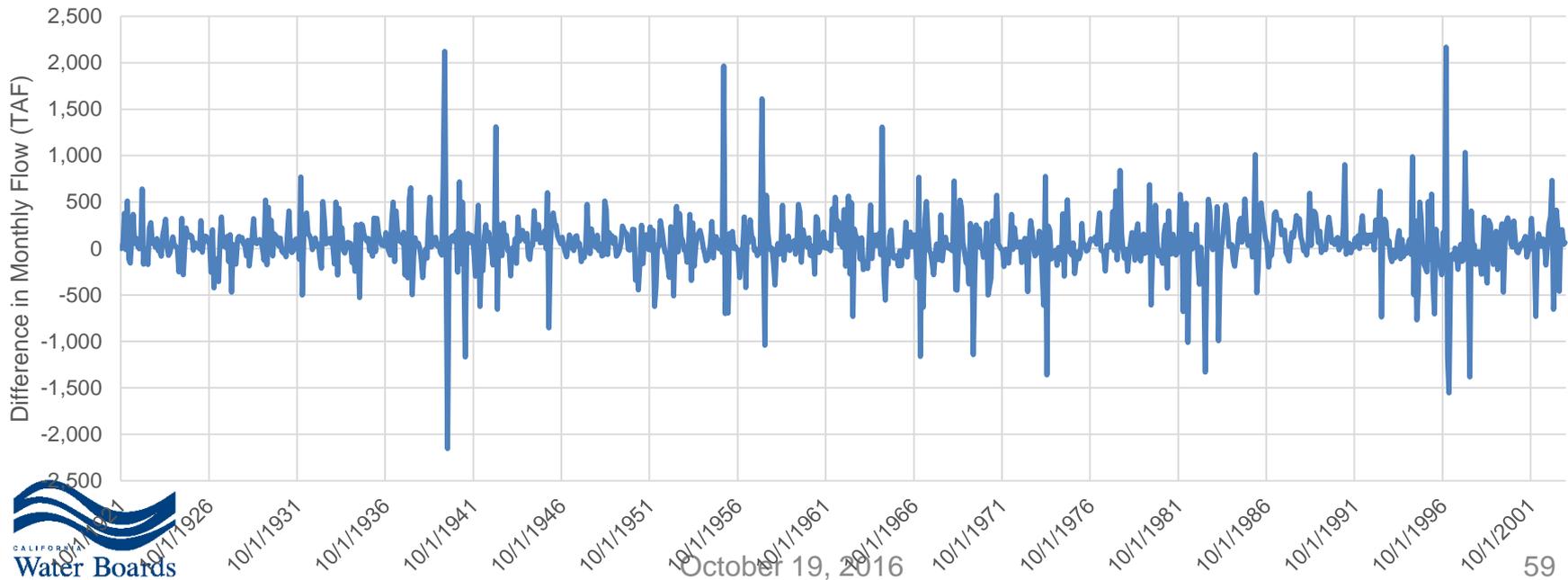
Hydrology Alignment

- For validation of operating rules introduced monthly time series of Delta inflows/outflows to temporarily align SacWAM hydrology to that of CalSim II

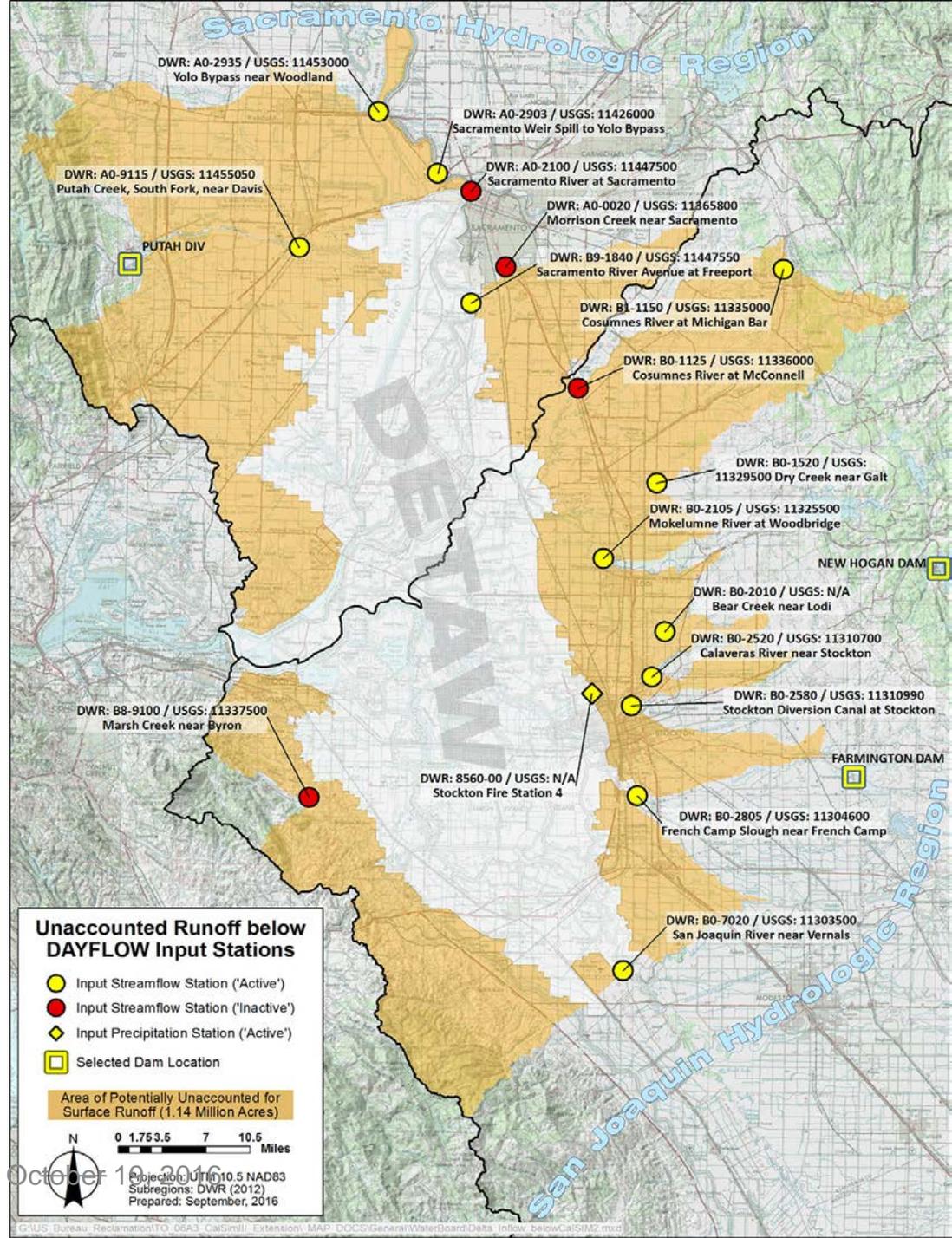
Delta Inflow less Storage Release and Imports



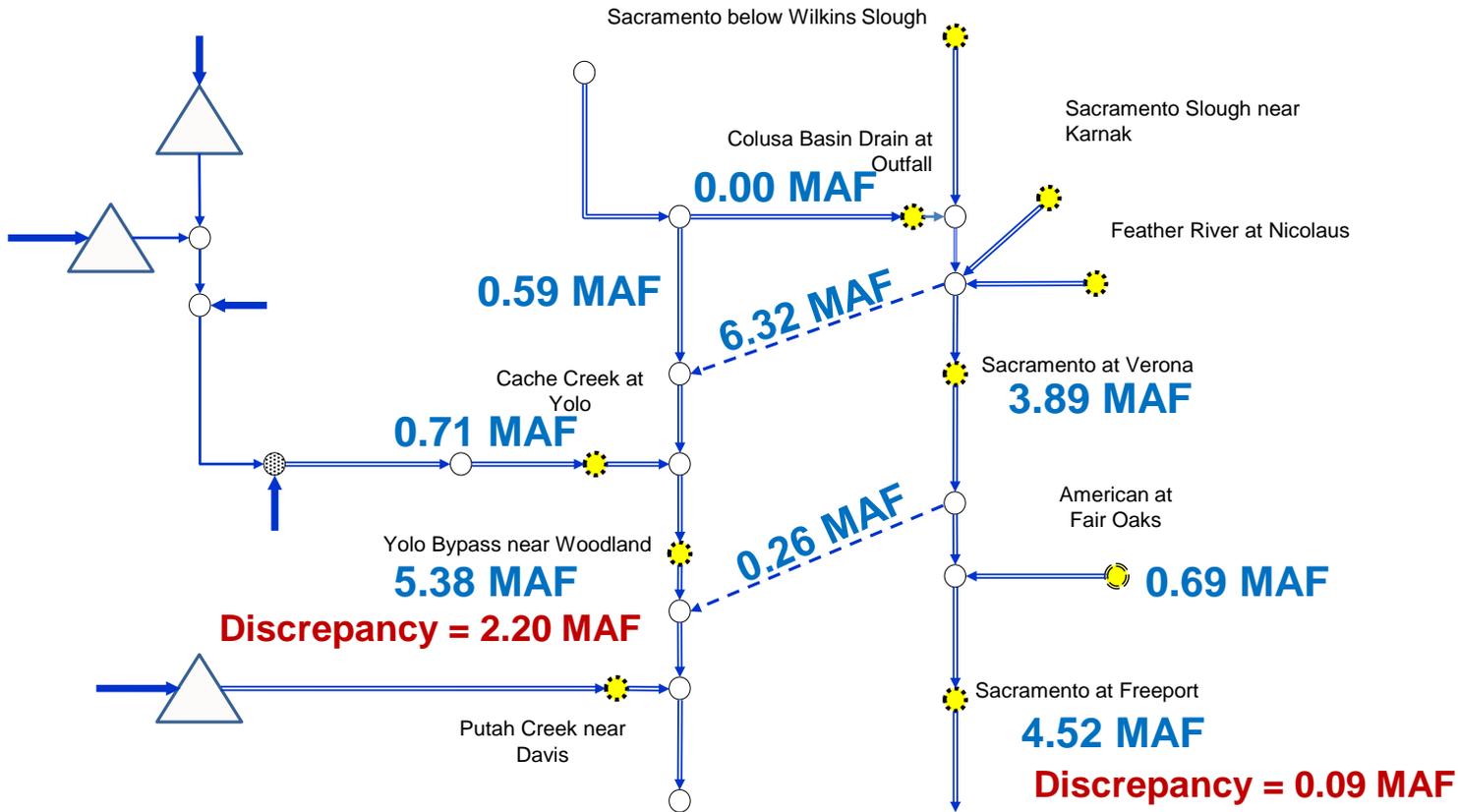
- SacWAM 3% greater than CalSim II 1922-2003



Delta Inflow



Delta Inflow – February 1998

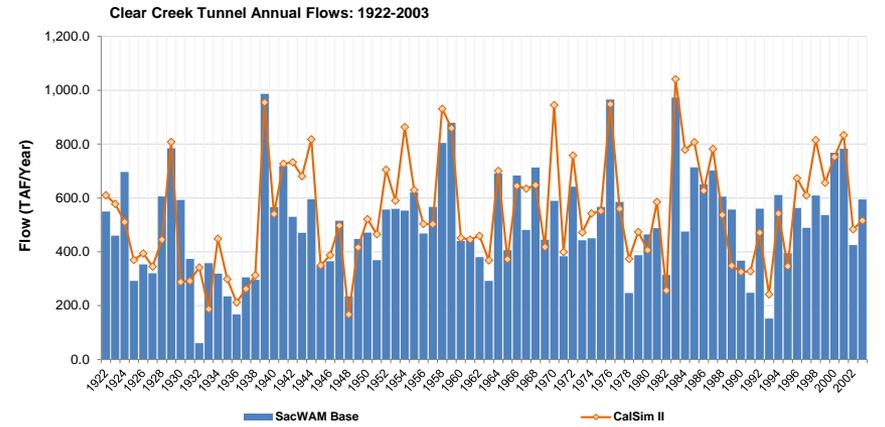
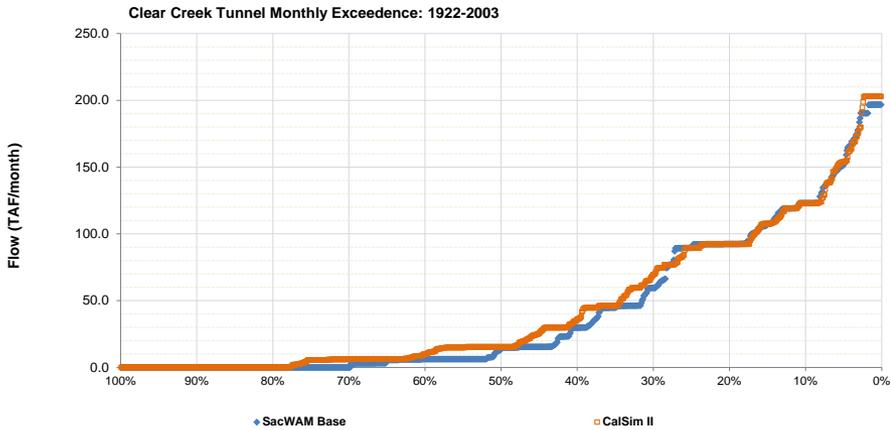
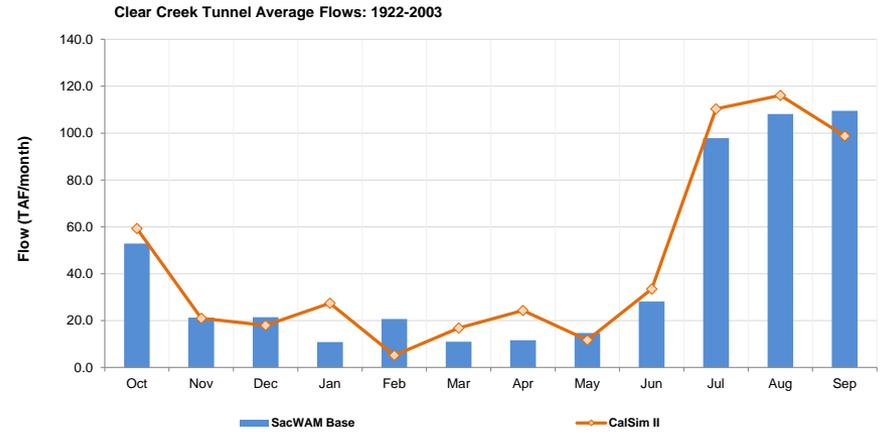
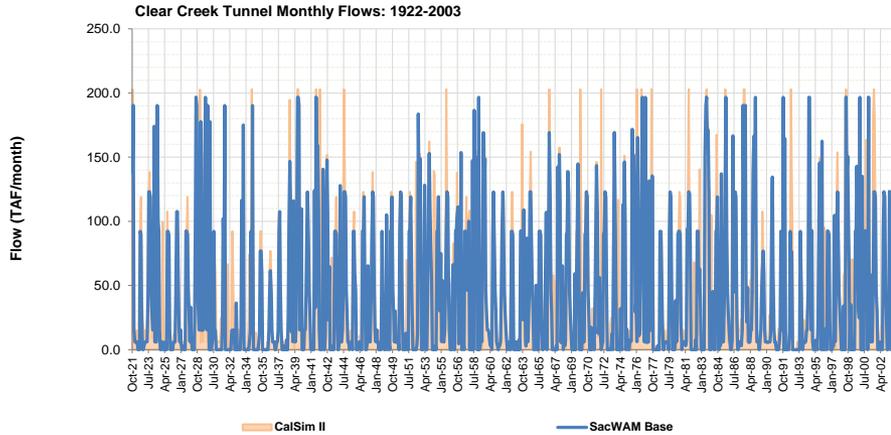


Validation of CVP-SWP Operations

- Trinity River imports
- CVP storage north of the Delta
- SWP storage north of the Delta
- Delta required outflow
- CVP and SWP exports
- San Luis Reservoir

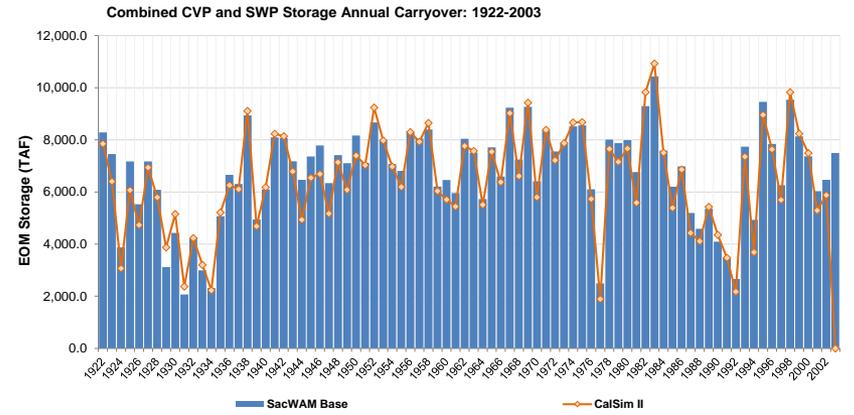
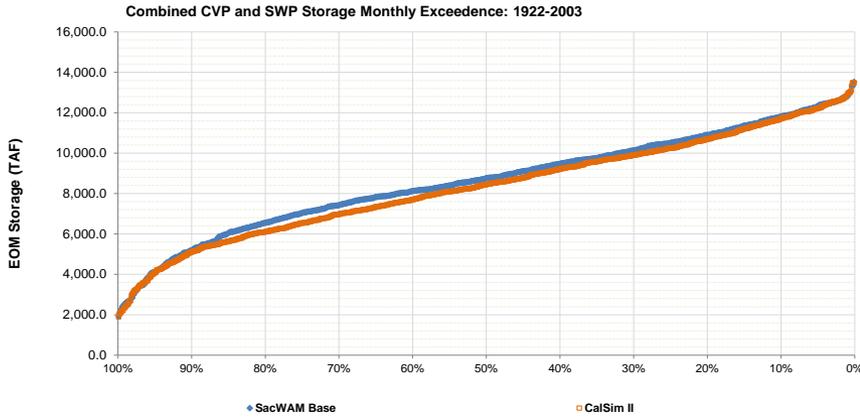
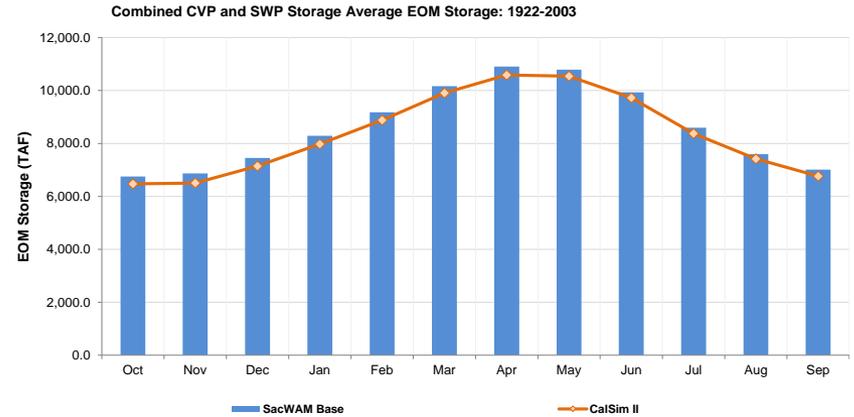
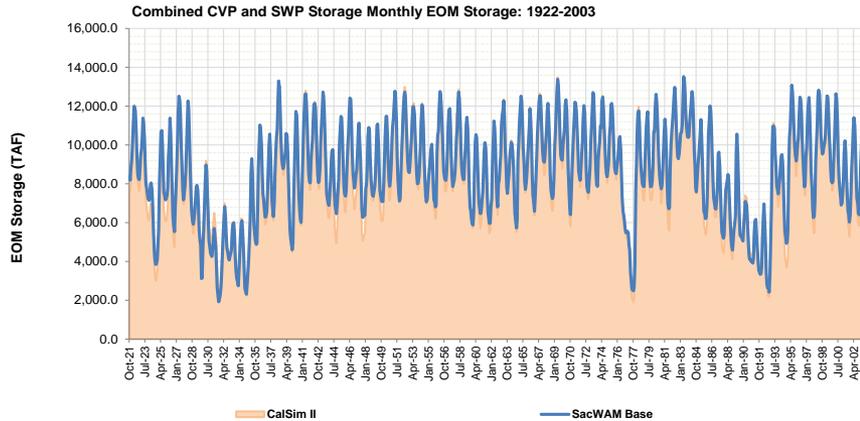
Trinity River Imports

CalSim II 542 TAF/yr, SacWAM -6%



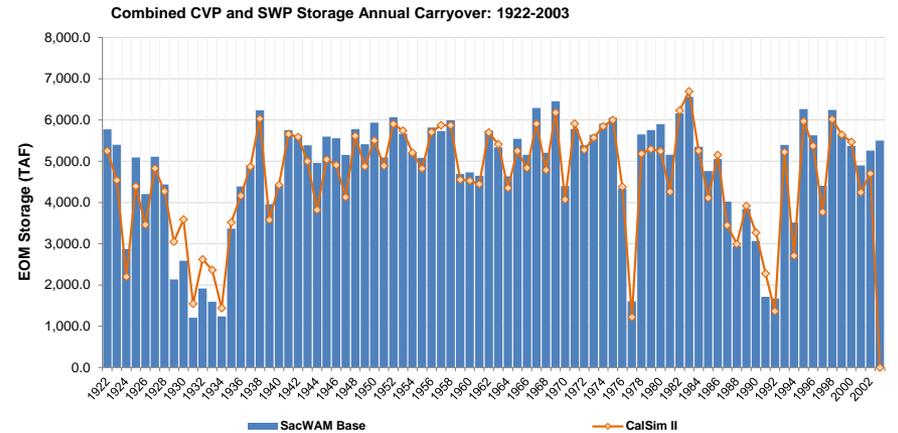
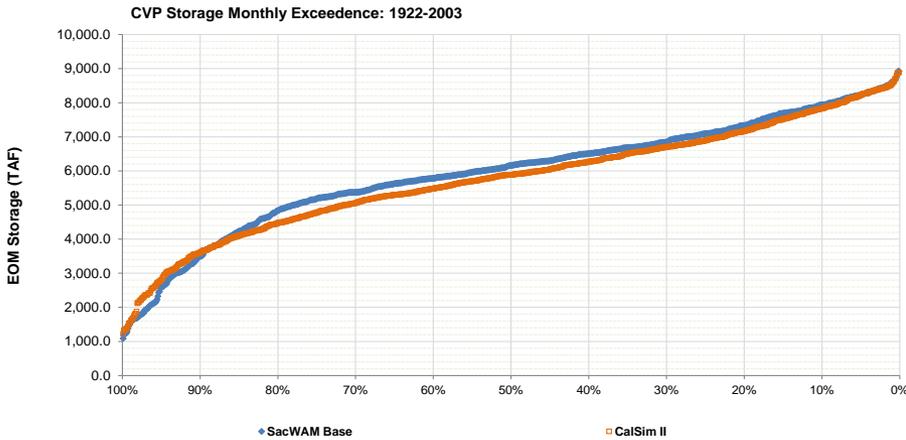
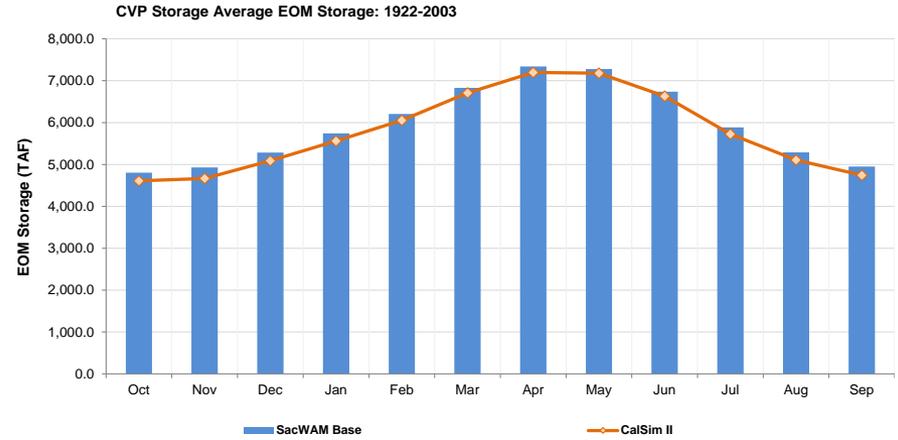
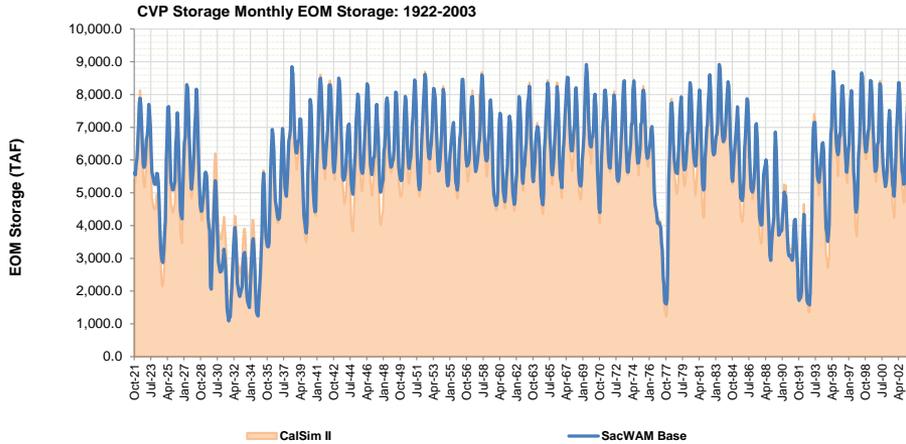
Combined CVP-SWP

CalSim II 4,561 TAF, SacWAM +3%



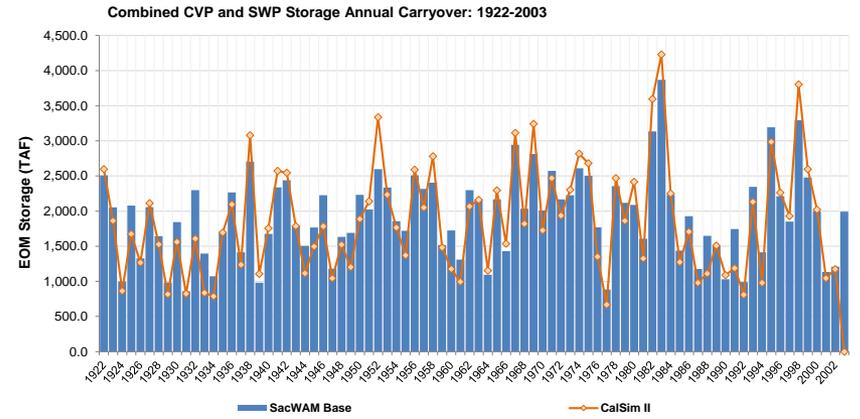
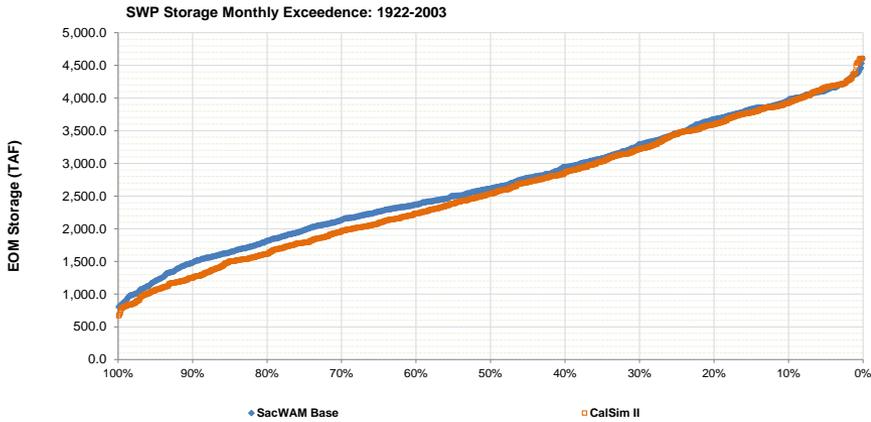
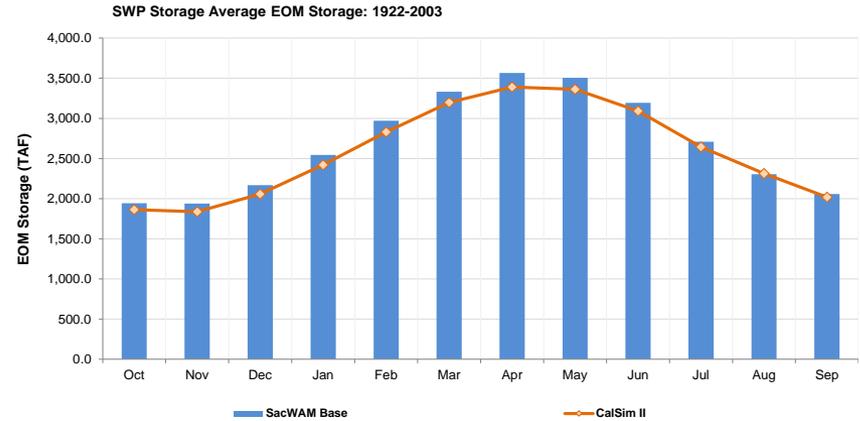
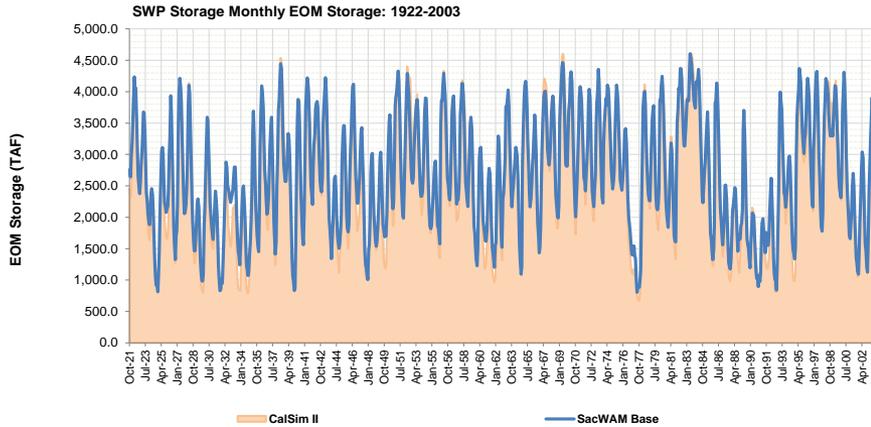
CVP North of Delta Storage – Trinity, Shasta, Folsom

CalSim II 4,561 TAF, SacWAM +3%



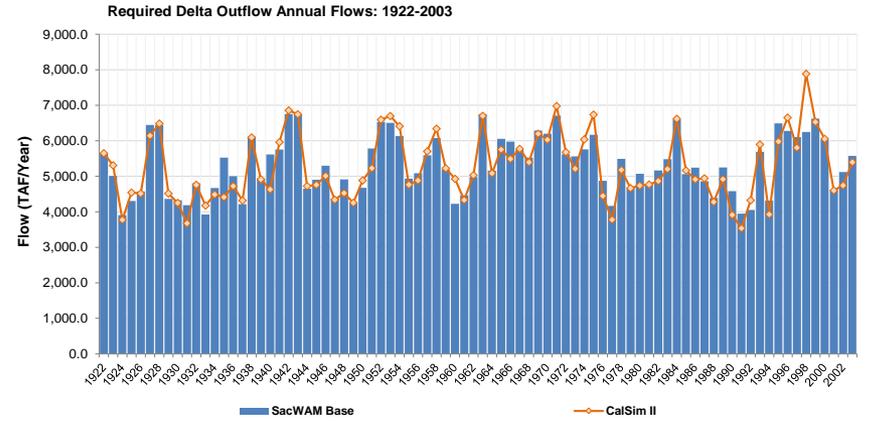
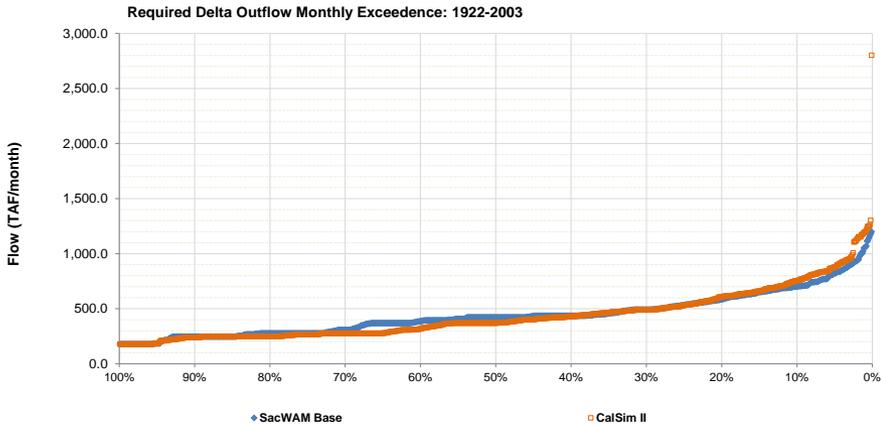
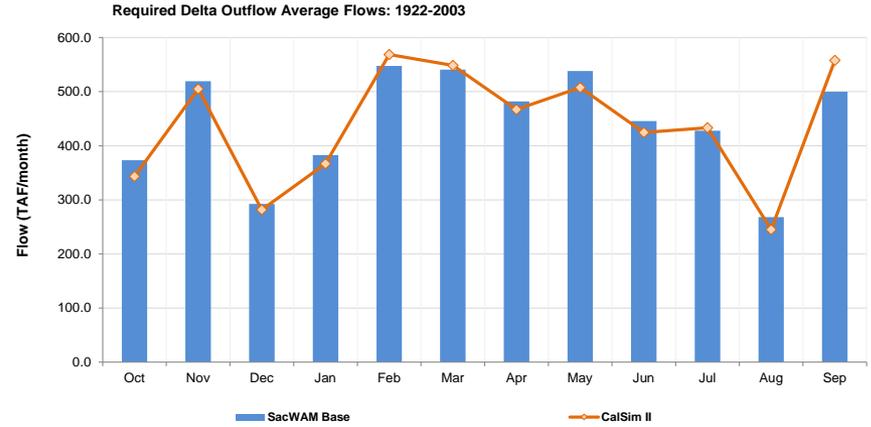
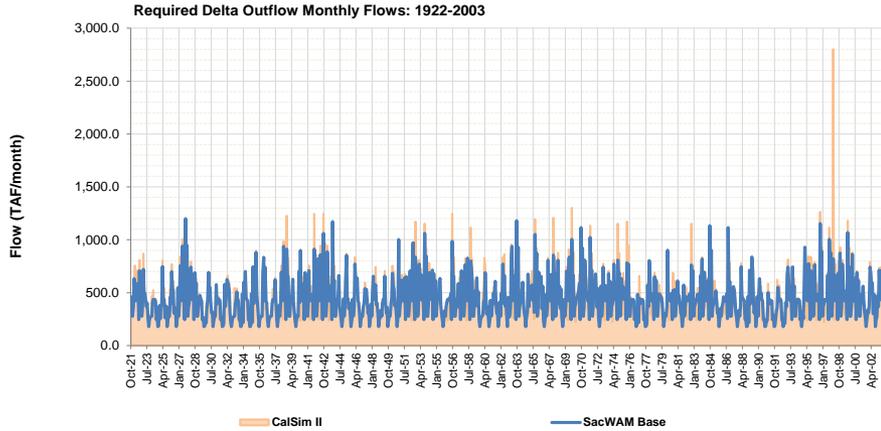
SWP North of Delta Storage - Oroville

CalSim II 1,677 TAF, SacWAM +4%



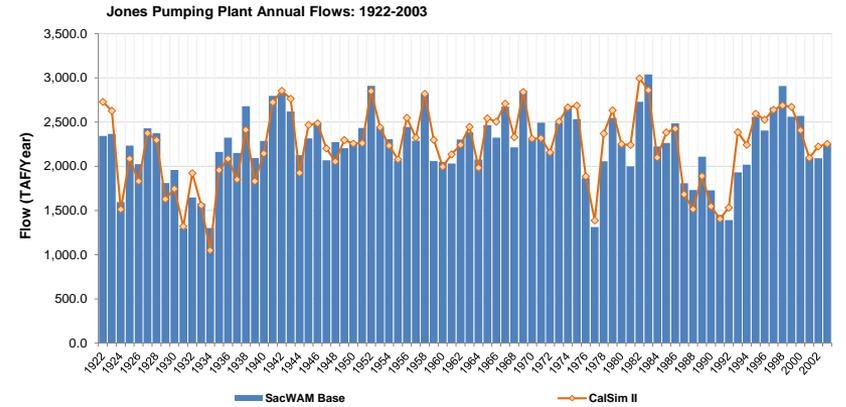
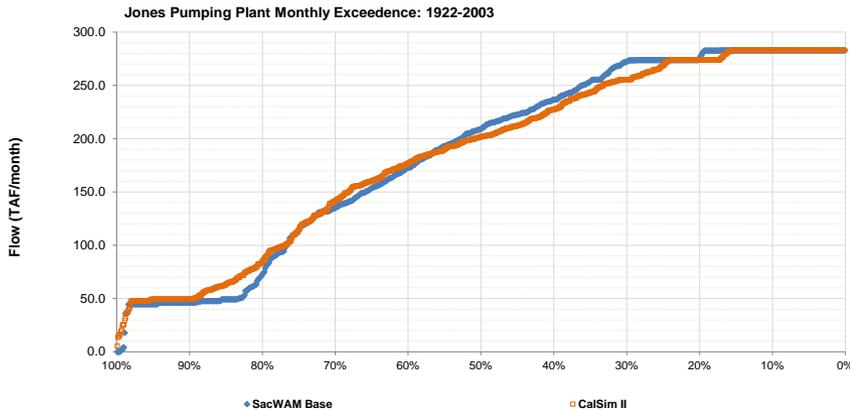
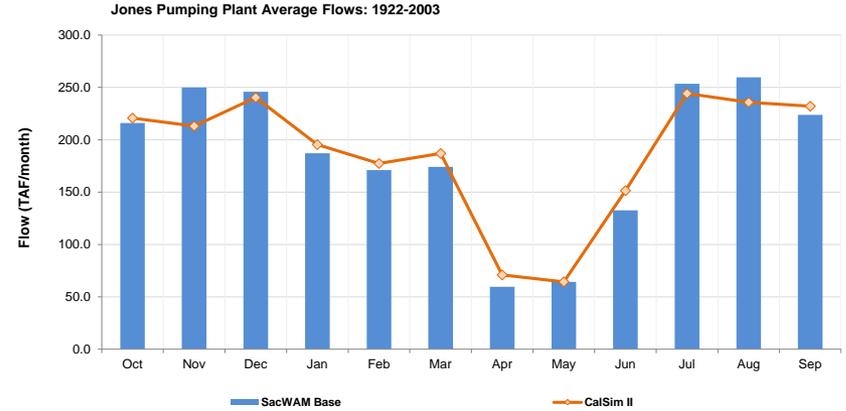
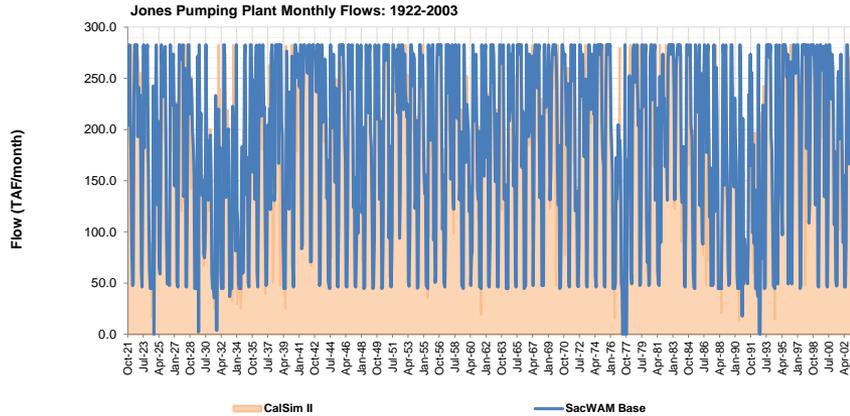
Required Delta Outflow

CalSim II 5,146 TAF/yr, SacWAM +1%



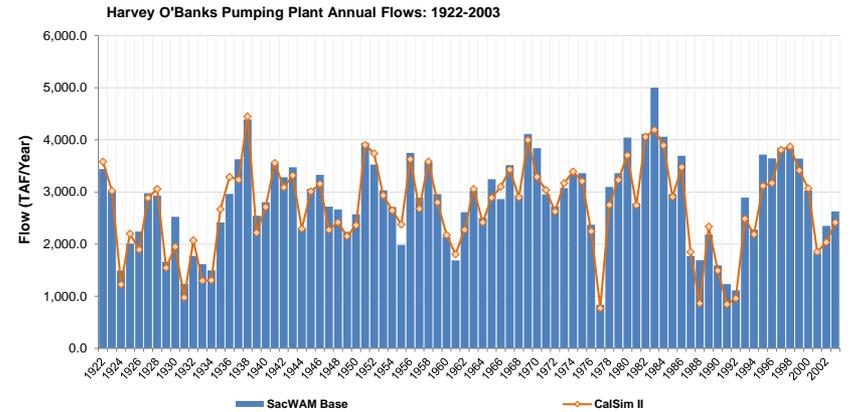
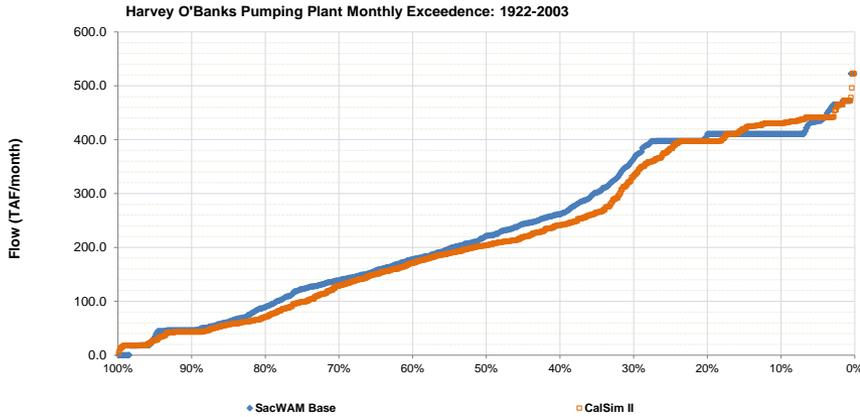
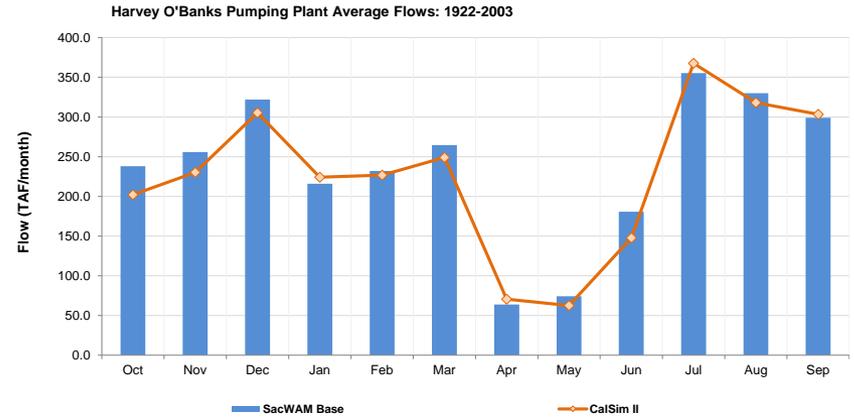
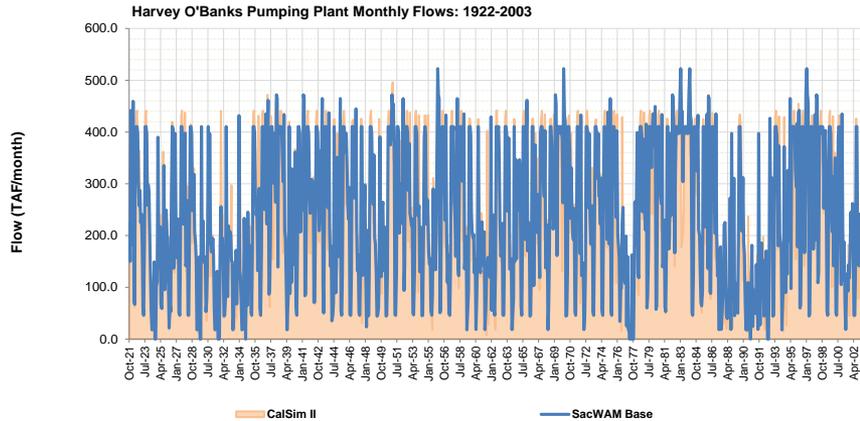
CVP South of Delta Exports

CalSim II 2,233 TAF/yr, SacWAM +0.2%



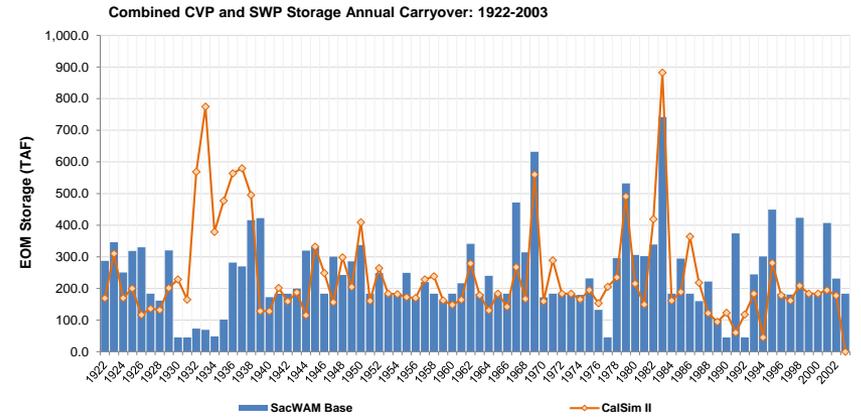
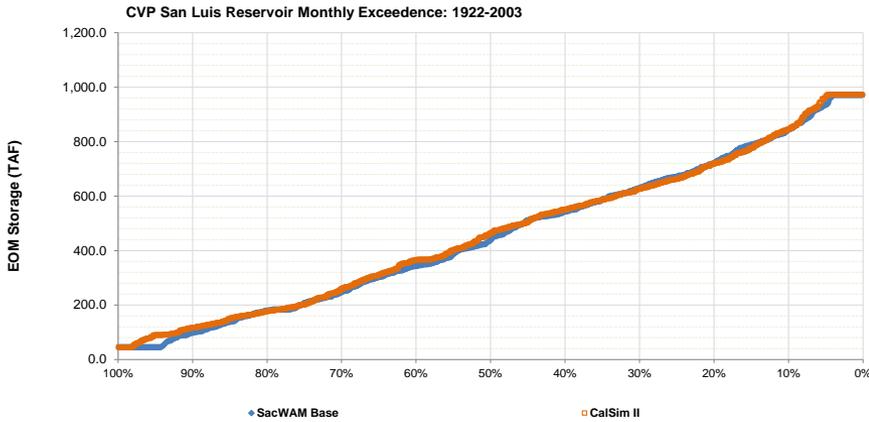
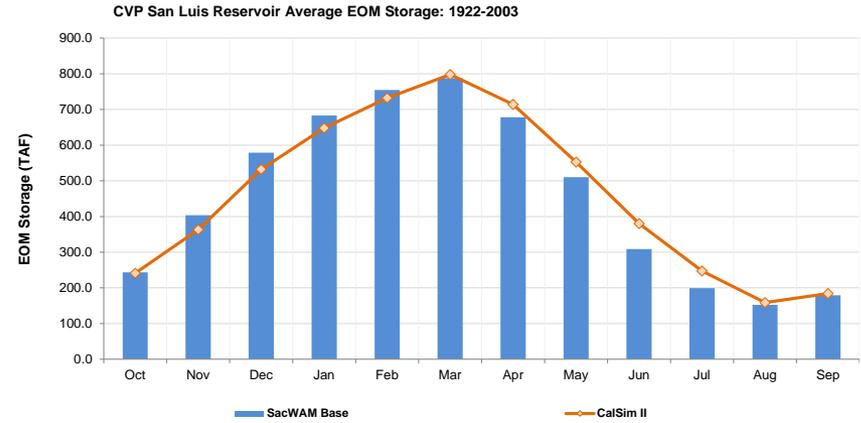
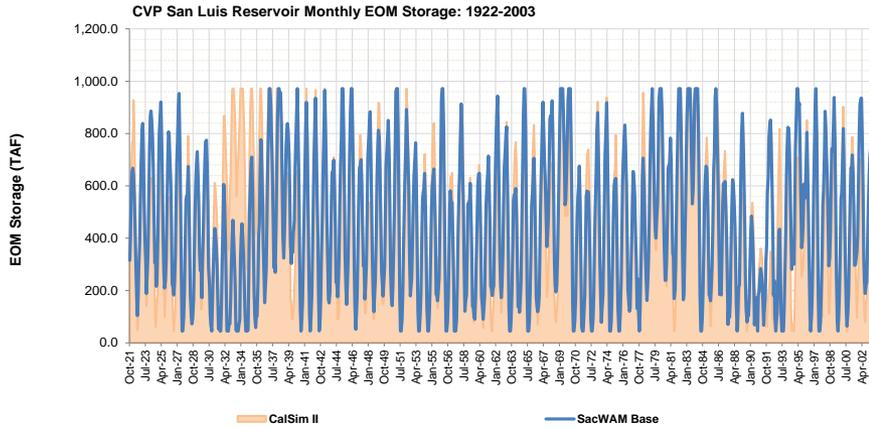
SWP South of Delta Exports

CalSim II 2,708 TAF/yr, SacWAM +5%



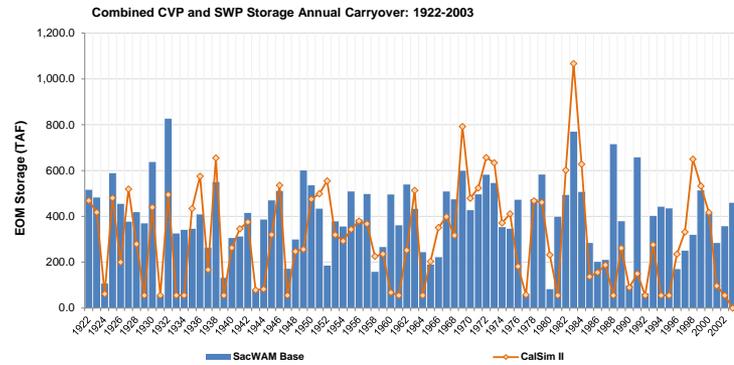
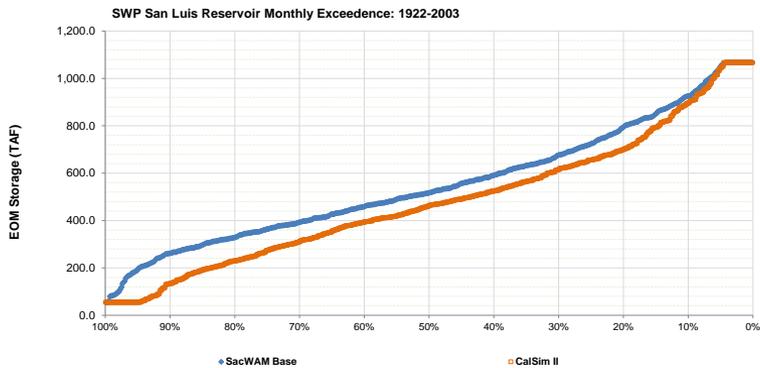
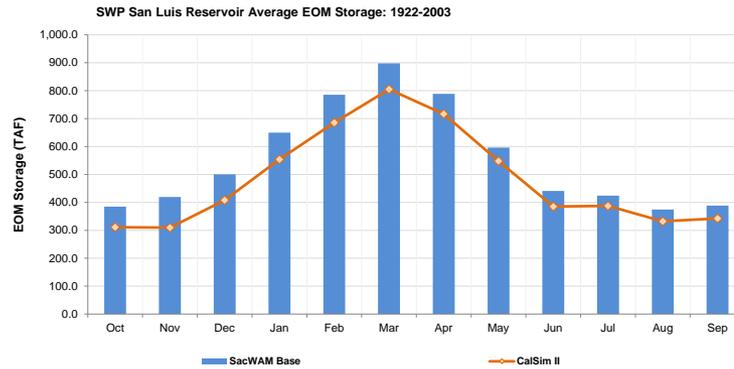
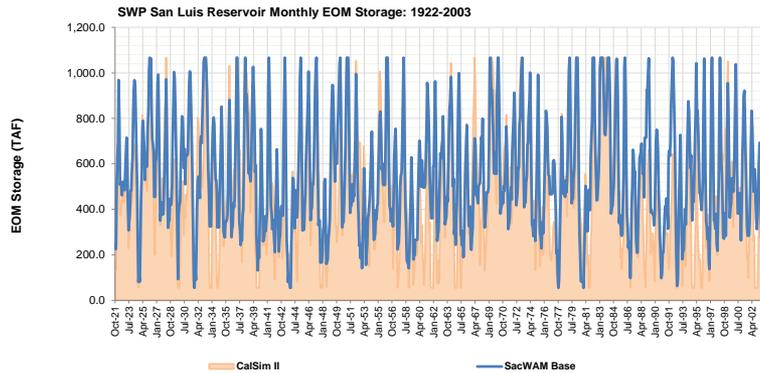
CVP San Luis Reservoir

CalSim II 184 TAF, SacWAM -1%



SWP San Luis Reservoir

CalSim II 342 TAF, SacWAM +15%



Summary

- Validation and model refinement on-going
- Extension of period of simulation would provide additional checks on model performance
- Reasonable match with CalSim II simulation after temporary alignment of model hydrologies