Appendix B. Sacramento Valley Floor and Delta Calibration

B.1 Introduction

This appendix contains a description of the procedure used in the calibration of simulated hydrological processes on the Sacramento Valley floor and Delta. It also contains a validation of the CVP and SWP operations, referred to here as "project operations." Forty four comparisons are provided between SacWAM and historical data and SacWAM and CalSim data. The CalSim data are used to verify the SacWAM simulation of CVP and SWP operations (Project Operations Validation). For project operations, comparisons to historical observations are not relevant since operations of both the CVP and SWP have changed operating rules in recent decades. Any references to "non-project" refer to streamflows and reservoirs not included in the CVP or SWP. This includes the Mokelumne, Calaveras, Cosumnes, Bear, and Yuba Rivers, and Stony, Cache, and Putah Creeks.

Following the calibration of the upper watersheds described in Appendix A, the next step in calibrating SacWAM was to focus on processes which occur on the Sacramento Valley floor. Here, the initial focus was on surface water diversions as they are largely a function of evapotranspiration and irrigation management parameters and independent of other processes in the model. Simulated evapotranspiration values were compared to values from the Department of Water Resources CUP model developed for the Basin Study. Simulated diversions were then compared to historical observations and adjustments to irrigation management parameters were made as needed. Following that, an iterative process was employed in calibrating the rainfall runoff processes and the stream-aquifer interactions to historical stream flow observations and simulated stream-aquifer interaction flows from the C2VSim groundwater model. These processes were calibrated in an iterative fashion due to the interactions between rainfall runoff processes and stream-aquifer interactions. Finally, operations logic in the Other Assumptions and User Defined LP Constraints were refined so that CVP and SWP operations closely matched the CalSim II model.

In this appendix, a discussion of the techniques used for each aspect of the calibration is provided in Sections B.2 – B.5. In Section B.6 a validation of project operations is provided using comparisons of SacWAM and CalSim. Sections B.7 and B.8 provide a validation of streamflows and storage on non-project streams using comparisons to historical data.

B.2 Evapotranspiration Calibration

During calibration of SacWAM ET, the target ET rates for crops were obtained from the CUP model analysis used in the Sacramento and San Joaquin Basins Study (Basin Study). In that study, values of crop ET were calculated for Water Year 2005 using reference ET values from the Davis, California Irrigation Management Information System (CIMIS) station. These values are provided in Table B-1. Since crop evapotranspiration in SacWAM is calculated using the dual crop coefficient method described in FAO56 (Allen et al., 1998) and the CUP model uses a single coefficient model, a calibration of the basal crop coefficients in SacWAM for each crop was required. The calibration was done by comparing CUP derived monthly ET rates and seasonal bias (April to September) 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 B-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 B-1 Water Year 2005 CUP Monthly Crop ET for Davis (source: Basin Study) (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

Table B-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

B.3 Water Diversion Calibration

Following the calibration of the ET parameters, surface water deliveries were calibrated for 15 of the largest diversions in the Sacramento Valley which represent 80% of the average annual total volume of surface water diversions simulated by SacWAM. In the discussion below, a comparison between observed and simulated diversions for the water years 2000 to 2009 is presented. These years were chosen for use in the calibration since they most closely match the period for which land use and municipal demands are represented in 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 demand units (DU). 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 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.

Below is a description of each of the 15 comparisons that were made in calibrating the surface water diversions. They are presented in decreasing size of the diversion. A positive reported bias indicates an over-estimate of diversions by SacWAM.

B.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_PA and A_08_SA2. Additional water is delivered to R_08_PR. Observed data are available for 12 months of the year. The average annual bias is 4.2%. 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.

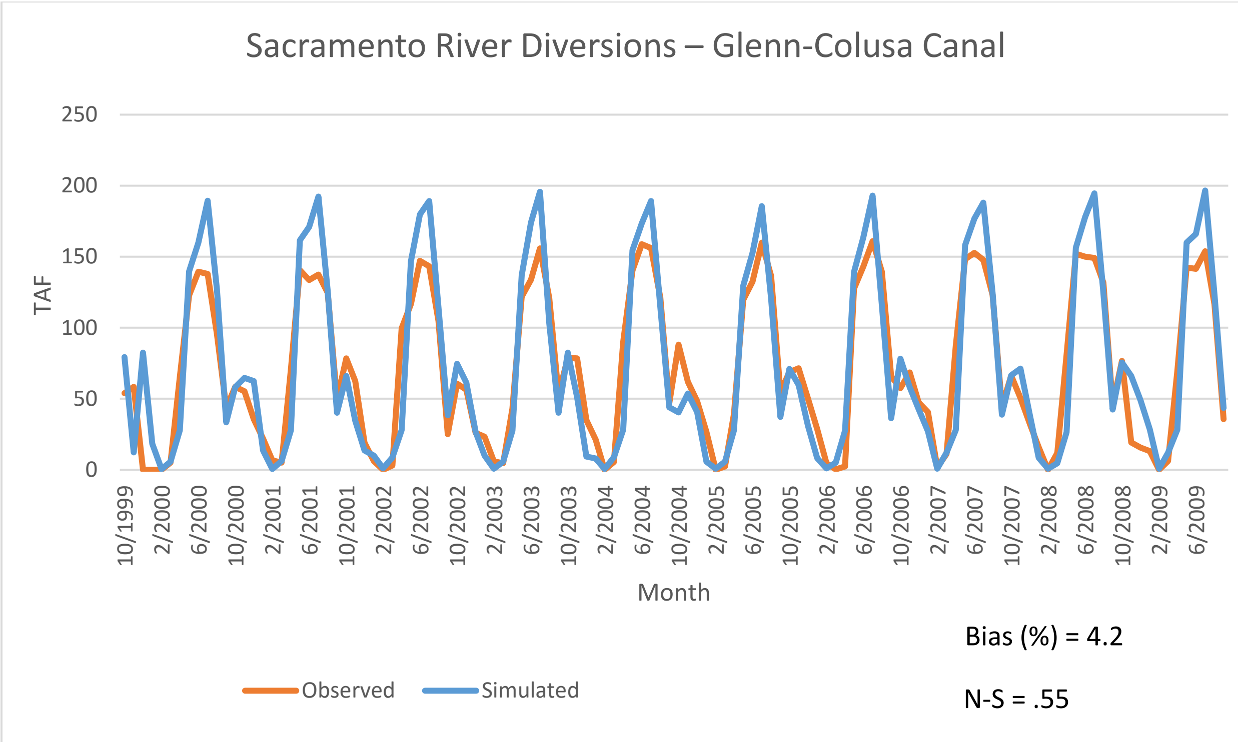

Figure B.3.1a Sacramento River Diversions – Glenn-Colusa Canal, Monthly 2000 to 2009

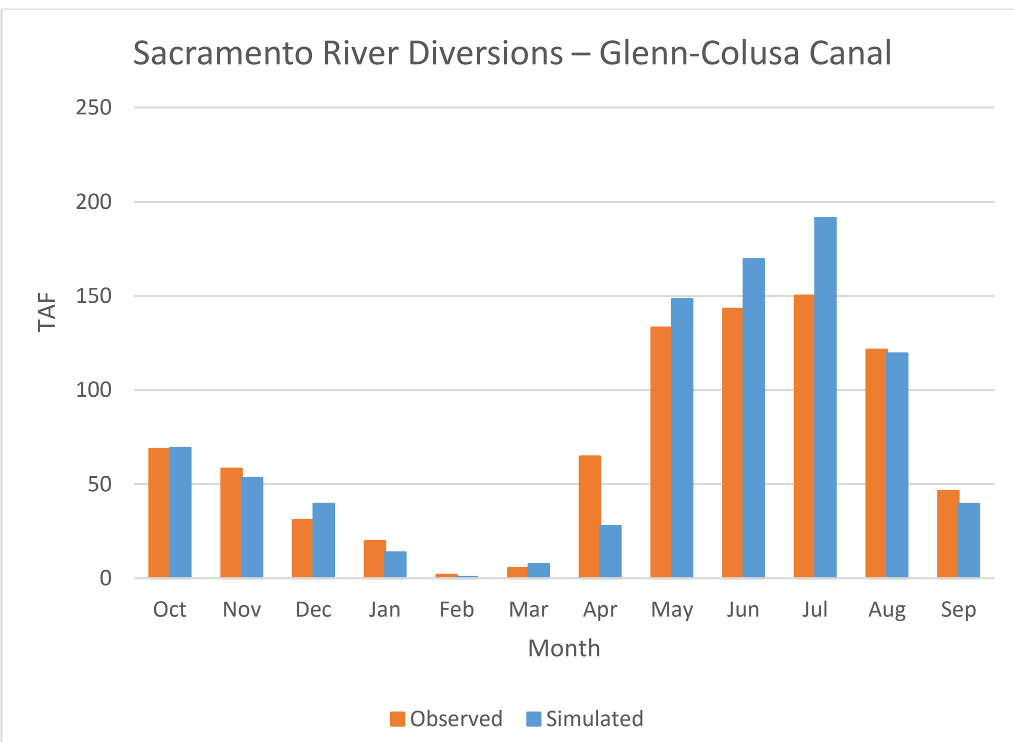

Figure B.3.1b Sacramento River Diversions – Glenn-Colusa Canal, Average Monthly

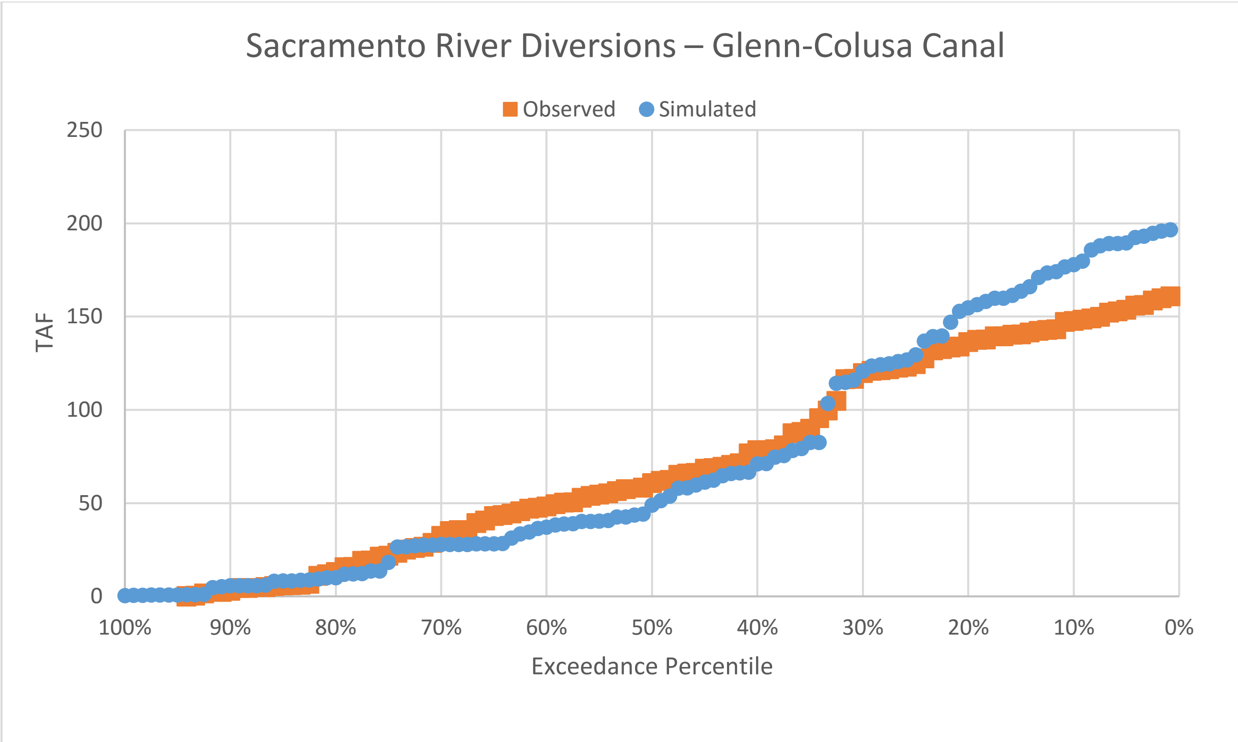

Figure B.3.1c Sacramento River Diversions – Glenn-Colusa Canal, Exceedance

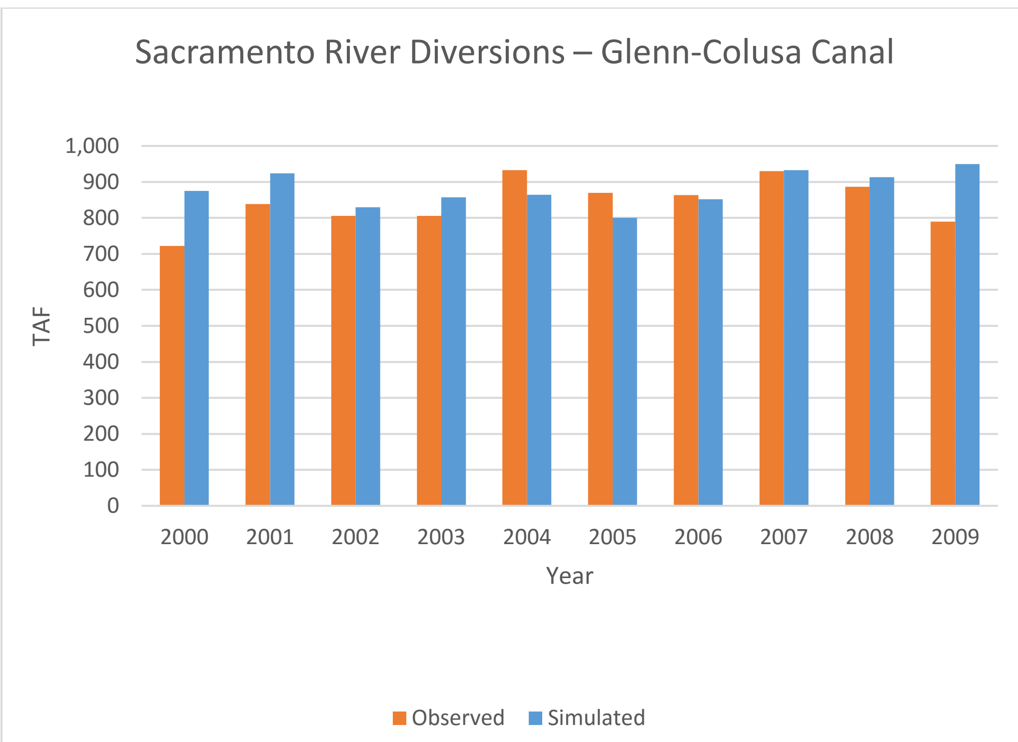

Figure B.3.1d Sacramento River Diversions – Glenn-Colusa Canal, Annual 2000 to 2009

B.3.2 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. Observed data are available for 12 months of the year. The average annual bias is 0.99%. During calibration the *Release Requirement* parameter was set to 8 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.

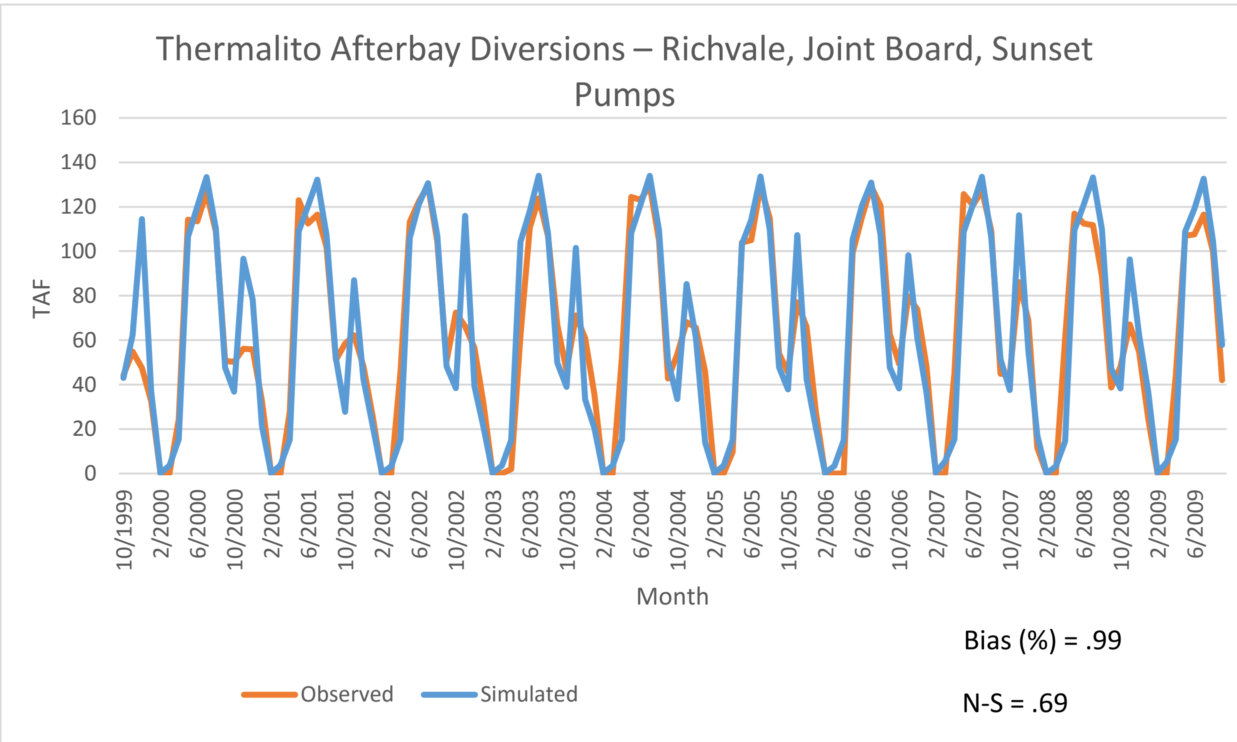

Figure B.3.2a Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Monthly 2000 to 2009

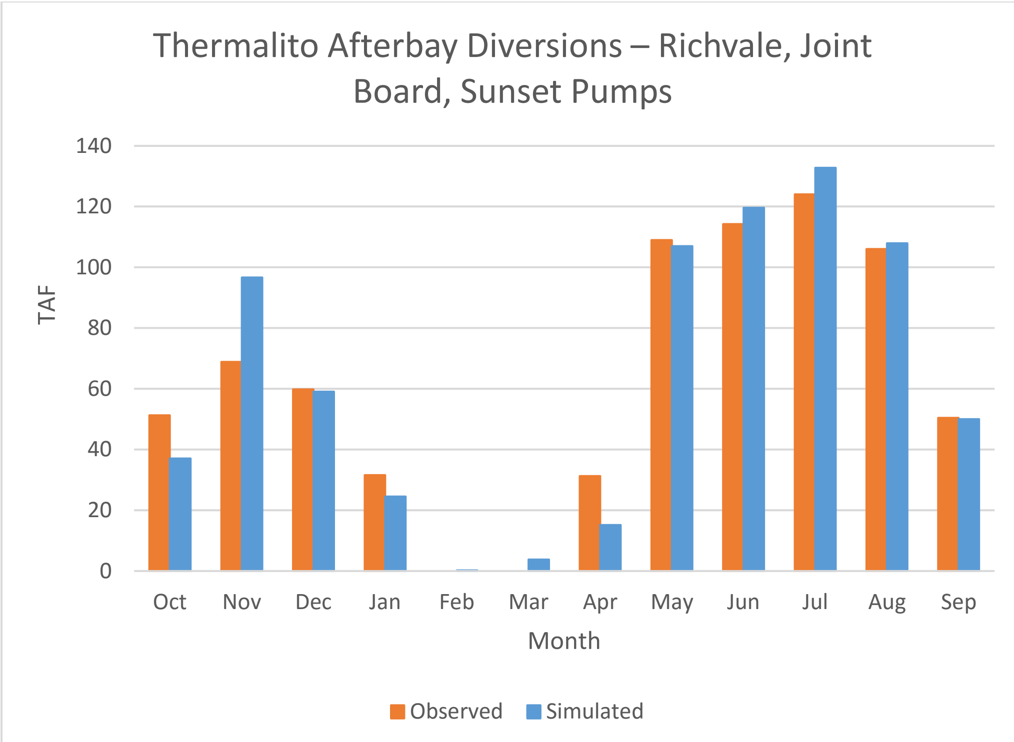

Figure B.3.2b Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Average Monthly

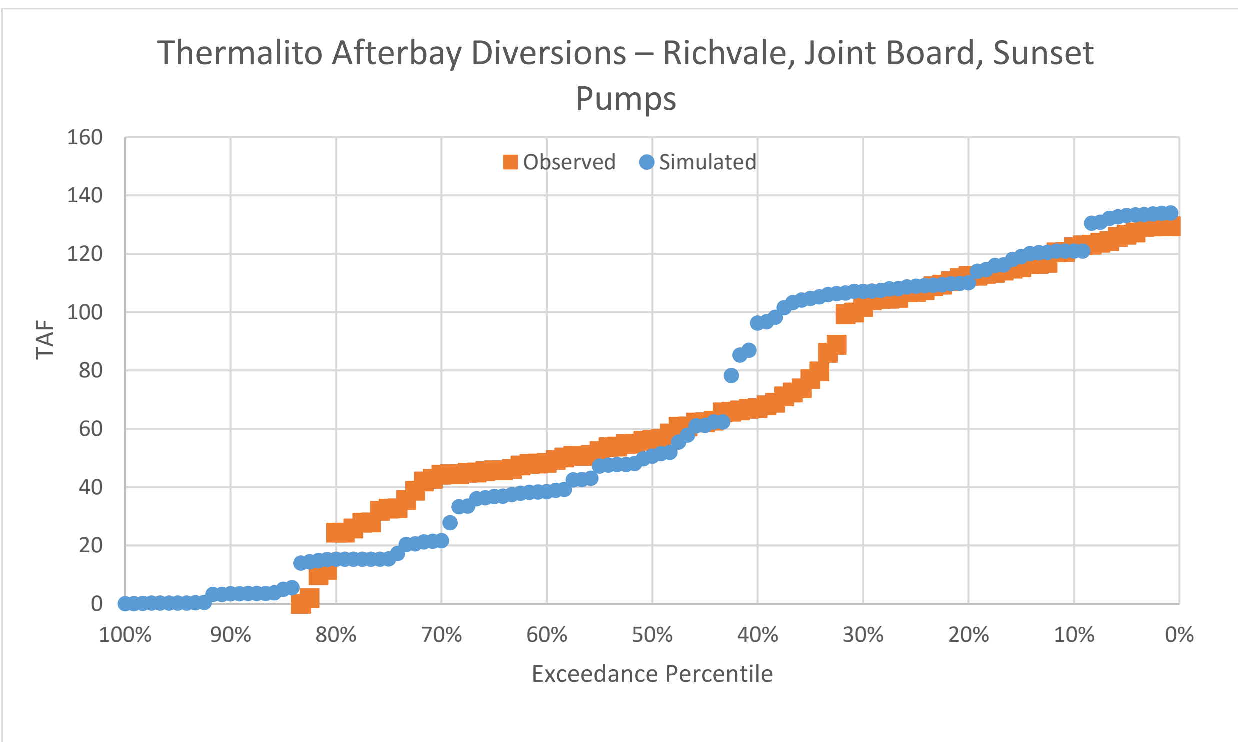

Figure B.3.2c Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Exceedance

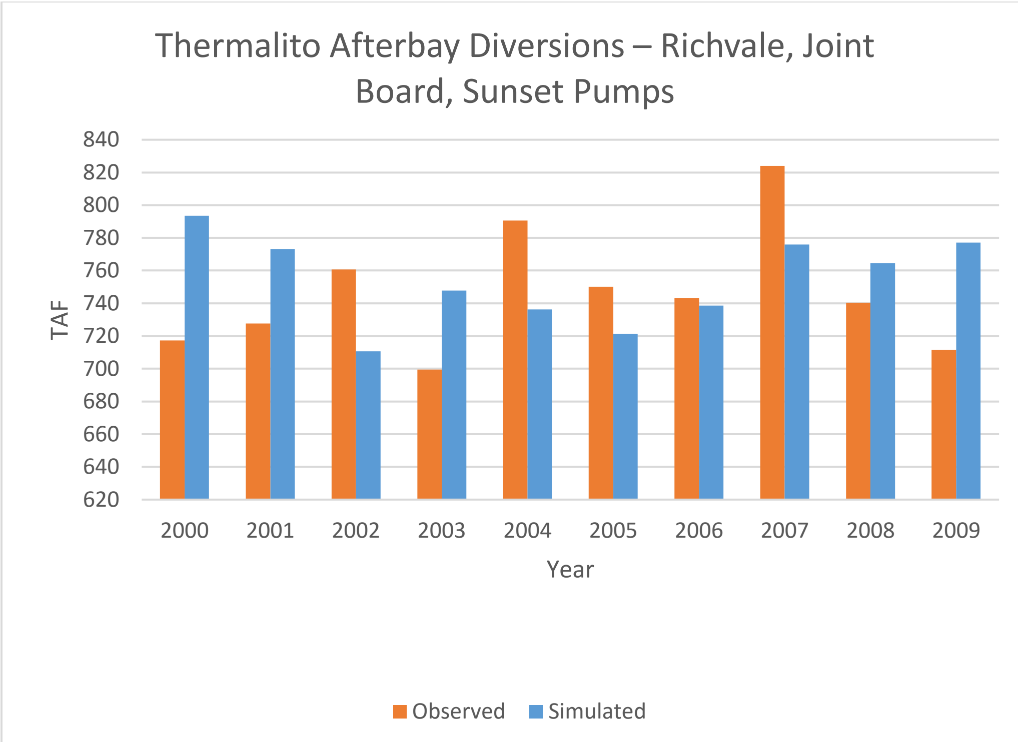

Figure B.3.2d Thermalito Afterbay Diversions – Richvale, Joint Board, Sunset Pumps, Annual 2000 to 2009

B.3.3 Thermalito Afterbay Diversions – Western Canal Water District

The diversions into the Western Canal from the Thermalito Afterbay serve DU A_11_SA1 and are largely used to irrigate rice. Additional water is delivered to R_11_PR. Observed data are available for 12 months of the year. The average annual bias is 1.19%. During calibration the *Release Requirement* was set to 4 mm/d. The simulated monthly pattern for this diversion is very similar to the observed.

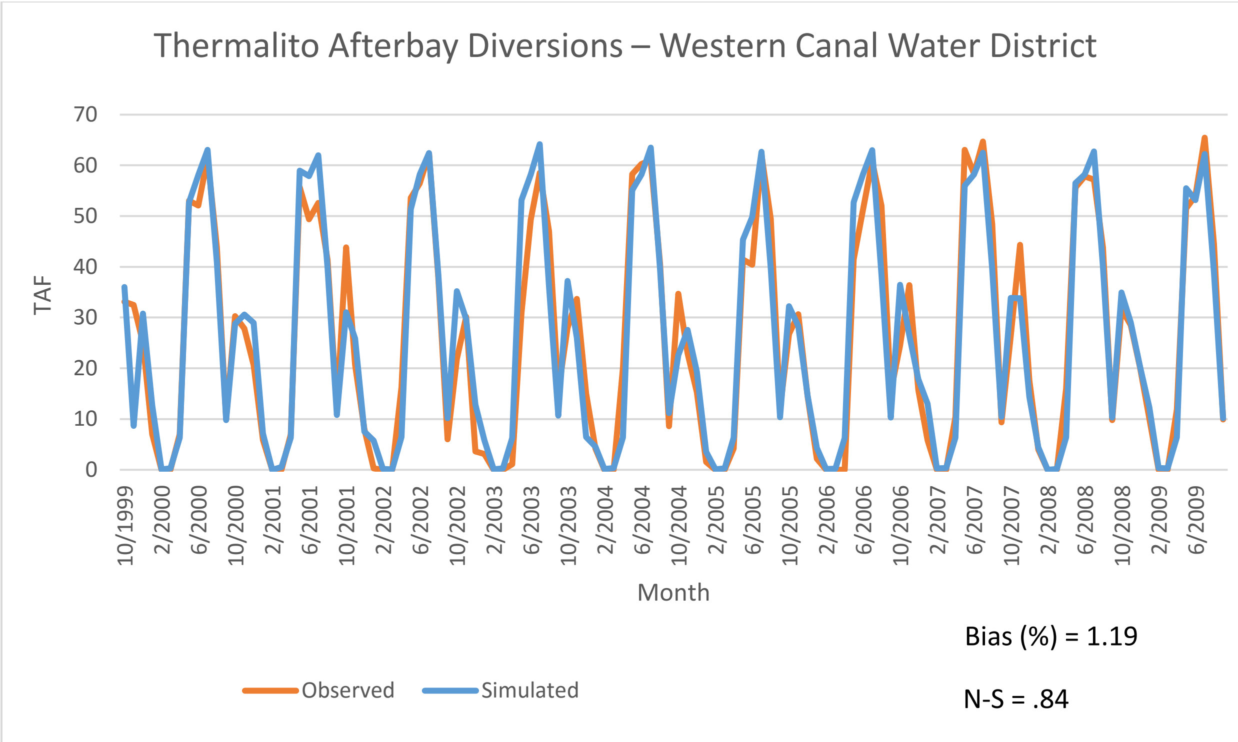

Figure B.3.3a Thermalito Afterbay Diversions – Western Canal Water District, Monthly 2000 to 2009

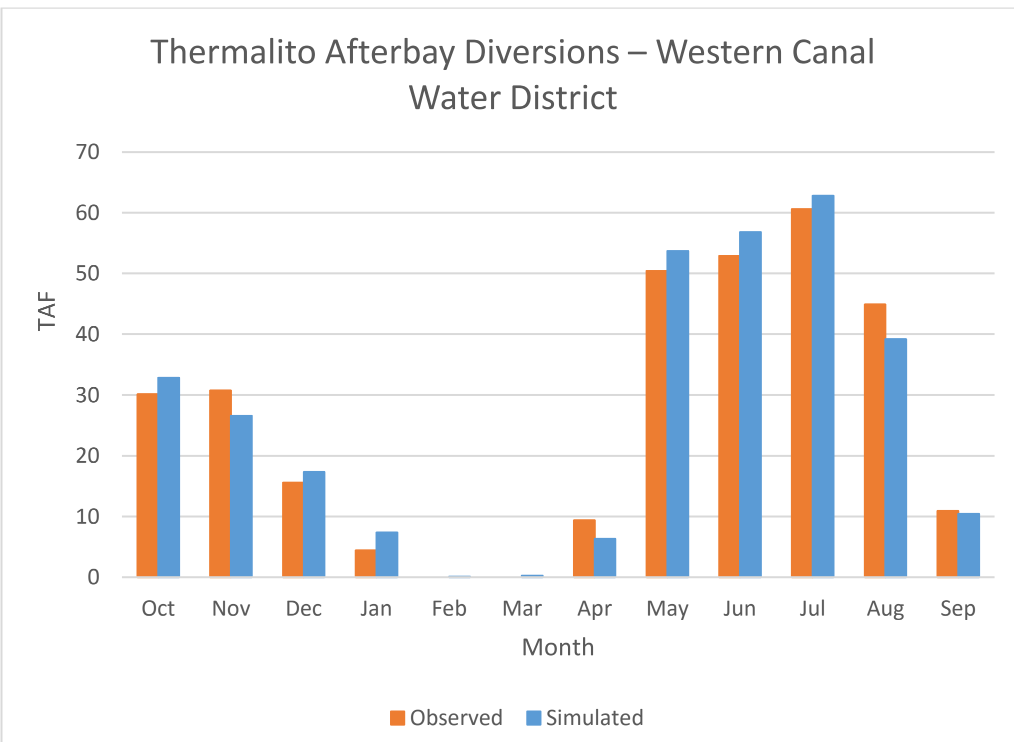

Figure B.3.3b Thermalito Afterbay Diversions – Western Canal Water District, Average Monthly

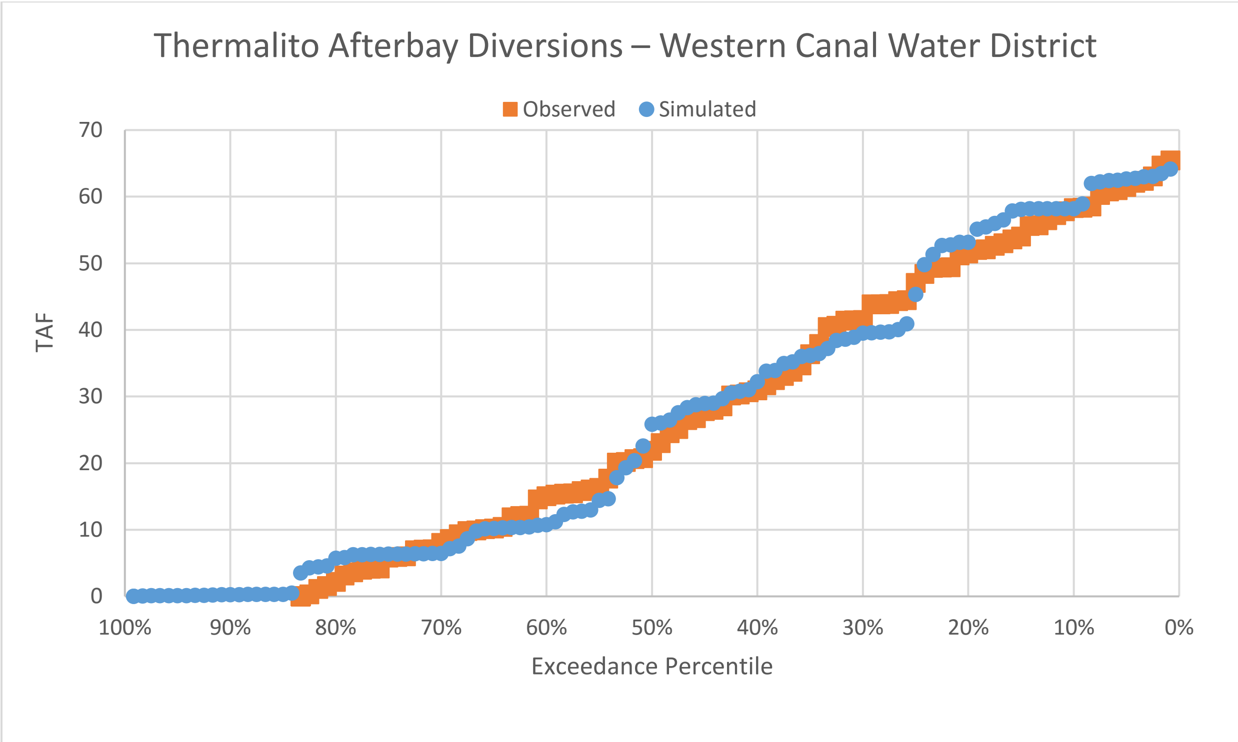

Figure B.3.3c Thermalito Afterbay Diversions – Western Canal Water District, Exceedance

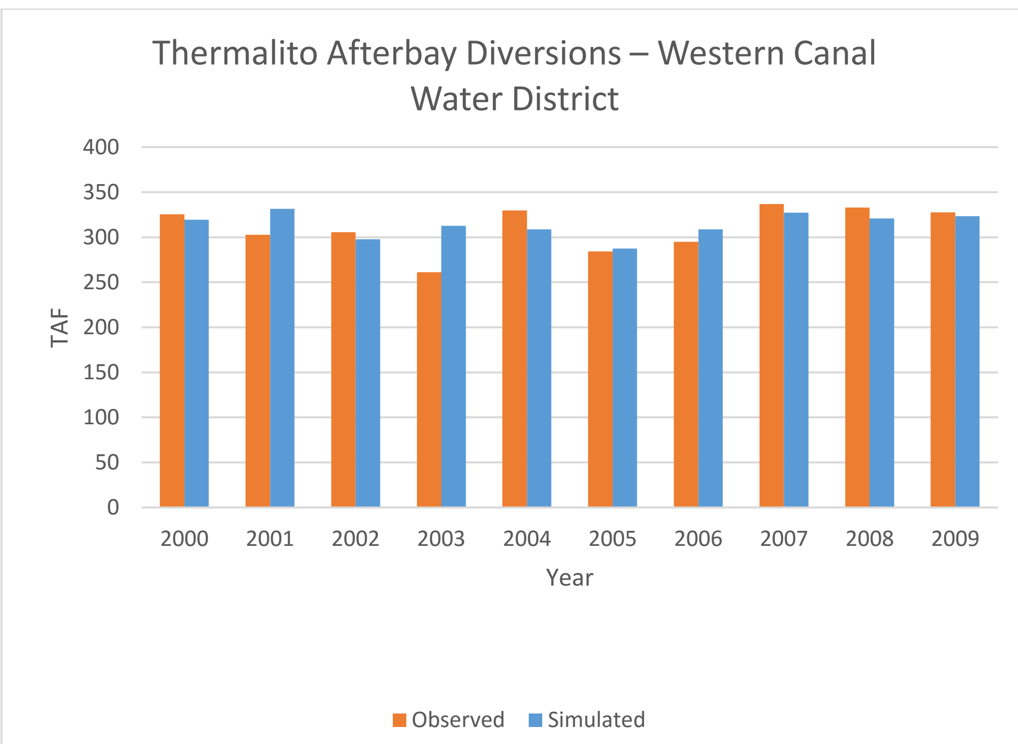

Figure B.3.3d Thermalito Afterbay Diversions – Western Canal Water District, Annual 2000 to 2009

B.3.4 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. Environmental and regulatory requirements restrict gravity diversions from the Sacramento River to the period from May 15 through September 15. Outside of this period, Sacramento River water is 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 average annual bias is -10.06%, however during 2007-2009 the observed data indicate reduced deliveries. If these years are removed from the analysis the resulting bias is 11%.

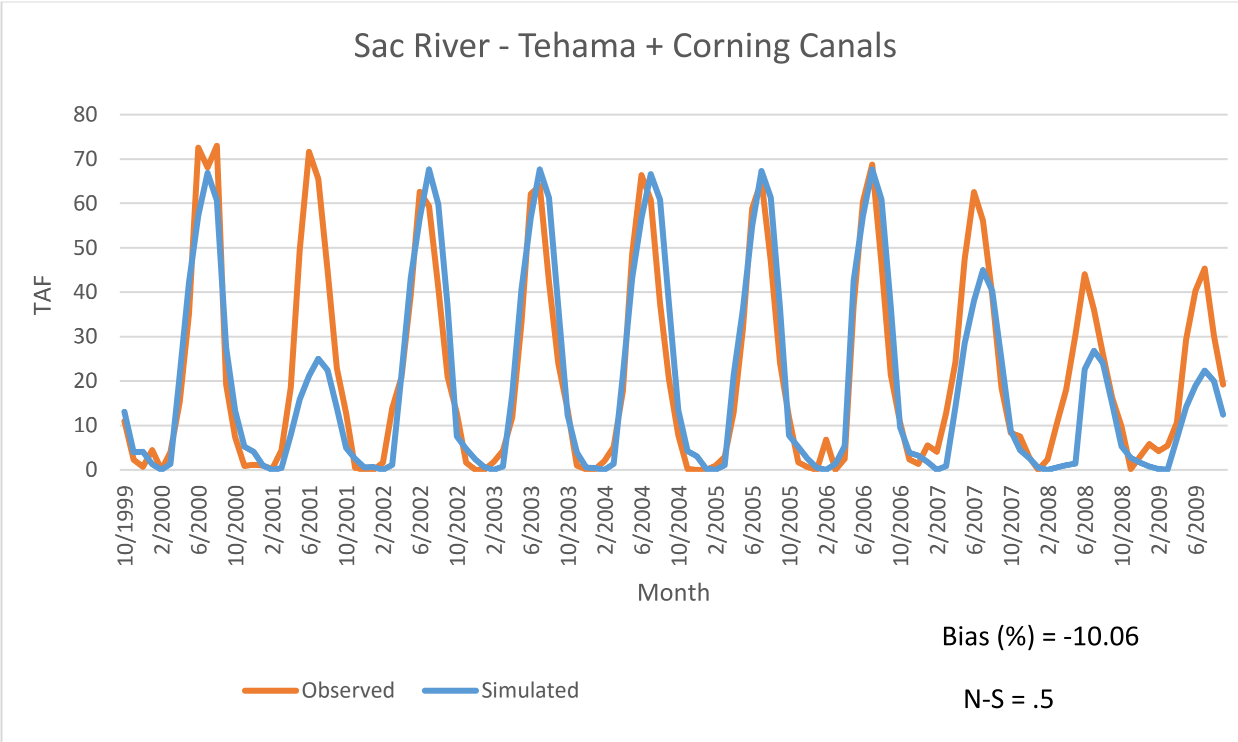

Figure B.3.4a Sacramento River Diversions - Tehama and Corning Canals, Monthly 2000 to 2009

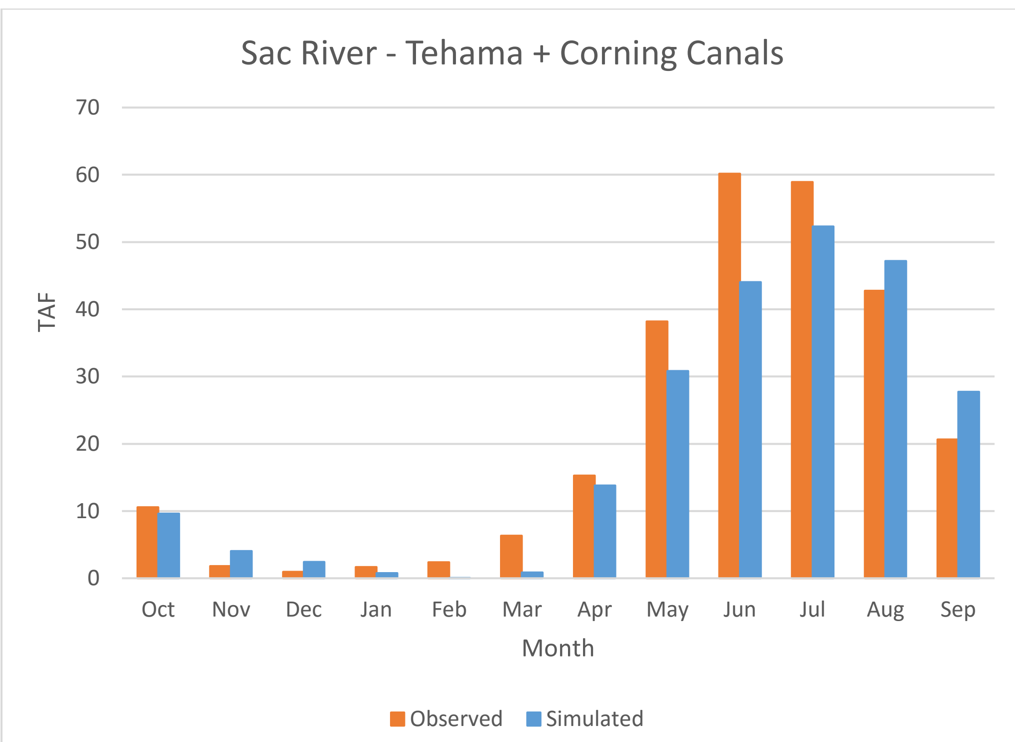

Figure B.3.4b Sacramento River Diversions - Tehama and Corning Canals, Average Monthly

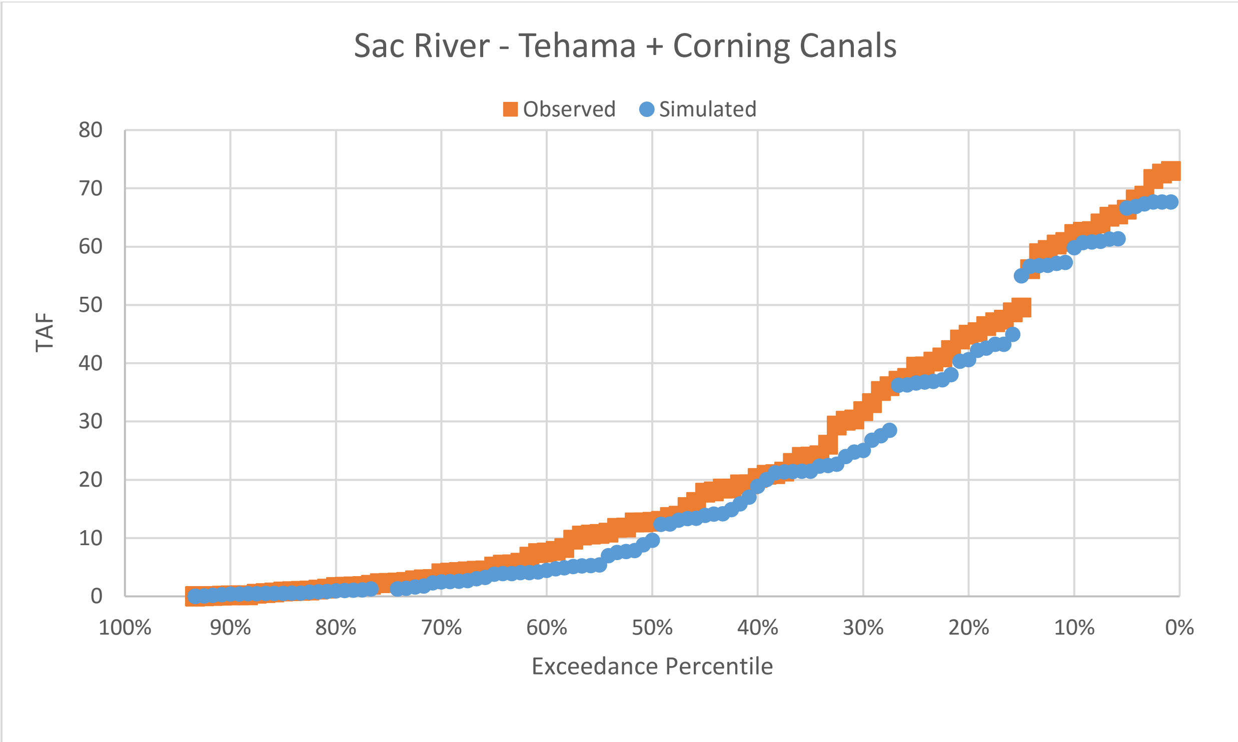

Figure B.3.4c Sacramento River Diversions - Tehama and Corning Canals, Exceedance

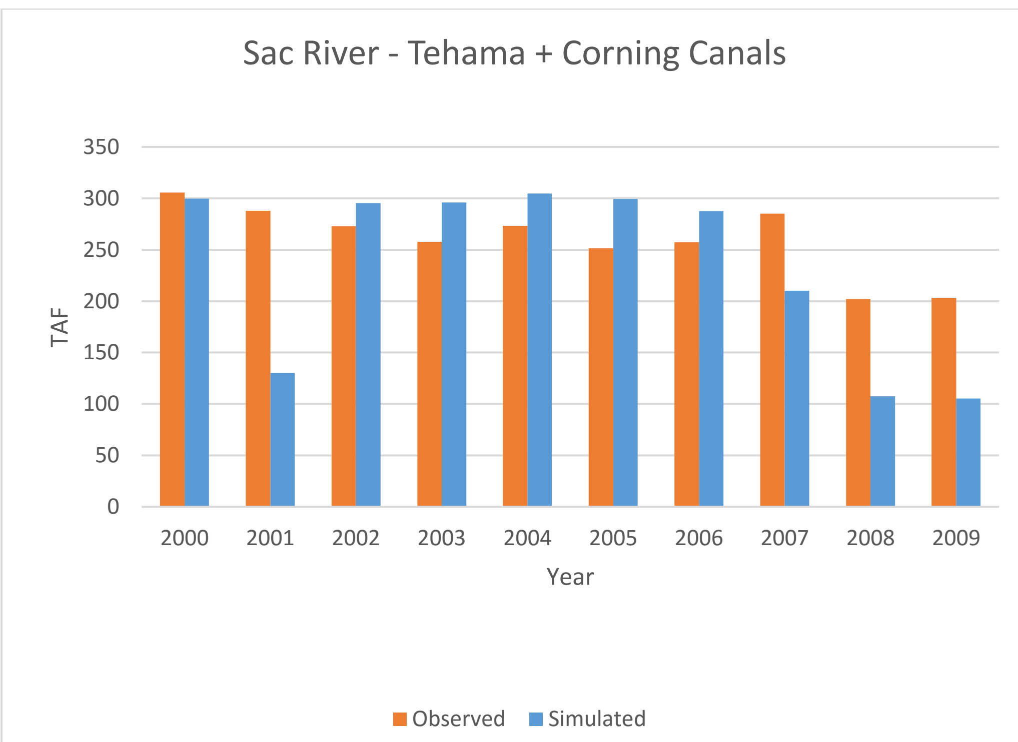

Figure B.3.4d Sacramento River Diversions - Tehama and Corning Canals, Annual 2000 to 2009

B.3.5 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. However, approximately 6 percent of the service area is located north 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 average annual bias for April to October is -0.53%. The simulated delivery pattern largely matches the observed pattern.

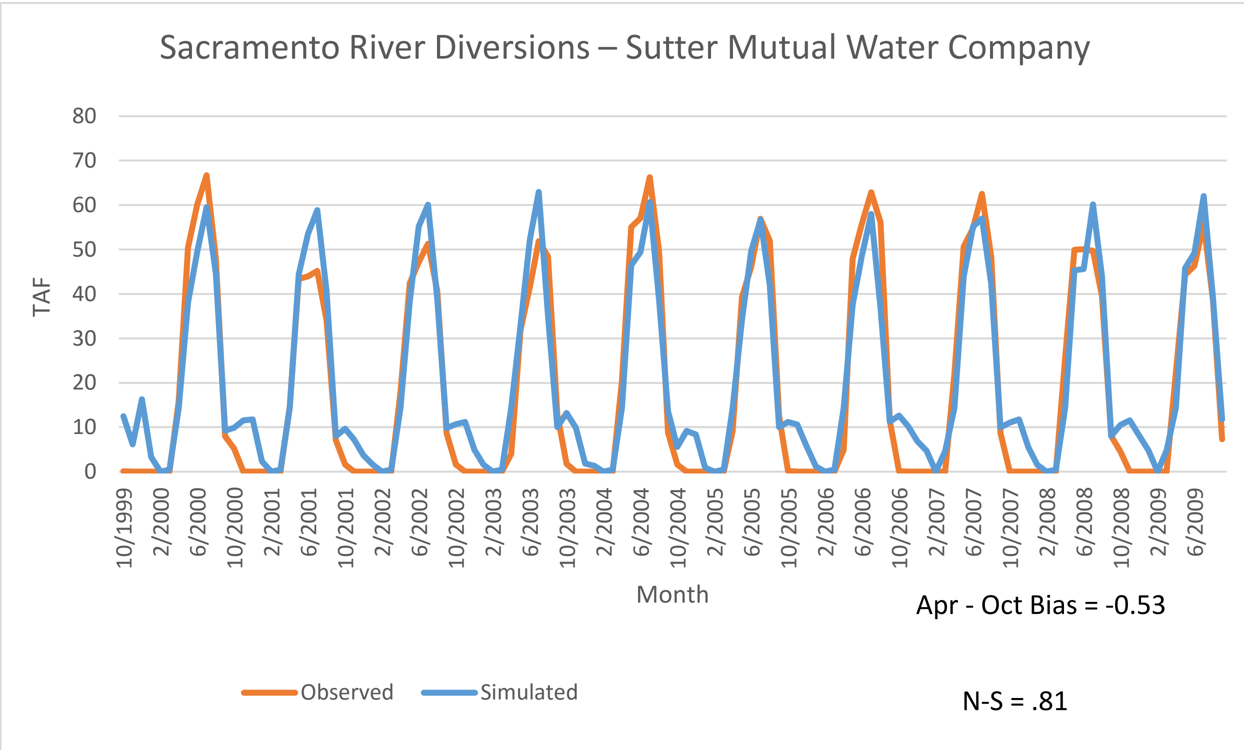

Figure B.3.5a Sacramento River Diversions – Sutter Mutual Water Company, Monthly 2000 to 2009

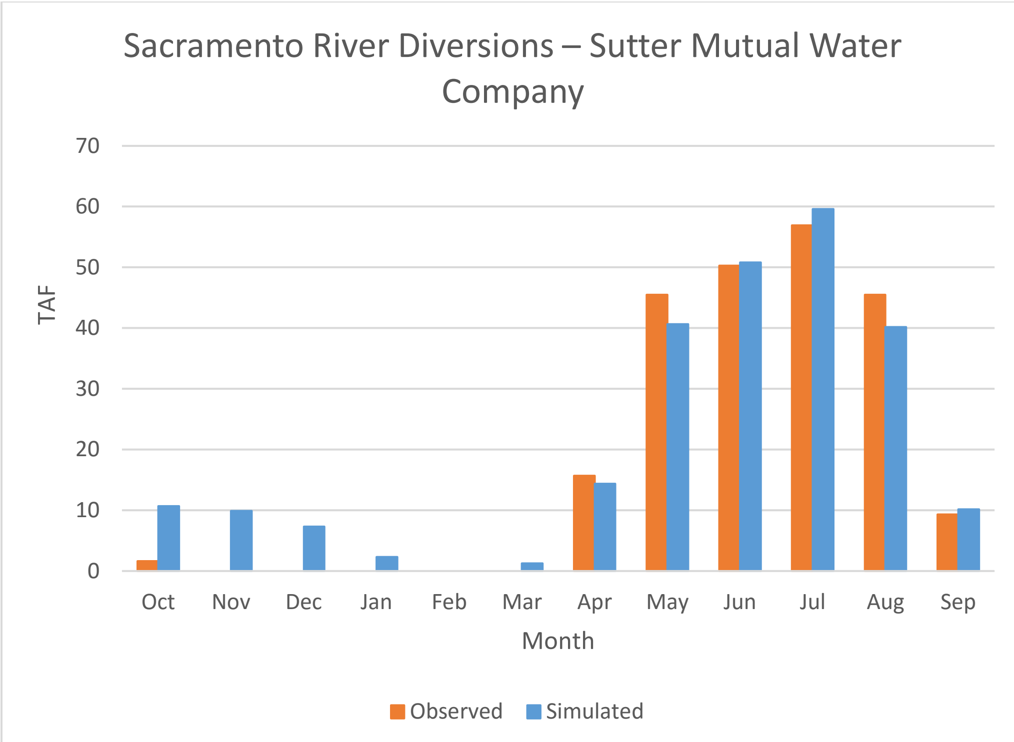

Figure B.3.5b Sacramento River Diversions – Sutter Mutual Water Company, Average Monthly

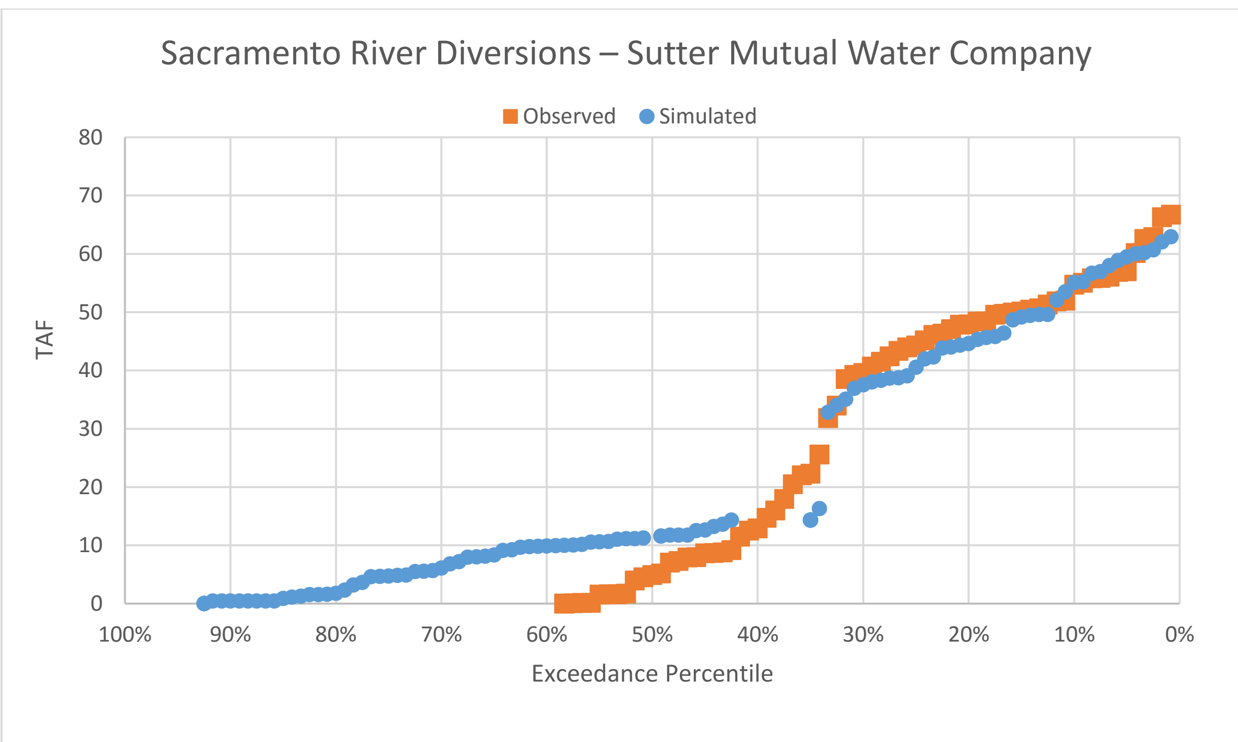

Figure B.3.5c Sacramento River Diversions – Sutter Mutual Water Company, Exceedance

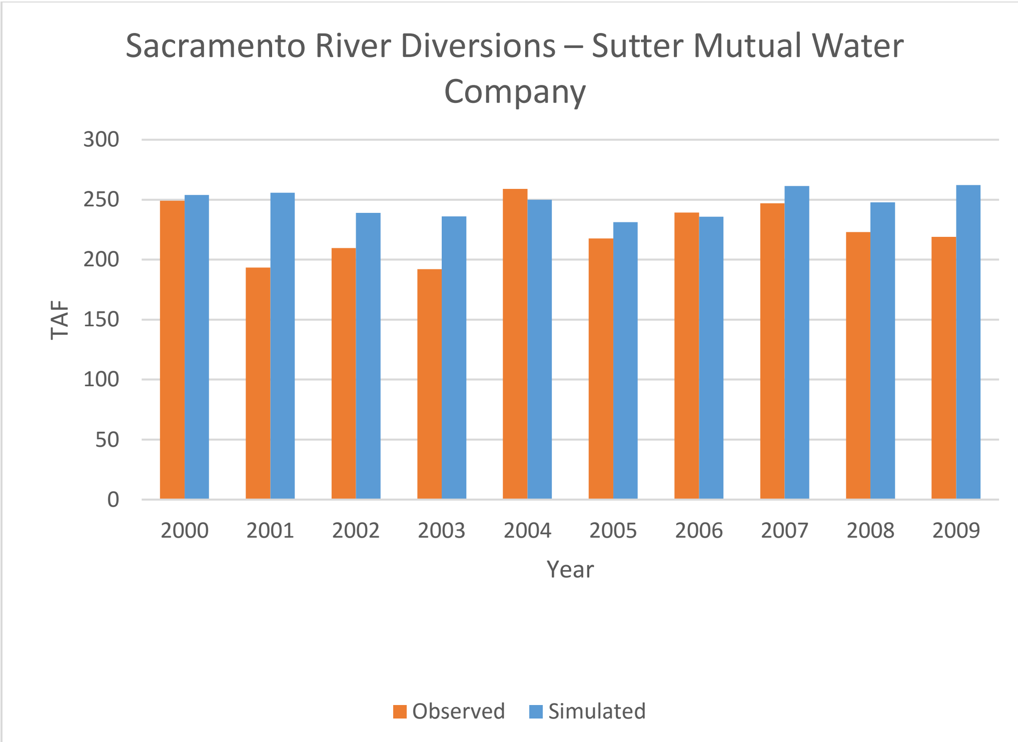

Figure B.3.5d Sacramento River Diversions – Sutter Mutual Water Company, Annual 2000 to 2009

B.3.6 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 average annual bias is -15.00%. The simulated delivery pattern largely matches the observed pattern except in the months of April – June.

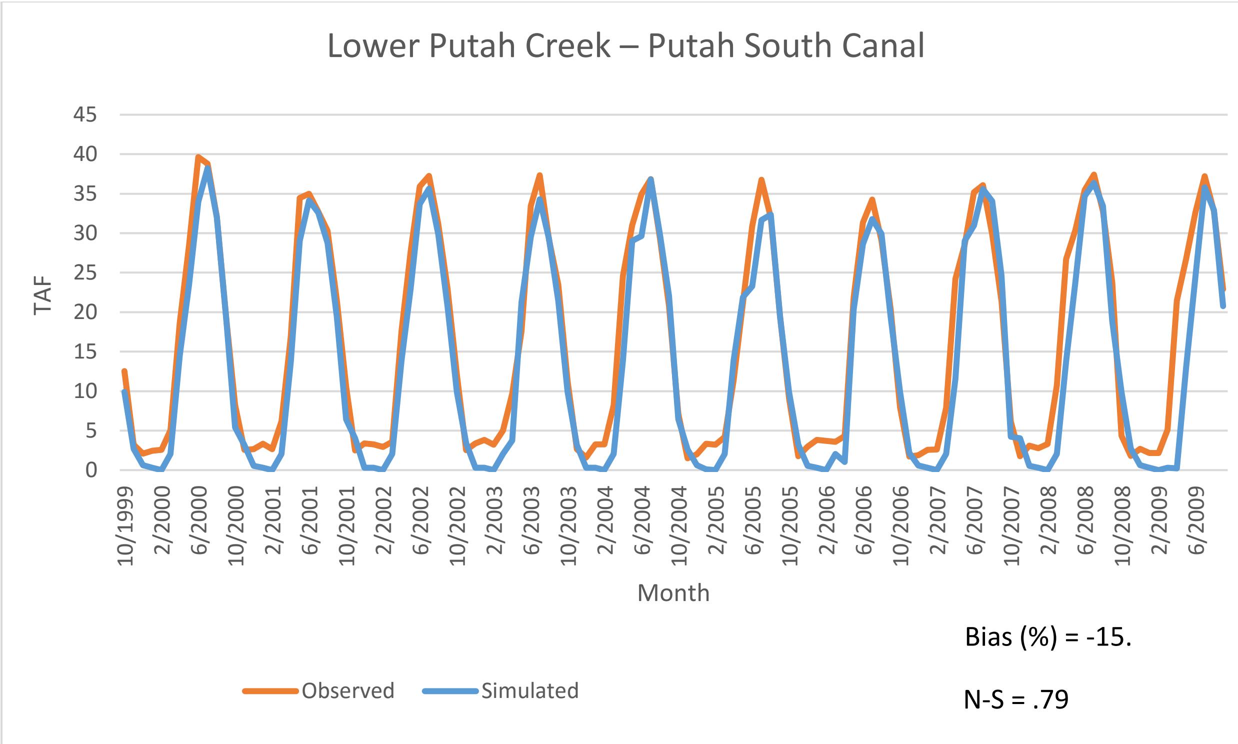

Figure B.3.6a Lower Putah Creek – Putah South Canal, Monthly 2000 to 2009

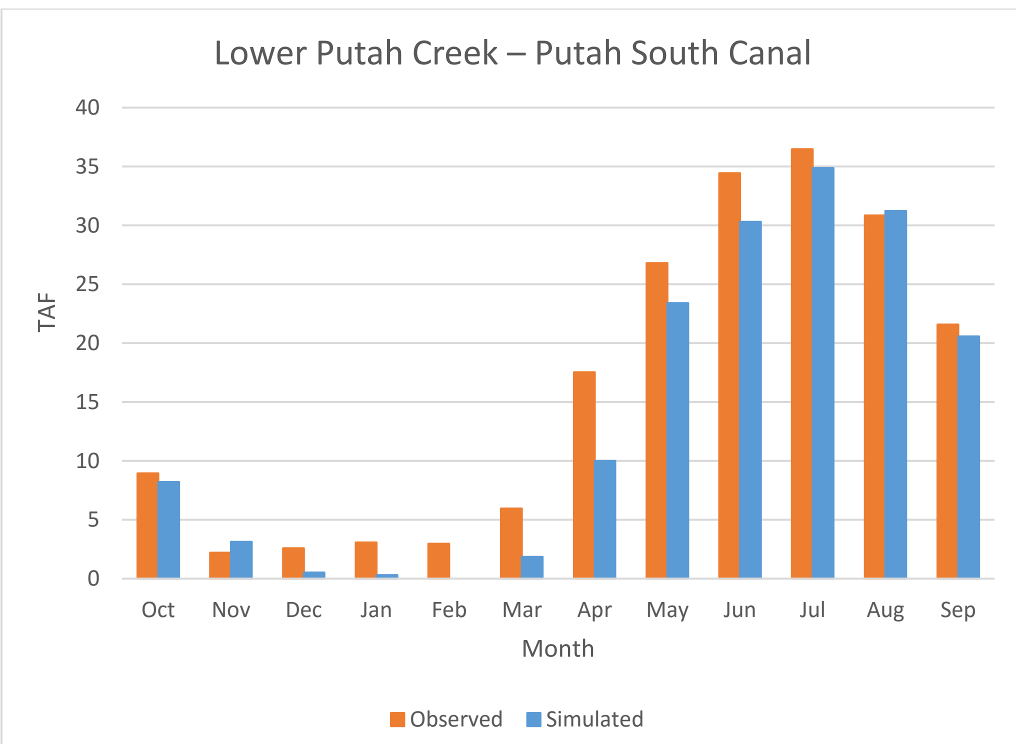

Figure B.3.6b Lower Putah Creek – Putah South Canal, Average Monthly

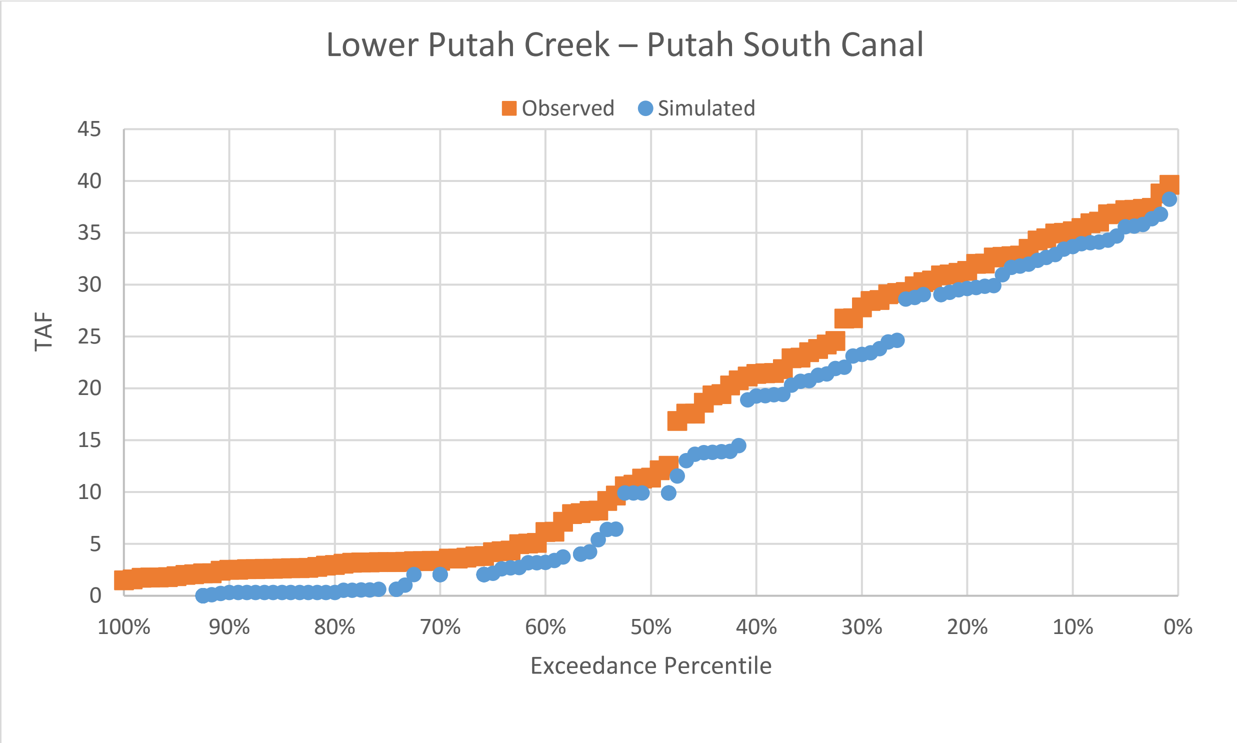

Figure B.3.6c Lower Putah Creek – Putah South Canal, Exceedance

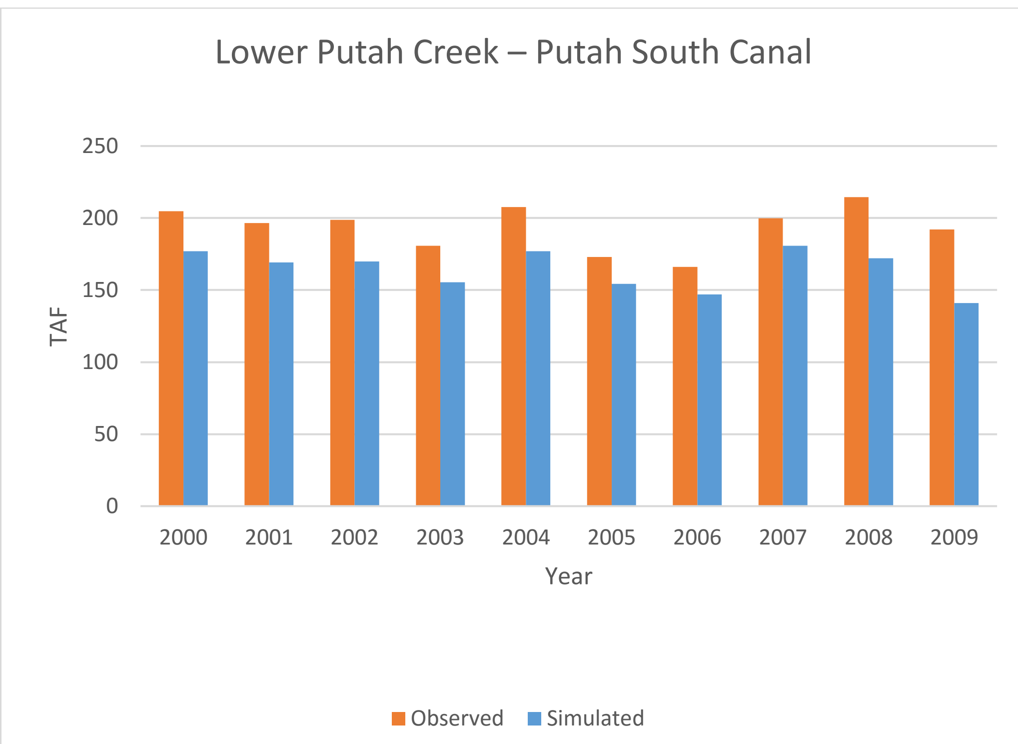

Figure B.3.6d Lower Putah Creek – Putah South Canal, Annual 2000 to 2009

B.3.7 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 average annual bias is 4.4%. The simulated delivery pattern largely matches the observed pattern except in the month of April.

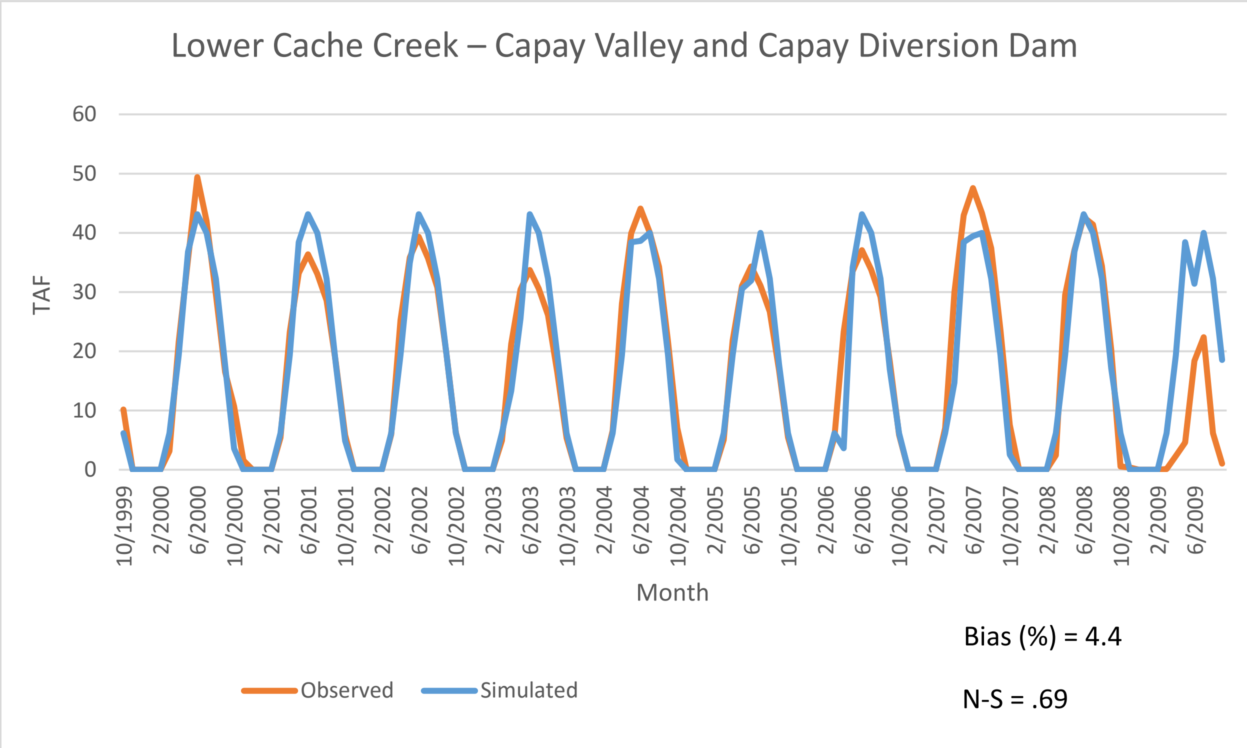

Figure B.3.7a Lower Cache Creek – Capay Valley and Capay Diversion Dam, Monthly 2000 to 2009

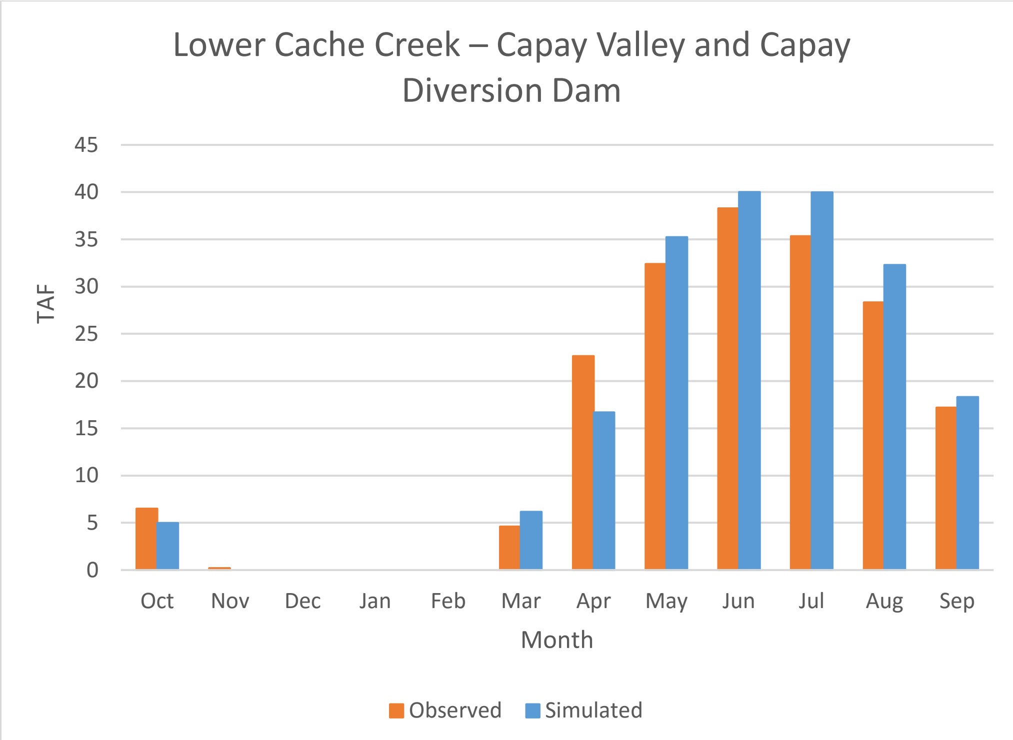

Figure B.3.7b Lower Cache Creek – Capay Valley and Capay Diversion Dam, Average Monthly

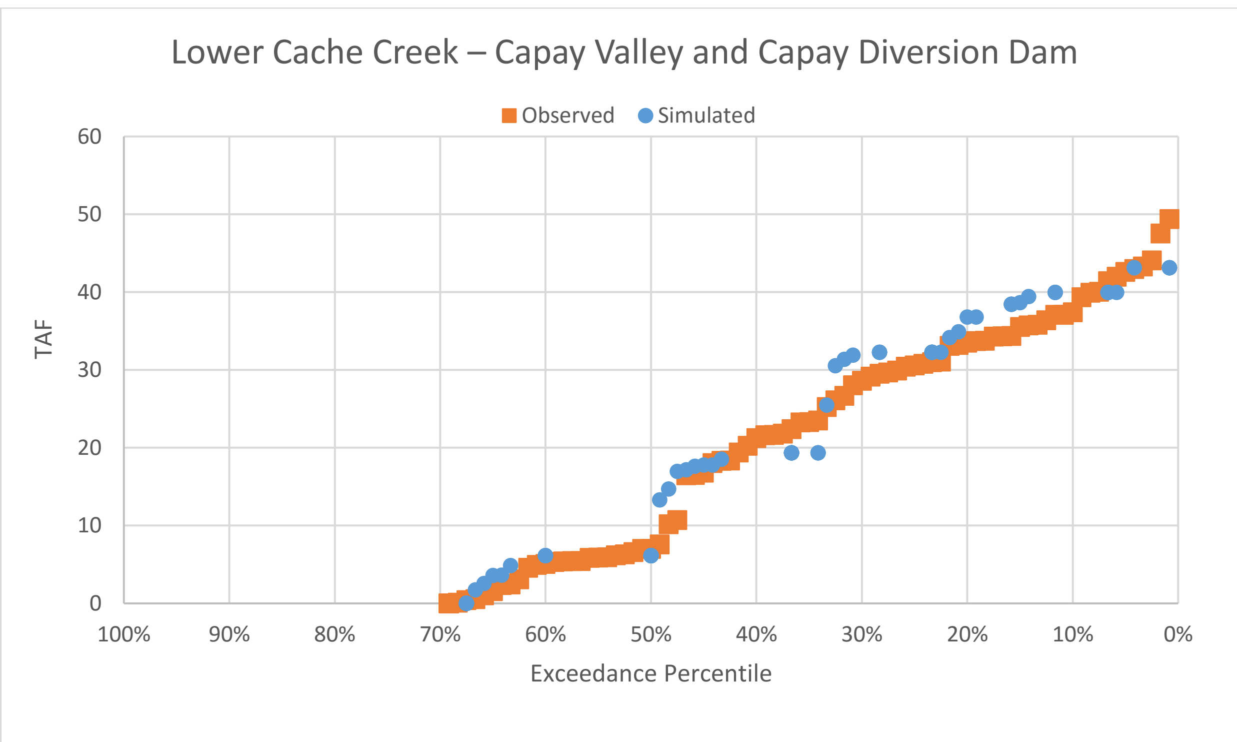

Figure B.3.7c Lower Cache Creek – Capay Valley and Capay Diversion Dam, Exceedance

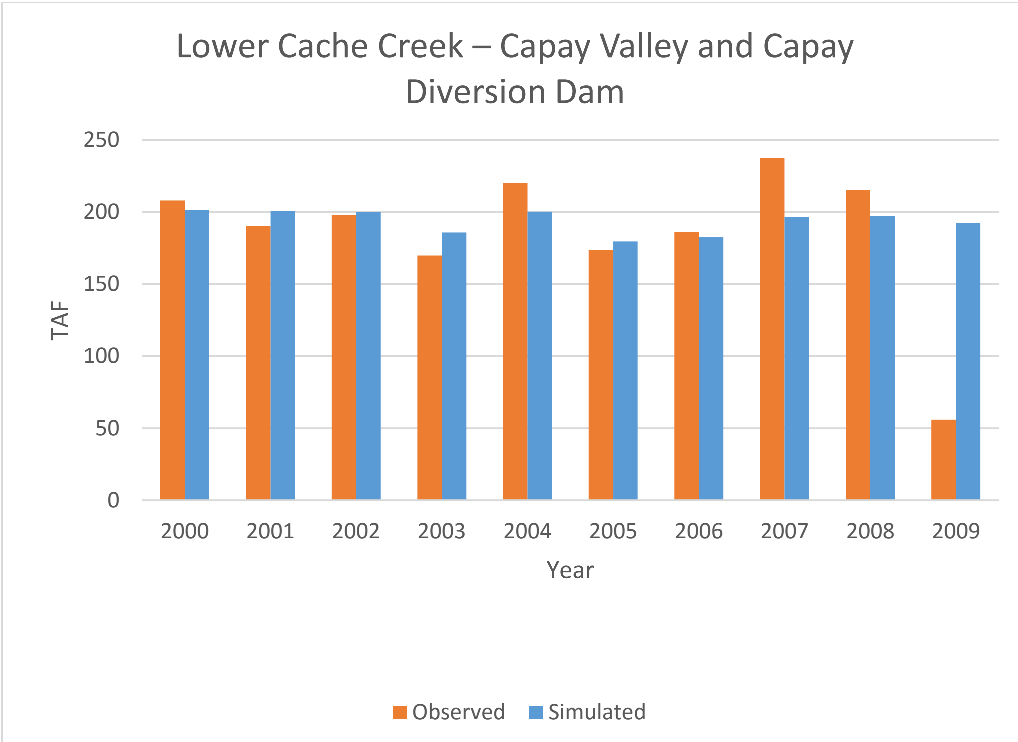

Figure B.3.7d Lower Cache Creek – Capay Valley and Capay Diversion Dam, Annual 2000 to 2009

B.3.8 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 CalSim 3.0, 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 average annual bias for Apr-Oct is -4.63%. 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.

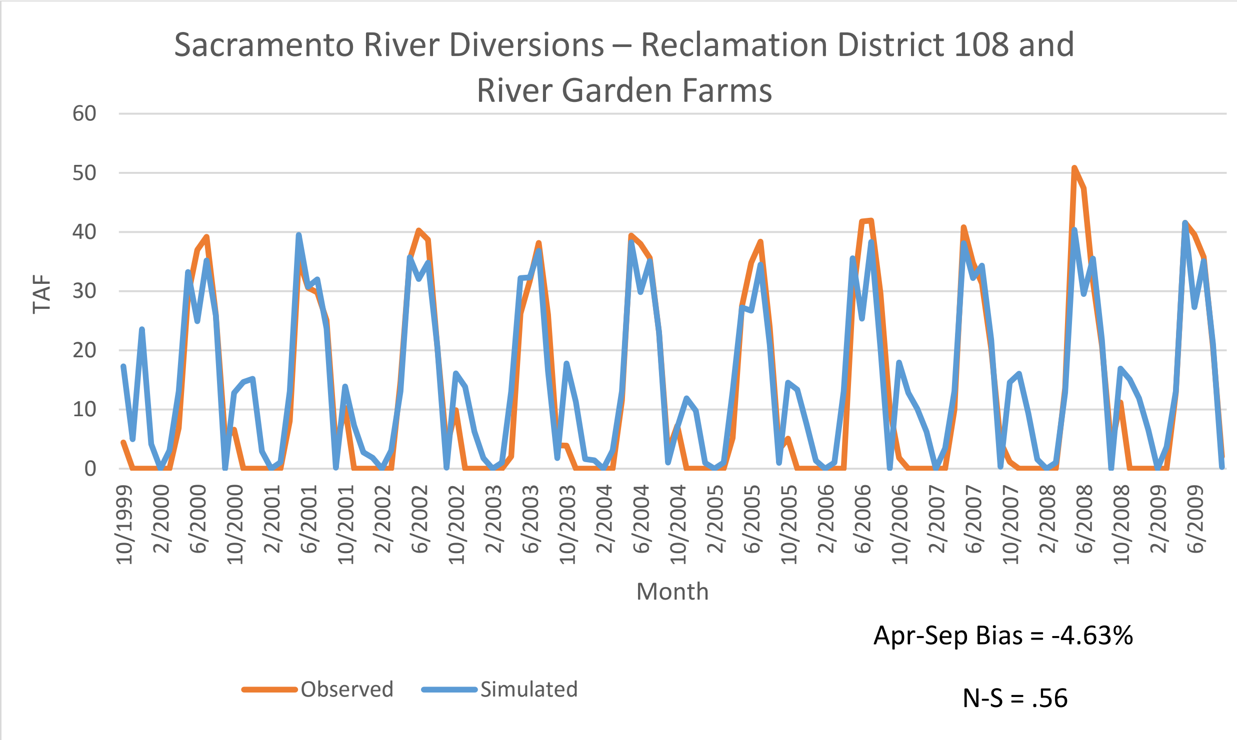

Figure B.3.8a Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Monthly 2000 to 2009

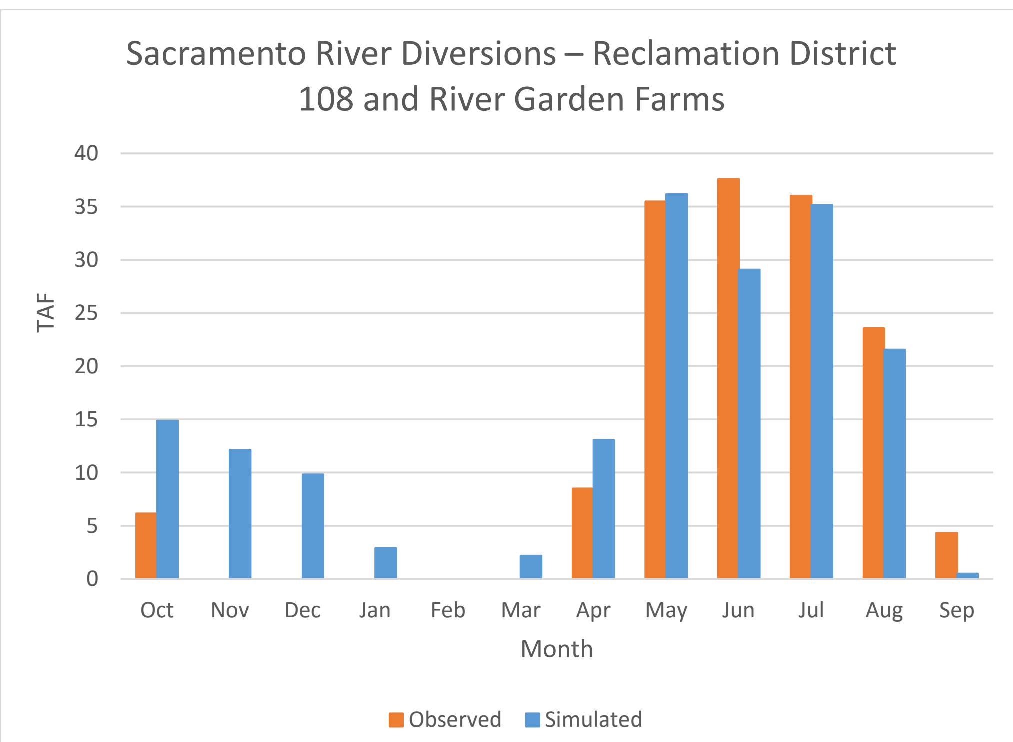

Figure B.3.8b Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Average Monthly

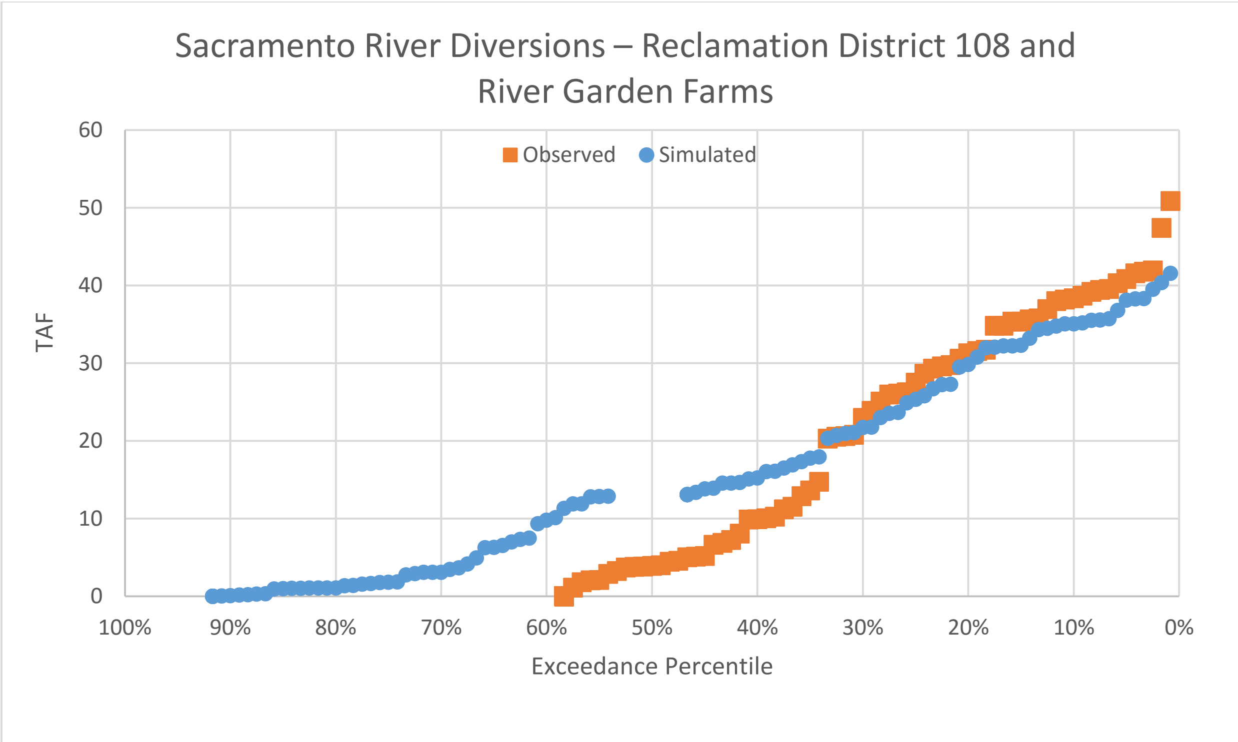

Figure B.3.8c Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Exceedance

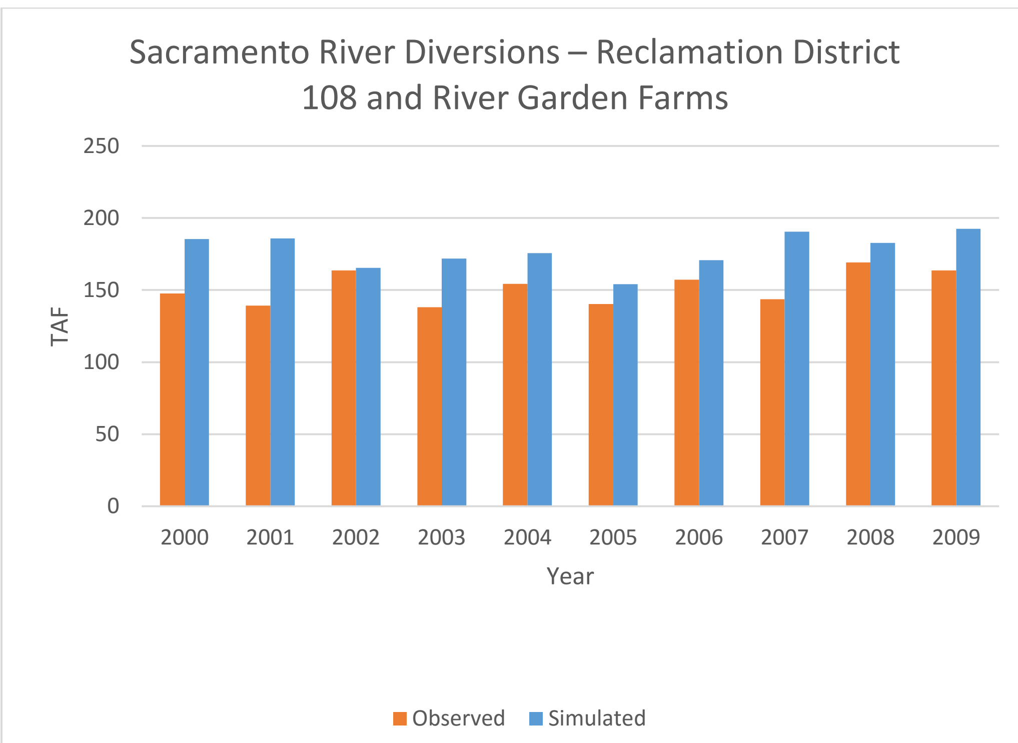

Figure B.3.8d Sacramento River Diversions – Reclamation District 108 and River Garden Farms, Annual 2000 to 2009

B.3.9 Lower Yuba River – Yuba County Water Agency Right Bank

The diversion from the right bank of the lower Yuba River to the Yuba County WA and Browns Valley ID serves DUs A_14_15N_NA2 and A_14_15N_NA3. The diversions are used to predominantly irrigate rice and pasture. Observed data are available for 12 months of the year. The average annual bias is -2.01%. During calibration the *Release Requirement* was set to 4.5 mm/d. The simulated delivery pattern largely matches the observed pattern except in July.

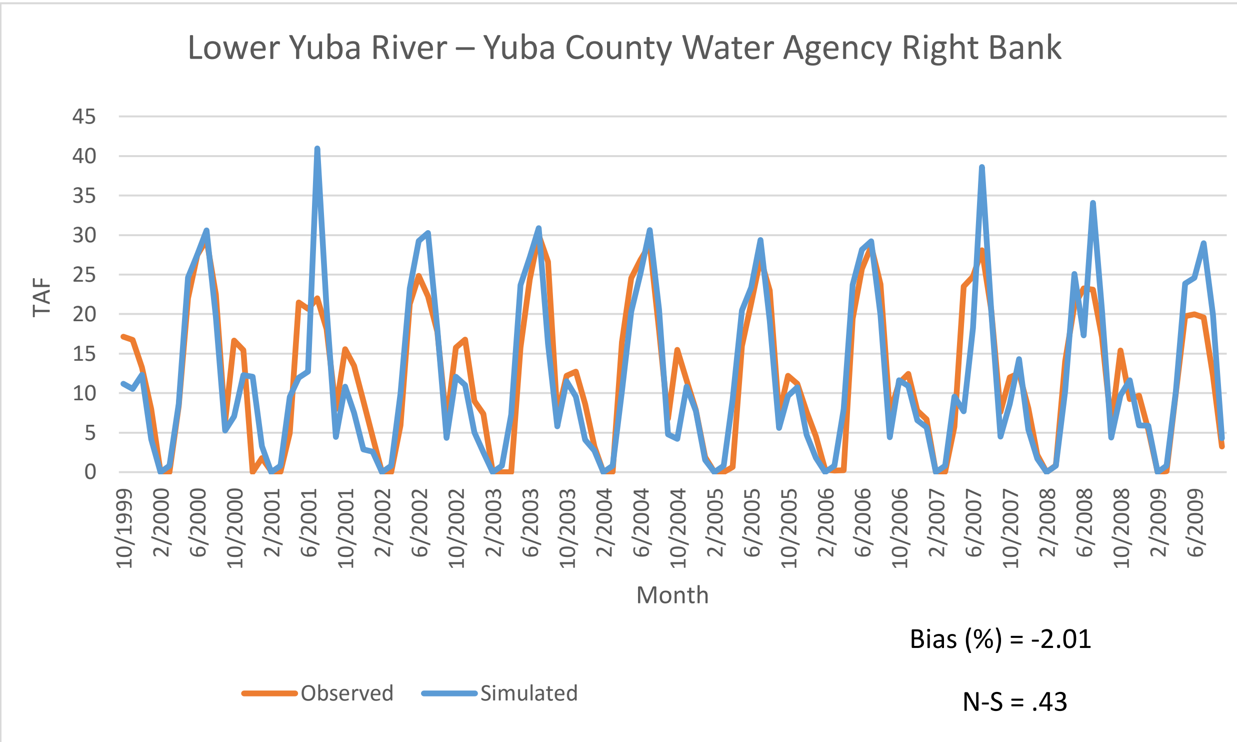

Figure B.3.9a Lower Yuba River – Yuba County Water Agency Right Bank, Monthly 2000 to 2009

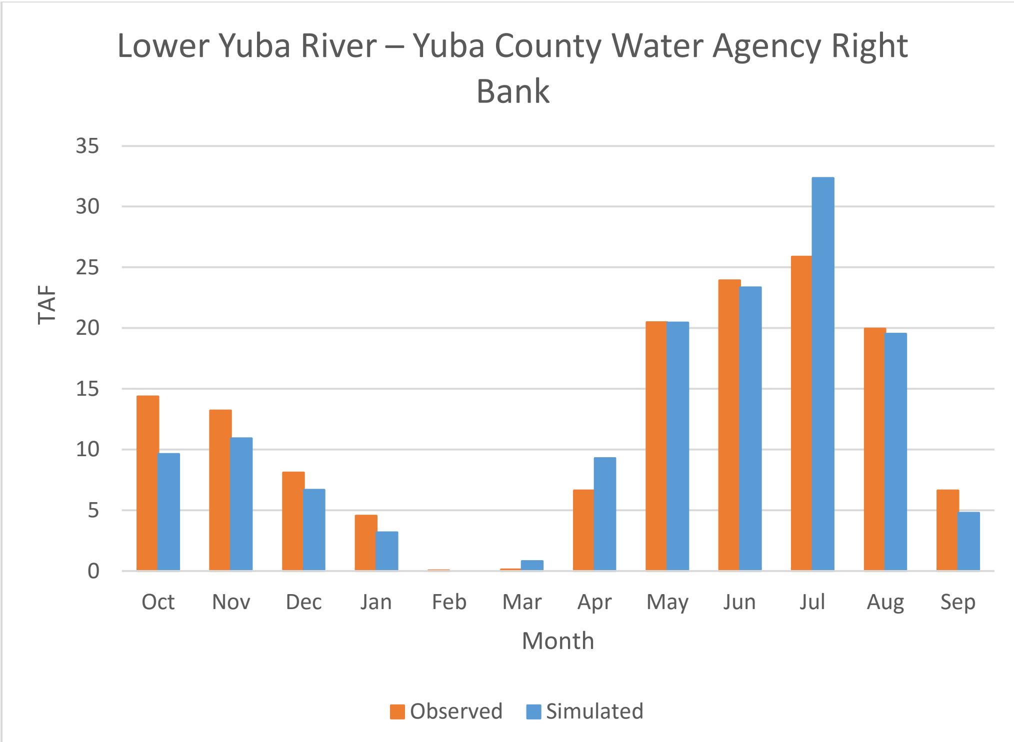

Figure B.3.9b Lower Yuba River – Yuba County Water Agency Right Bank, Average Monthly

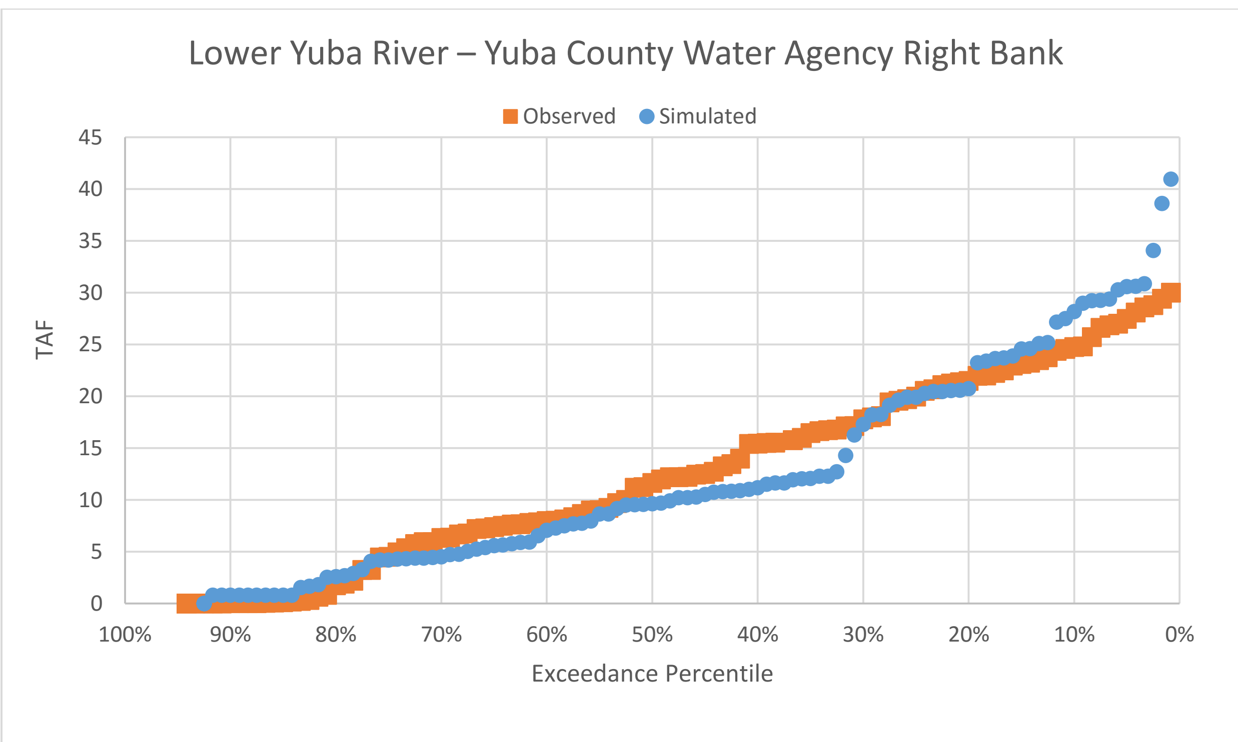

Figure B.3.9c Lower Yuba River – Yuba County Water Agency Right Bank, Exceedance

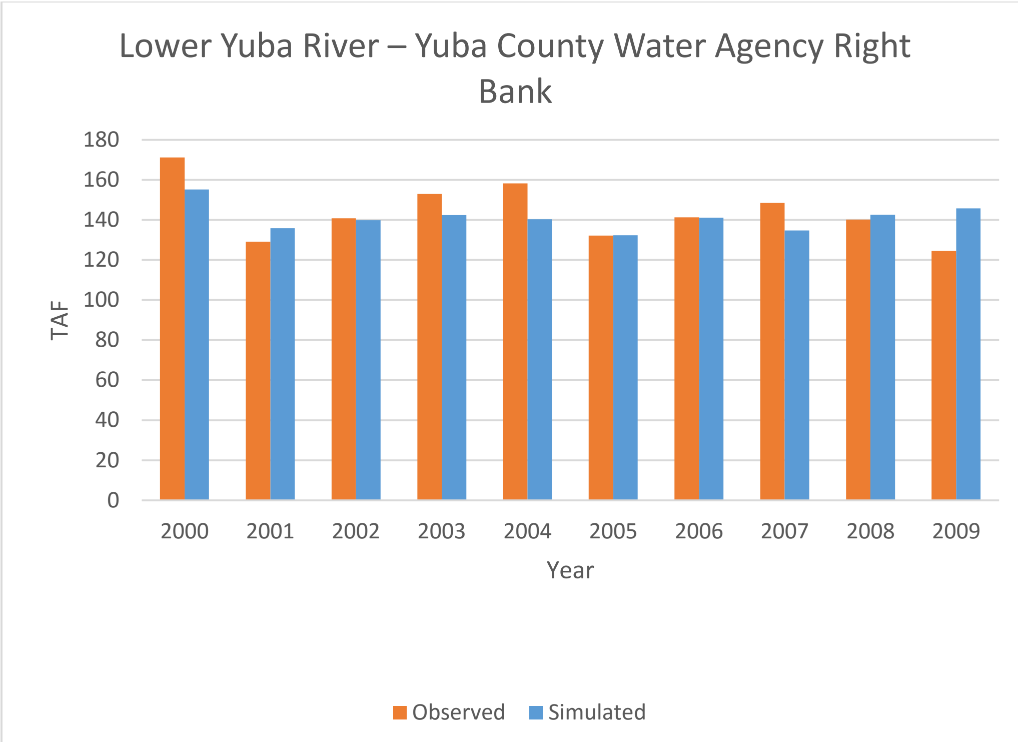

Figure B.3.9d Lower Yuba River – Yuba County Water Agency Right Bank, Annual 2000 to 2009

B.3.10 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 average annual bias for Apr-Oct is 10.32%. 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. It is likely the model is not diverting as much from the Drain as is done in reality.

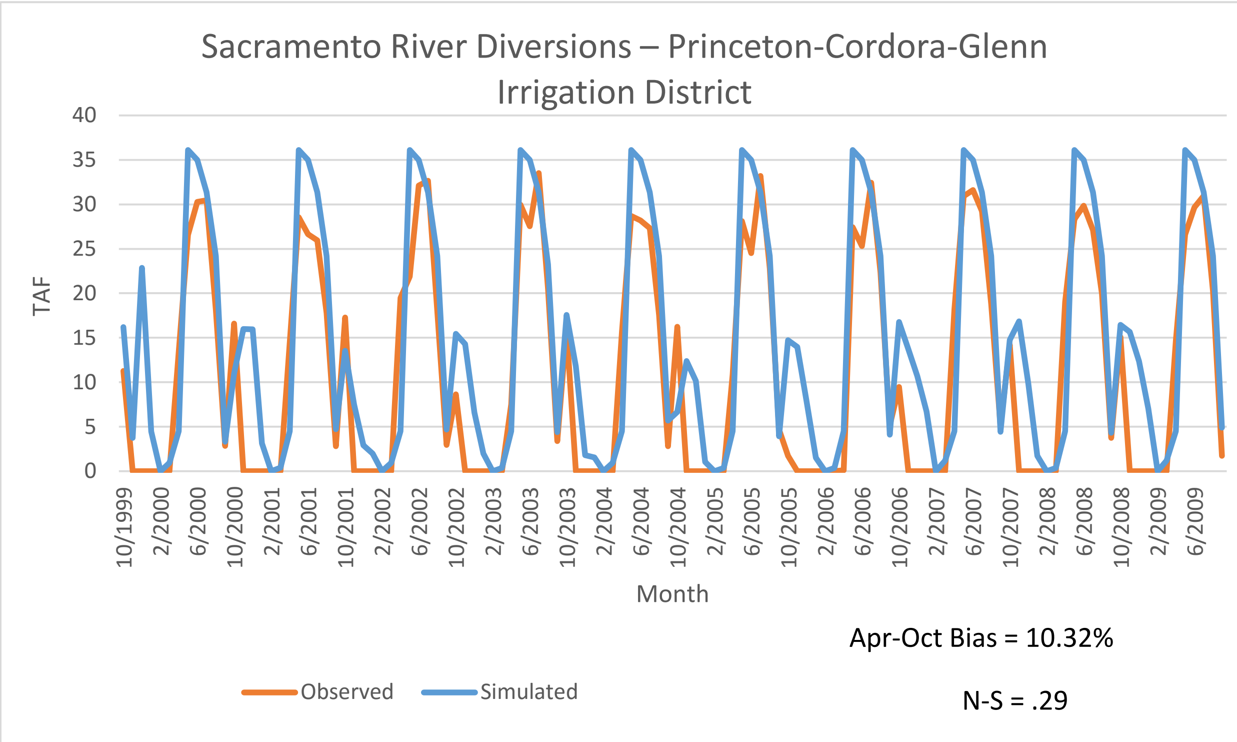

Figure B.3.10a Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Monthly 2000 to 2009

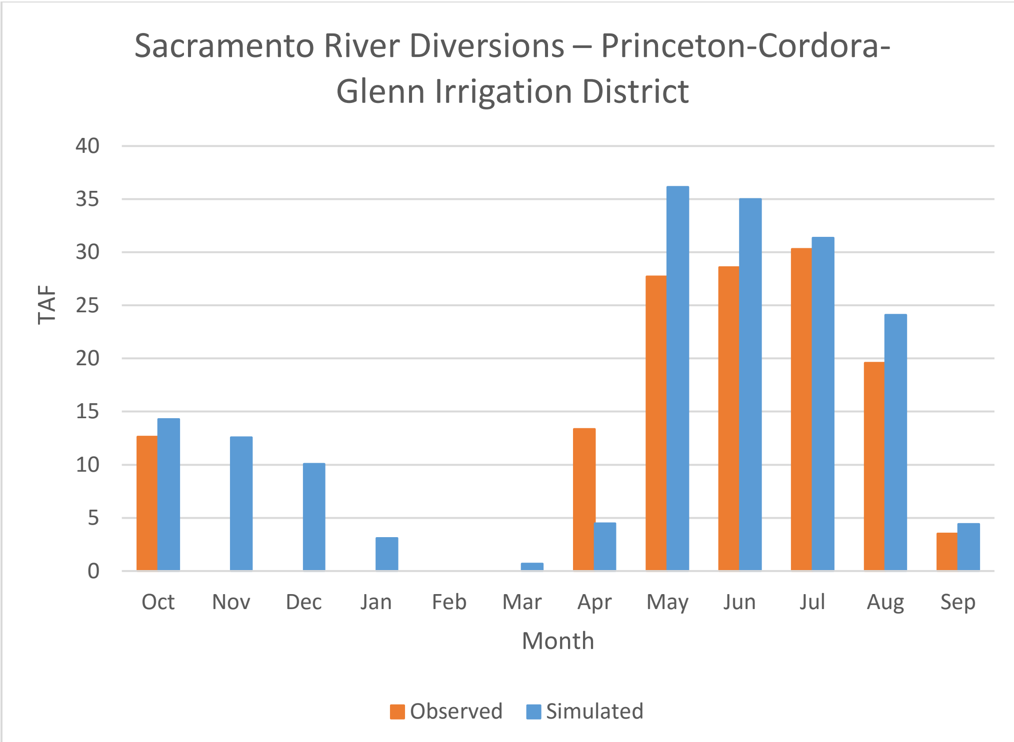

Figure B.3.10b Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Average Monthly

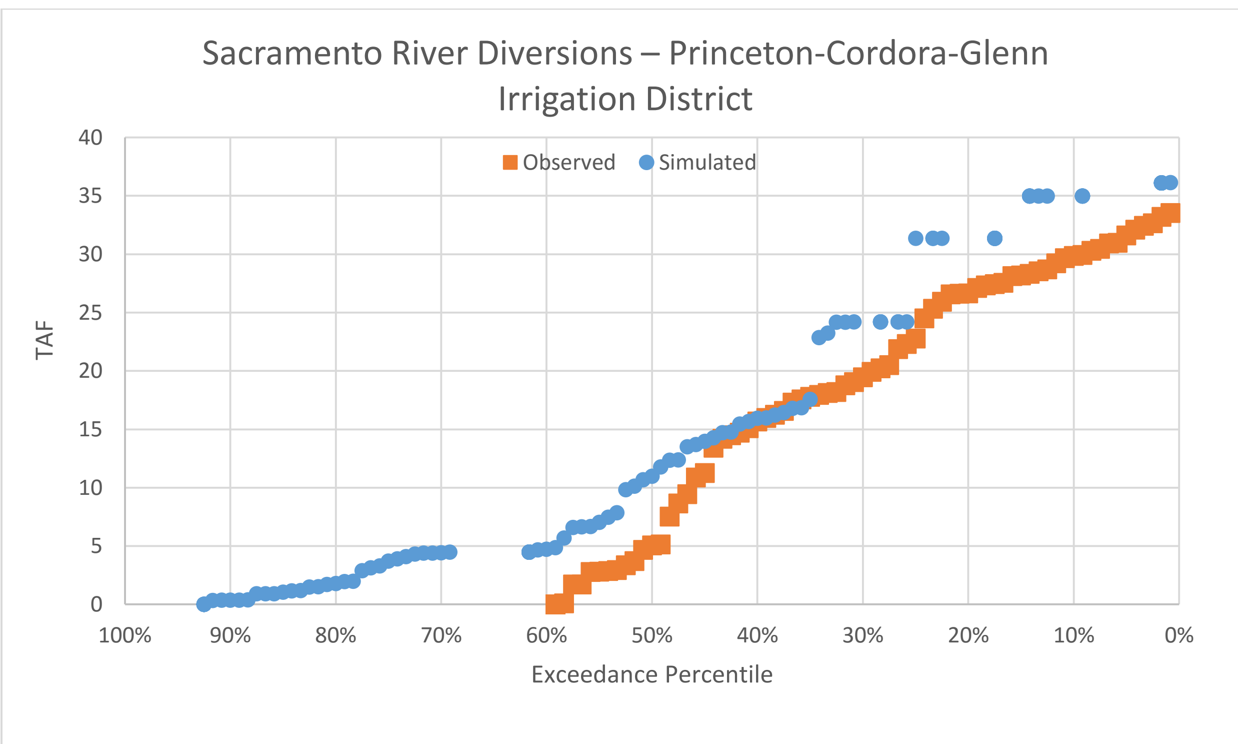

Figure B.3.10c Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Exceedance

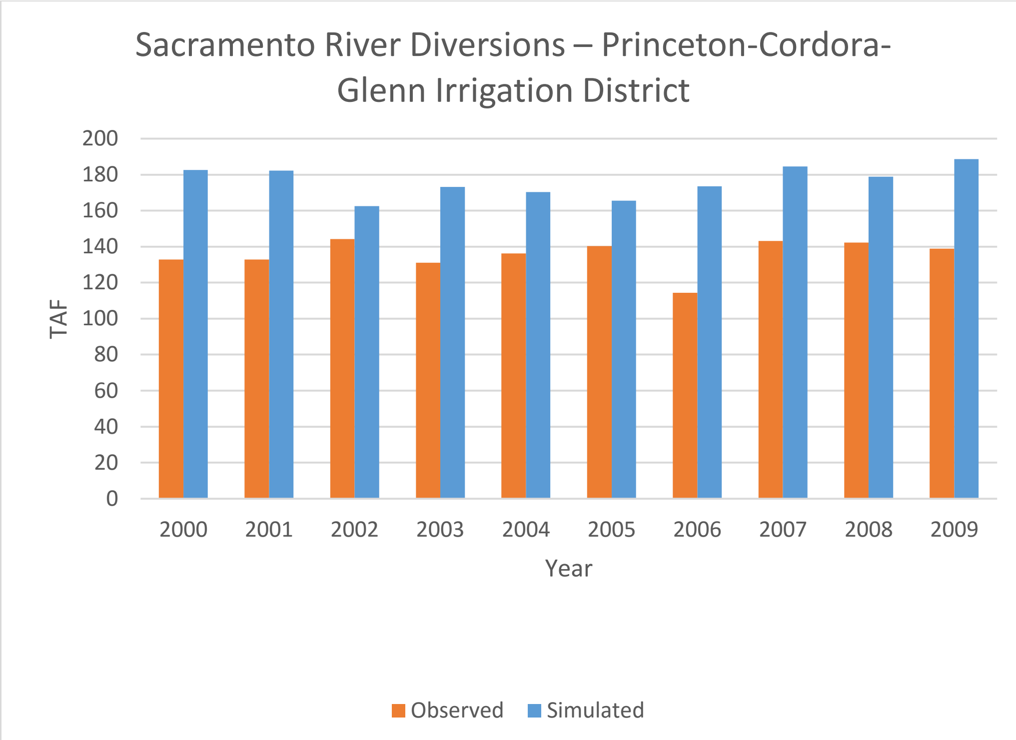

Figure B.3.10d Sacramento River Diversions – Princeton-Cordora-Glenn Irrigation District, Annual 2000 to 2009

B.3.11 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 average annual bias is 6.64%. The simulated monthly pattern reasonably represents the observed data.

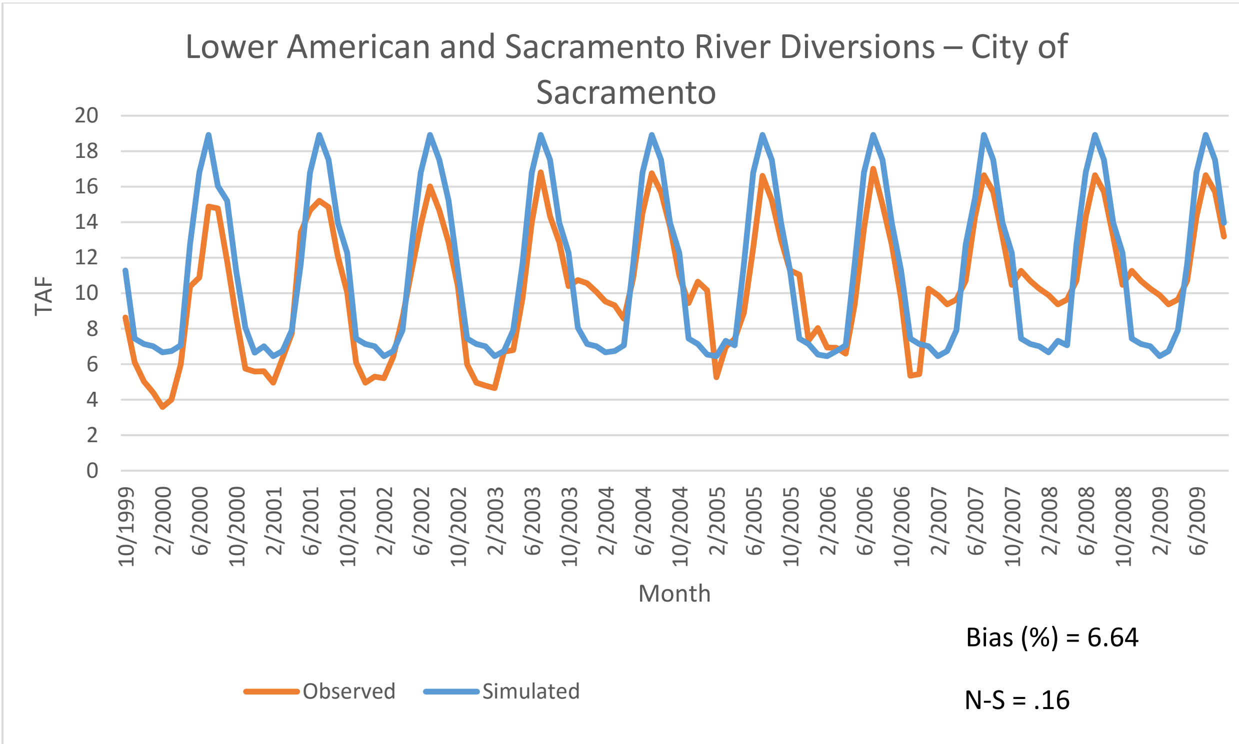

Figure B.3.11a Lower American and Sacramento River Diversions – City of Sacramento, Monthly 2000 to 2009

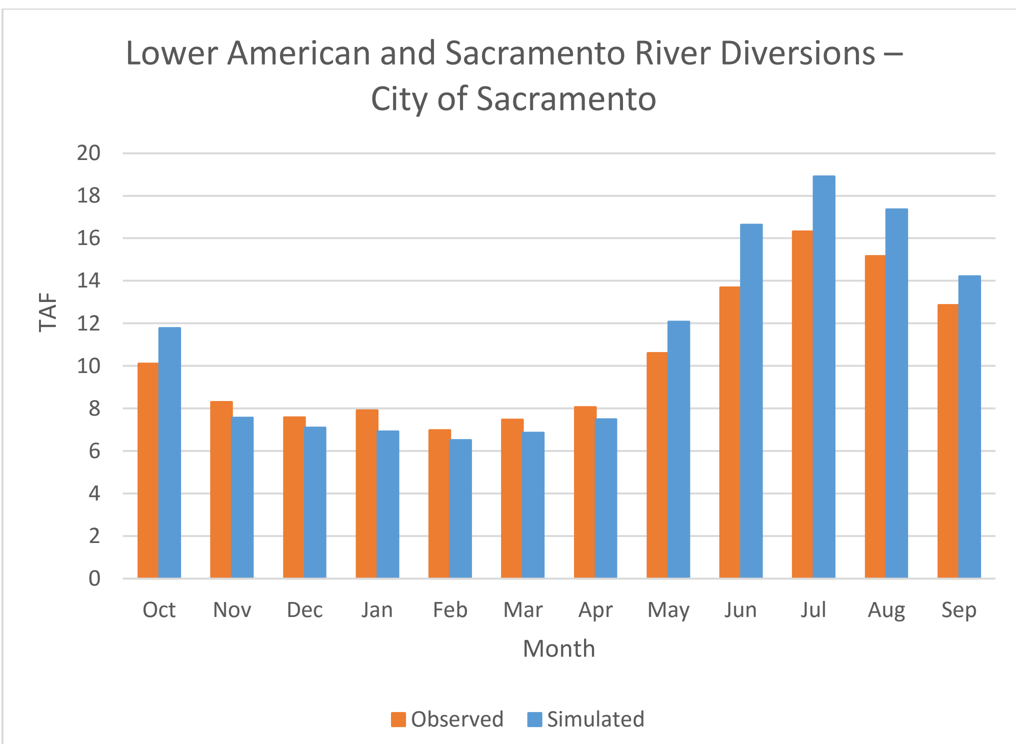

Figure B.3.11b Lower American and Sacramento River Diversions – City of Sacramento, Average Monthly

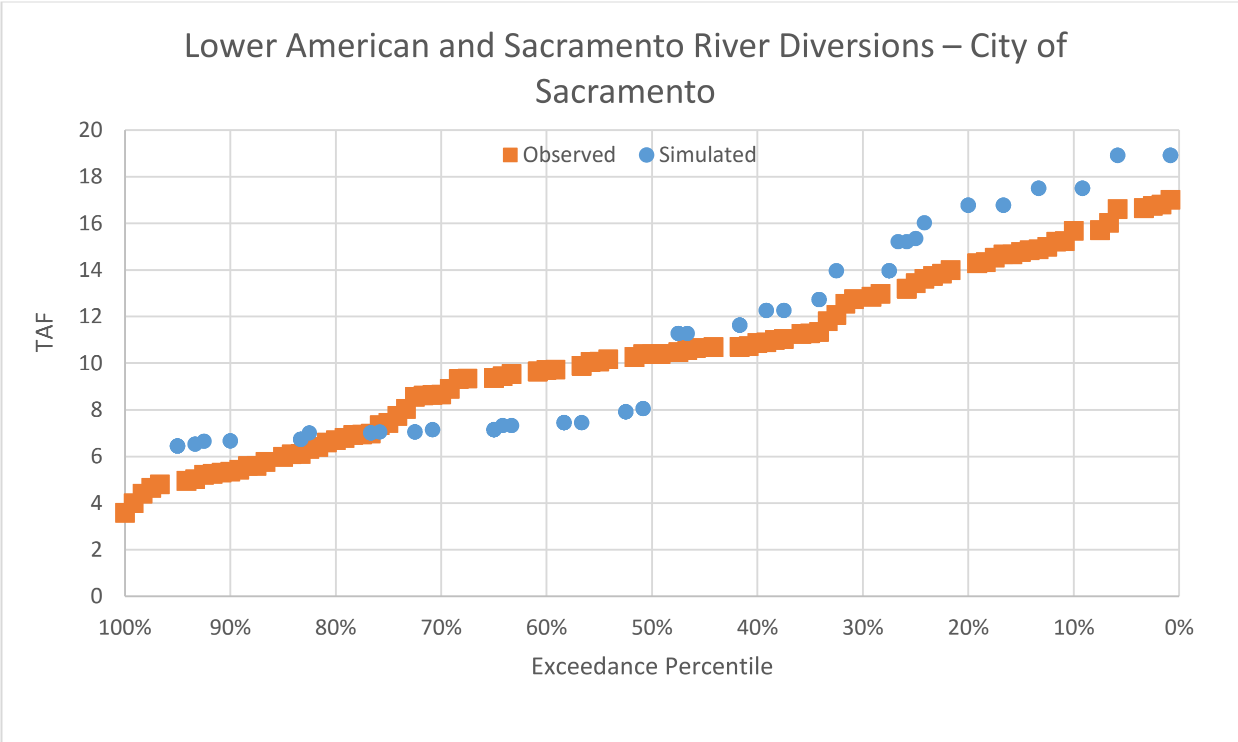

Figure B.3.11c Lower American and Sacramento River Diversions – City of Sacramento, Exceedance

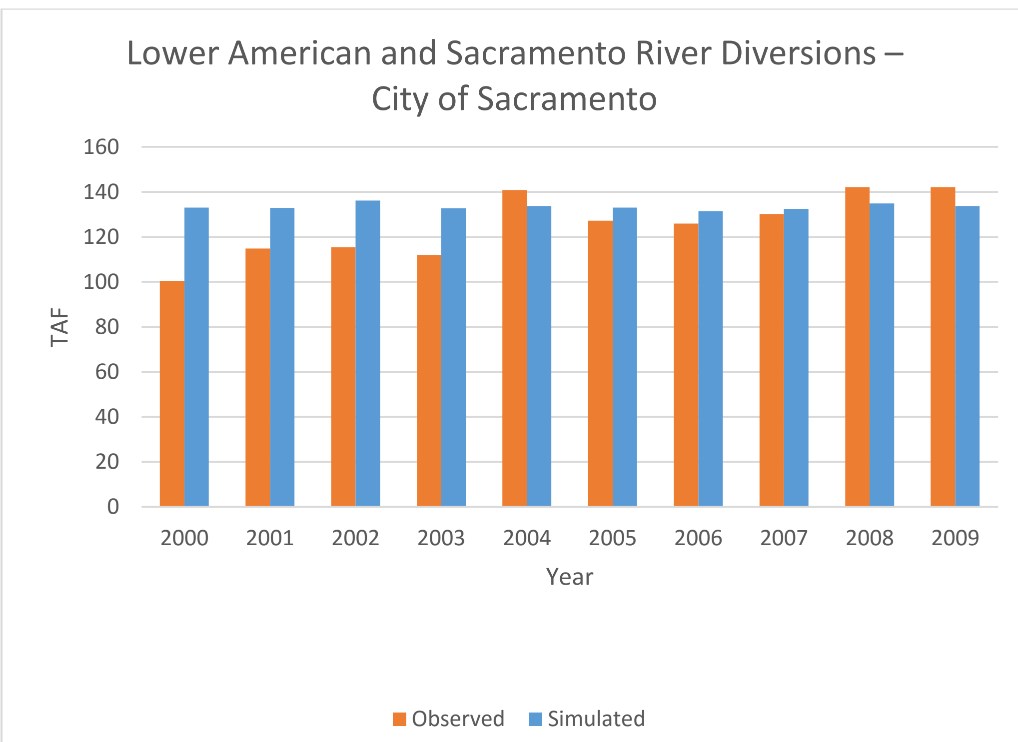

Figure B.3.11d Lower American and Sacramento River Diversions – City of Sacramento, Annual 2000 to 2009

B.3.12 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 average annual Apr-Oct bias is -15.37%. The simulated monthly pattern under predicts April, May, and September. This is probably due to the operational constraints of this canal system that require a large minimum diversion to operate.

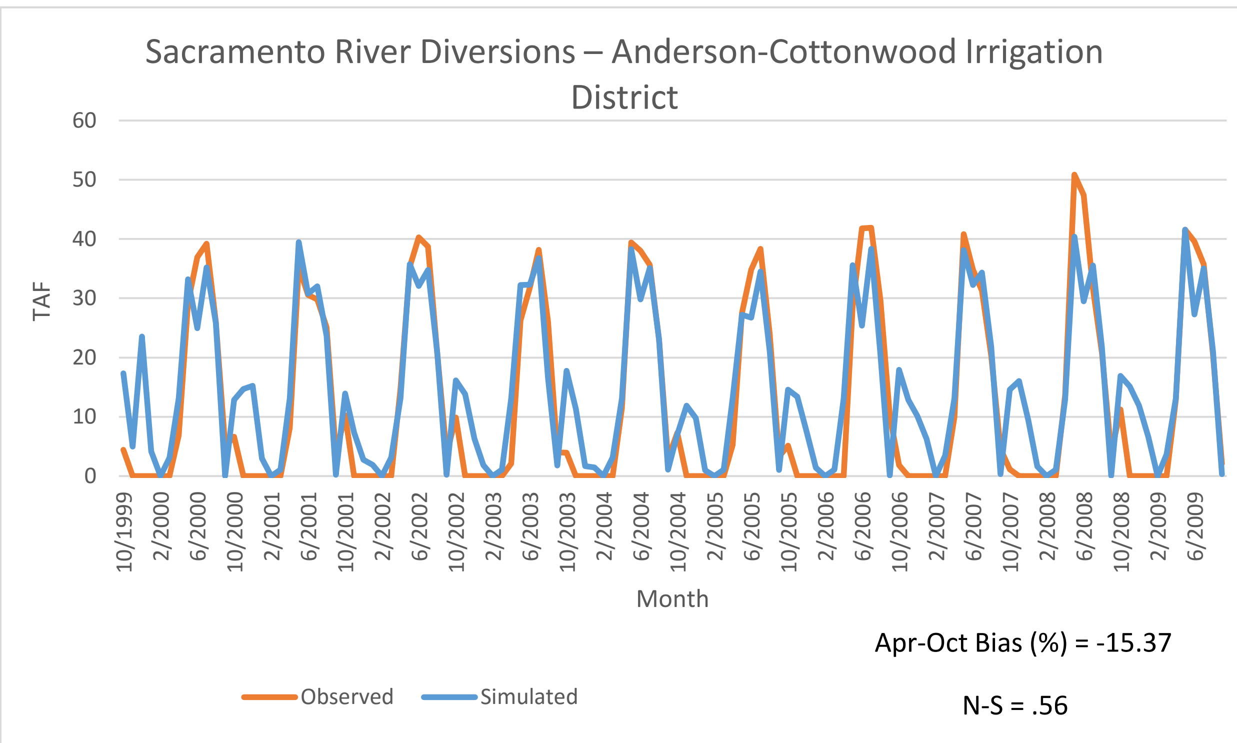

Figure B.3.12a Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Monthly 2000 to 2009

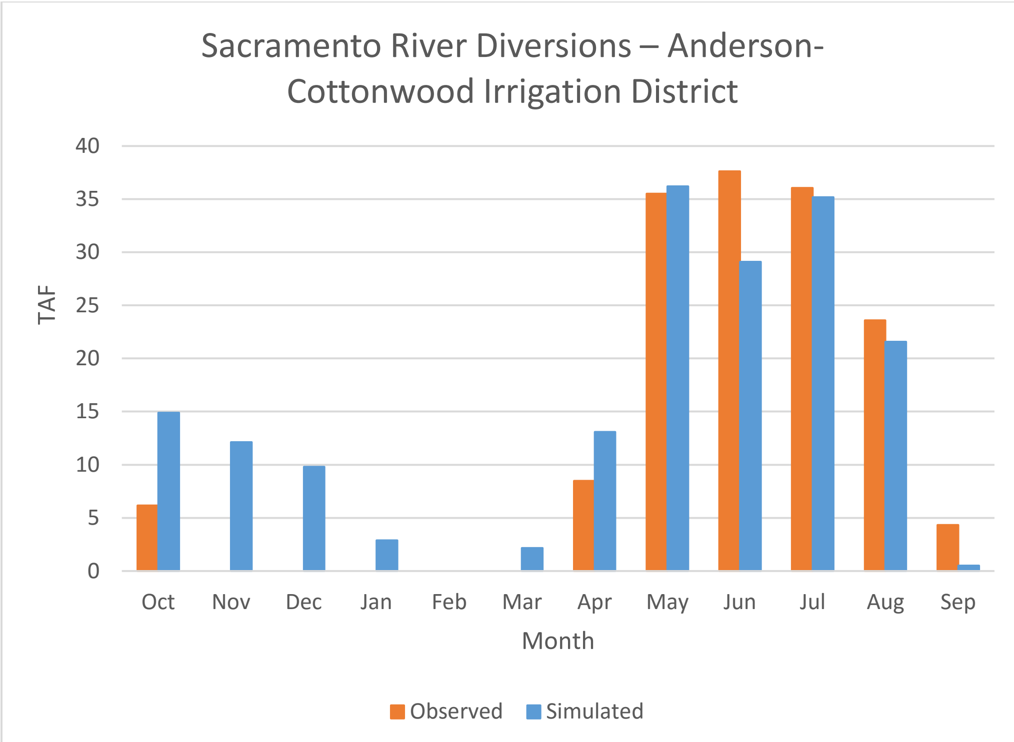

Figure B.3.12b Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Average Monthly

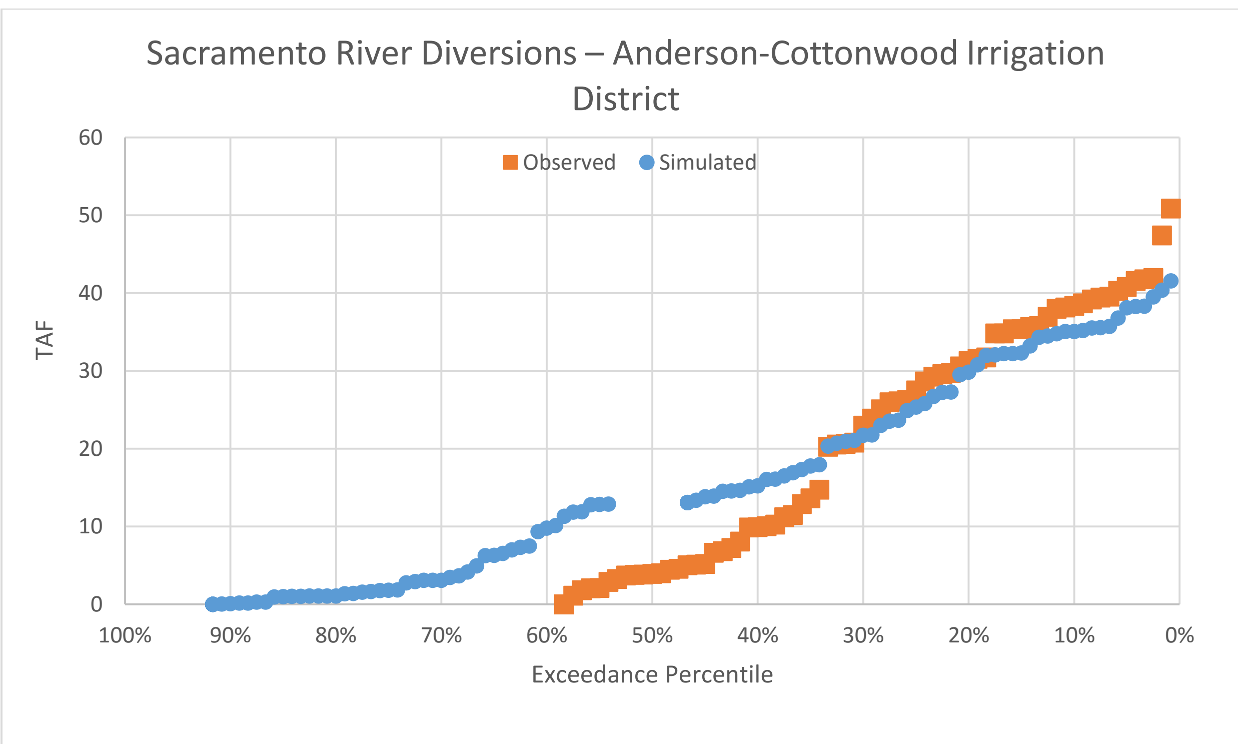

Figure B.3.12c Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Exceedance

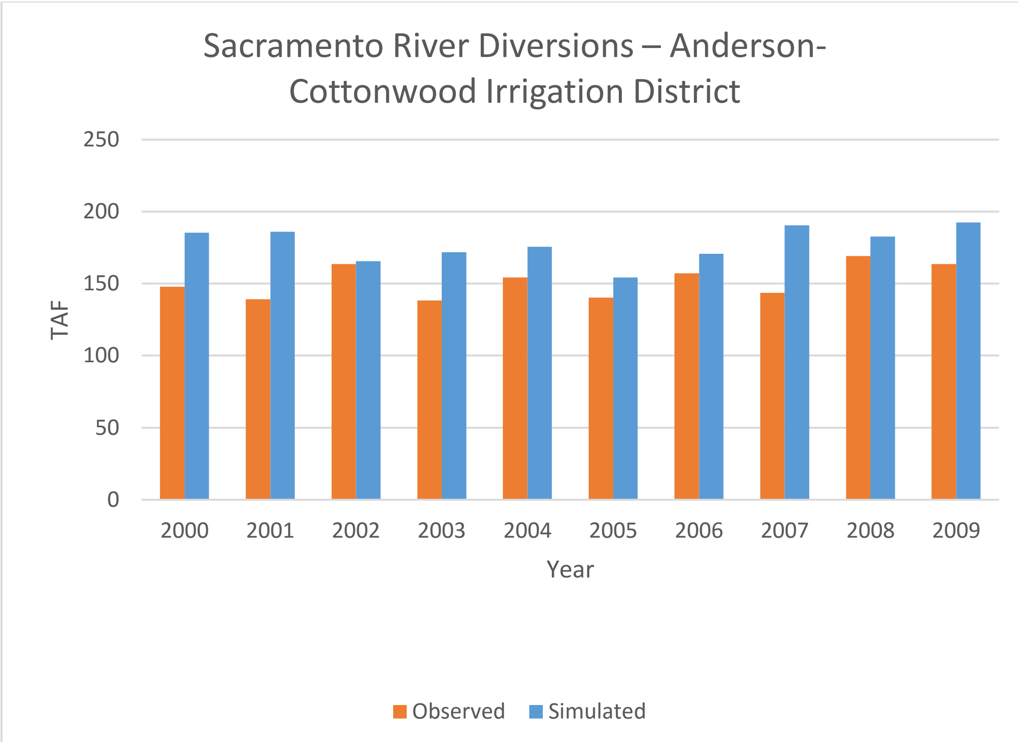

Figure B.3.12d Sacramento River Diversions – Anderson-Cottonwood Irrigation District, Annual 2000 to 2009

B.3.13 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 8.38%. 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.

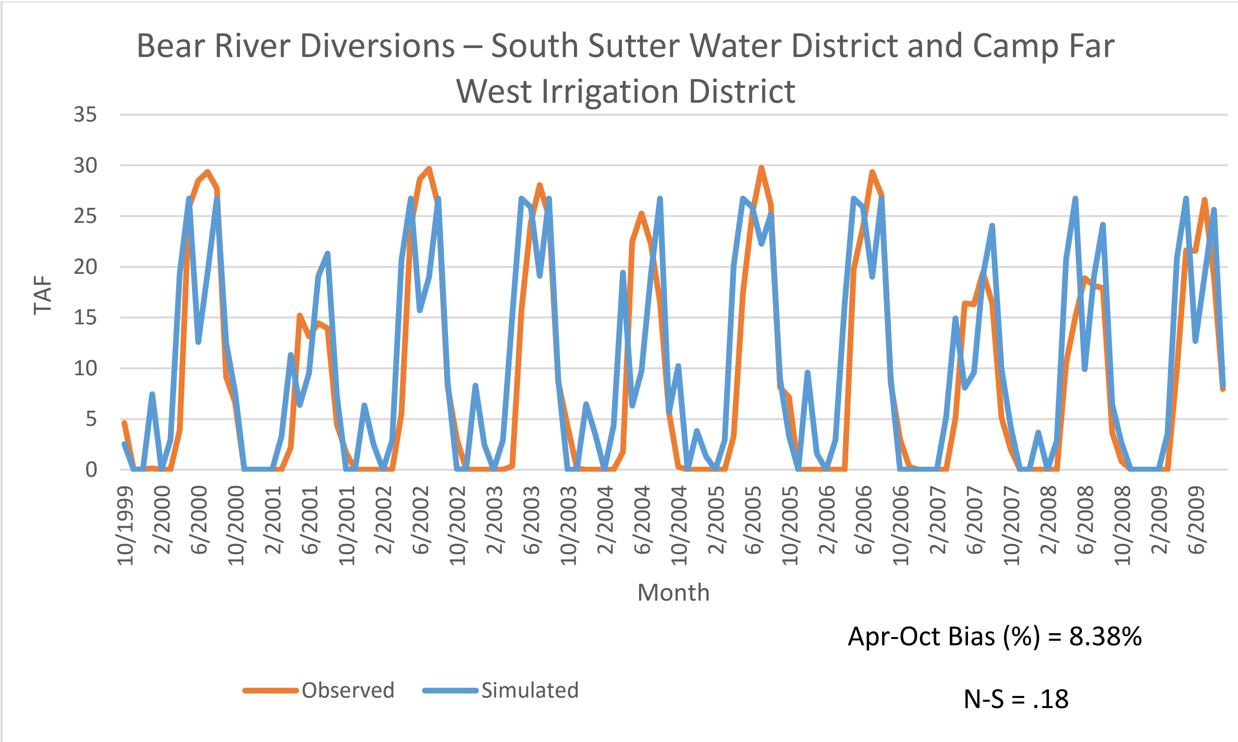

Figure B.3.13a Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Monthly 2000 to 2009

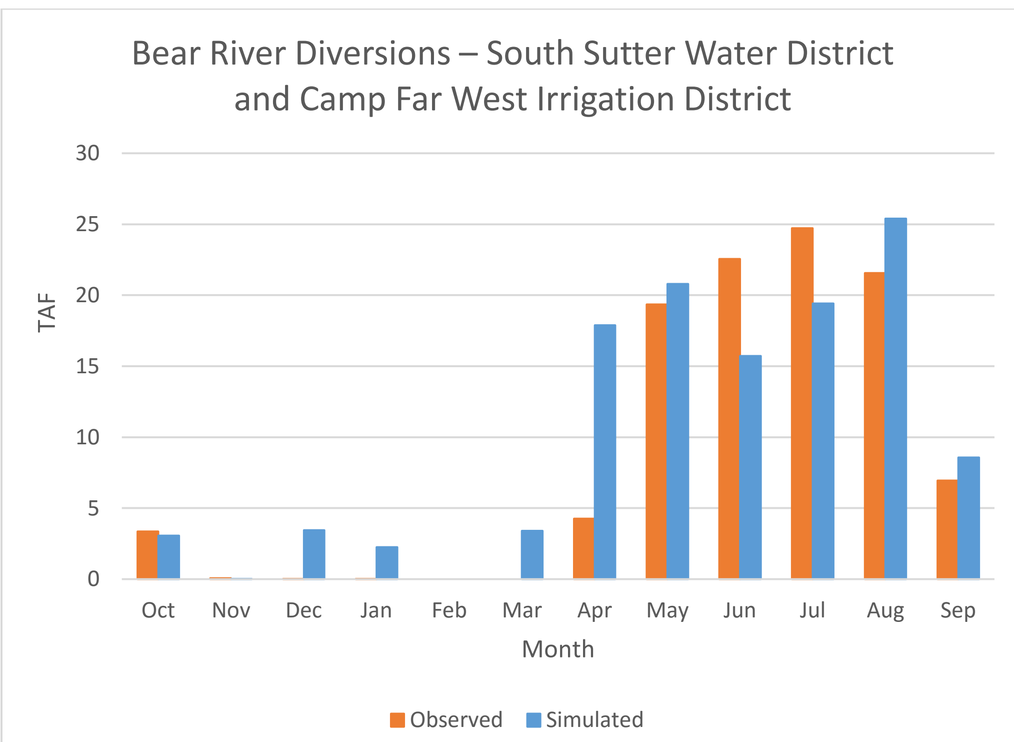

Figure B.3.13b Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Average Monthly

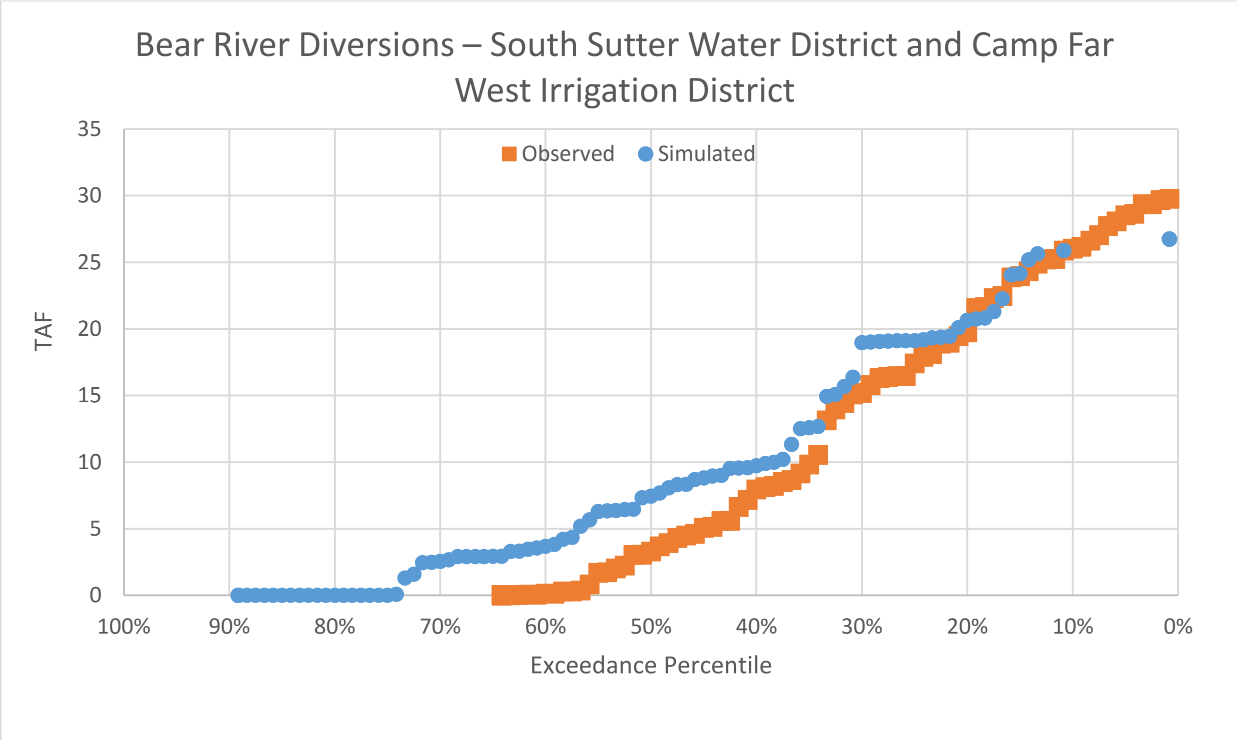

Figure B.3.13c Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Exceedance

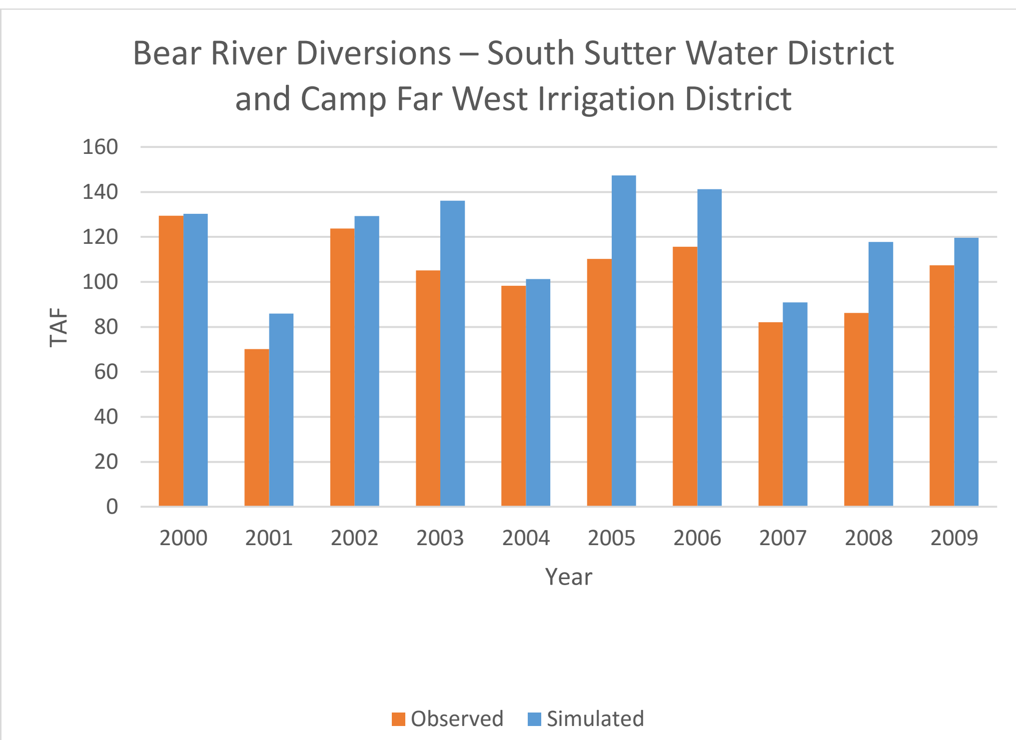

Figure B.3.13d Bear River Diversions – South Sutter Water District and Camp Far West Irrigation District, Annual 2000 to 2009

B.3.14 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 average annual bias is 6.34%. The simulated monthly pattern largely agrees with the observed data.

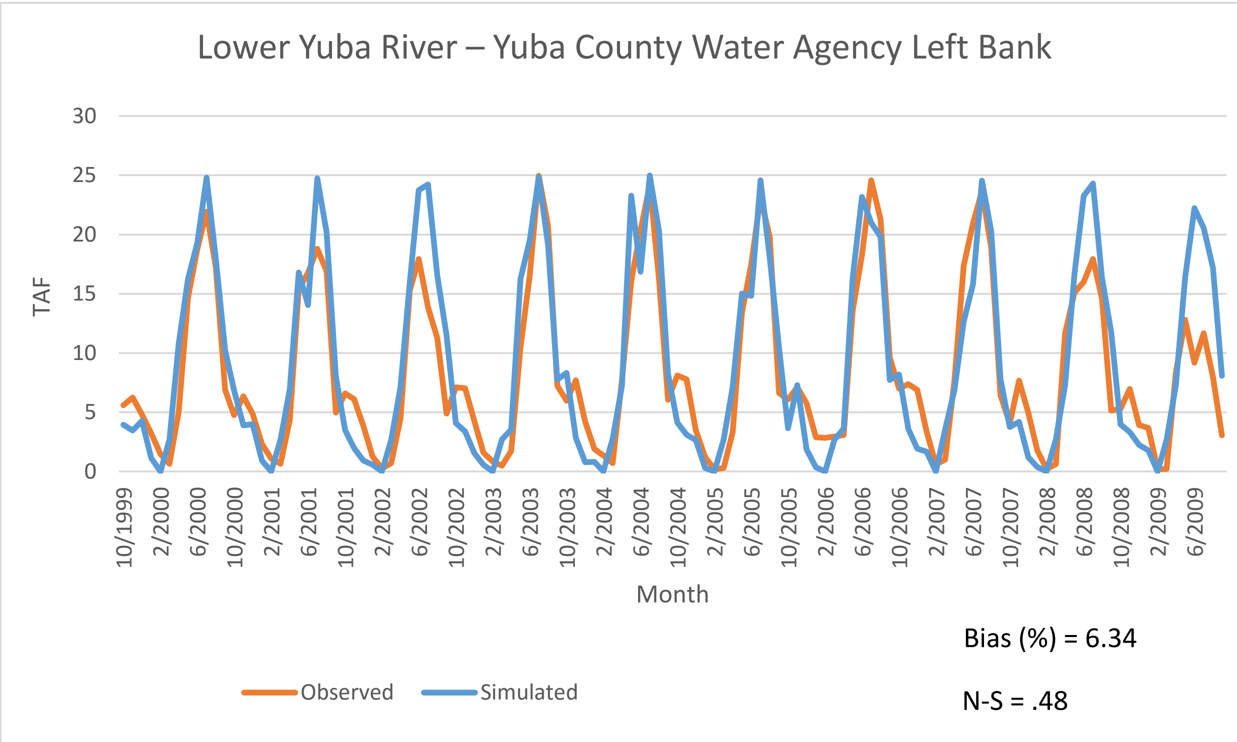

Figure B.3.14a Lower Yuba River – Yuba County Water Agency Left Bank, Monthly 2000 to 2009

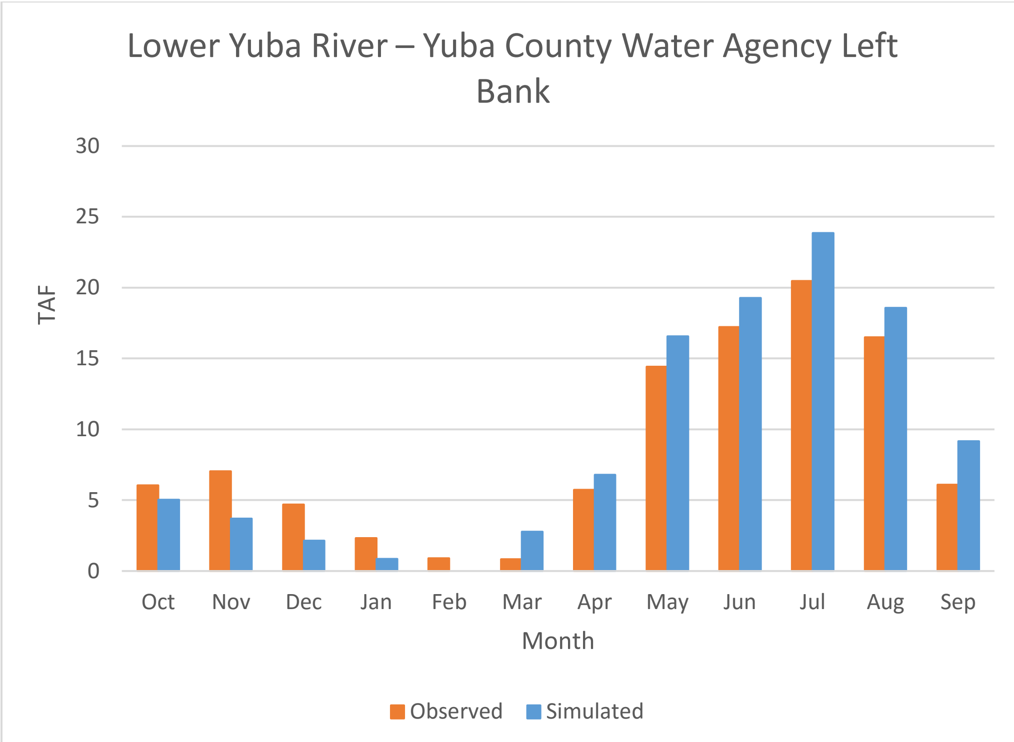

Figure B.3.14b Lower Yuba River – Yuba County Water Agency Left Bank, Average Monthly

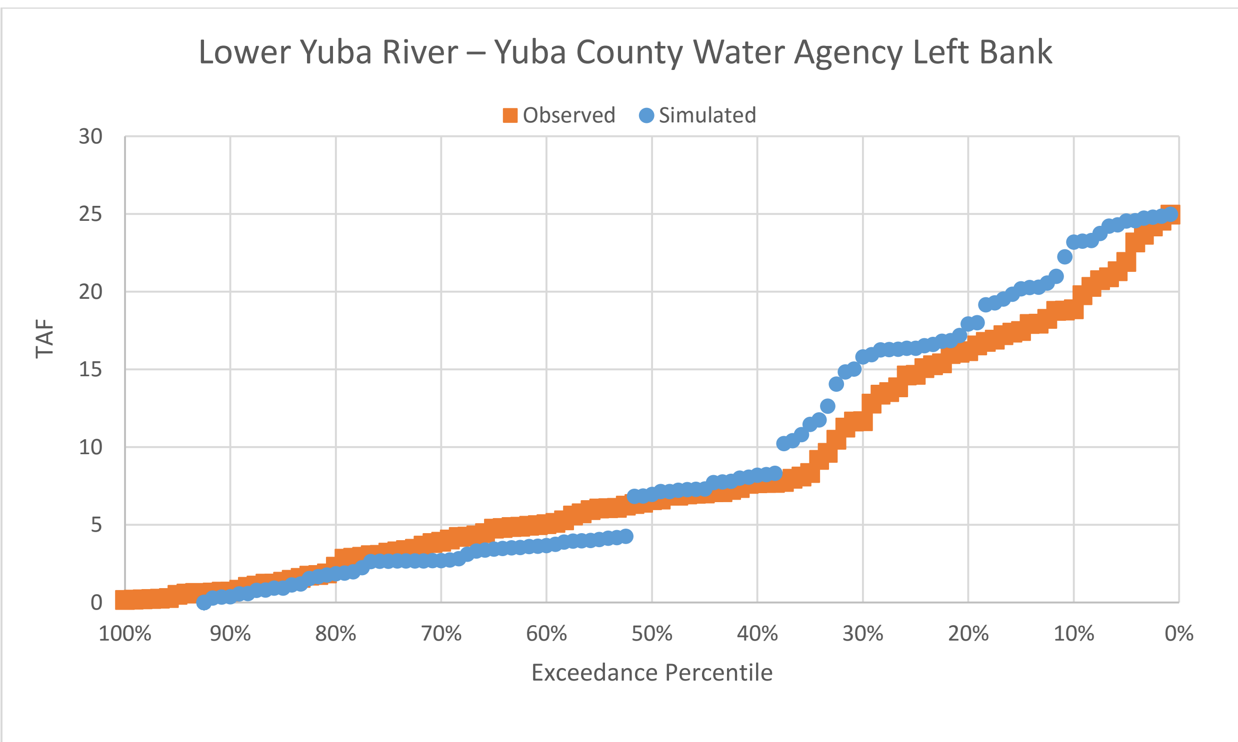

Figure B.3.14c Lower Yuba River – Yuba County Water Agency Left Bank, Exceedance

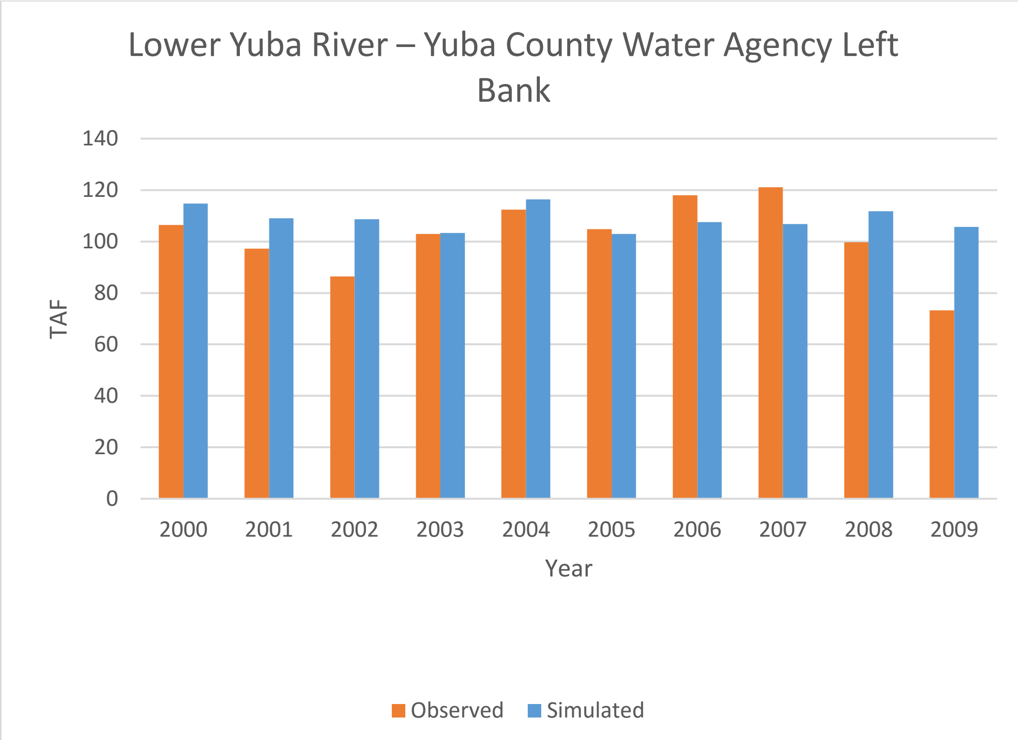

Figure B.3.14d Lower Yuba River – Yuba County Water Agency Left Bank, Annual 2000 to 2009

B.3.15 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_PA3. The water is predominantly used to irrigate pasture, alfalfa, and orchards. Observed data are available for 12 months. The average annual bias is 4.32%. The simulated monthly pattern largely agrees with the observed data except in October.

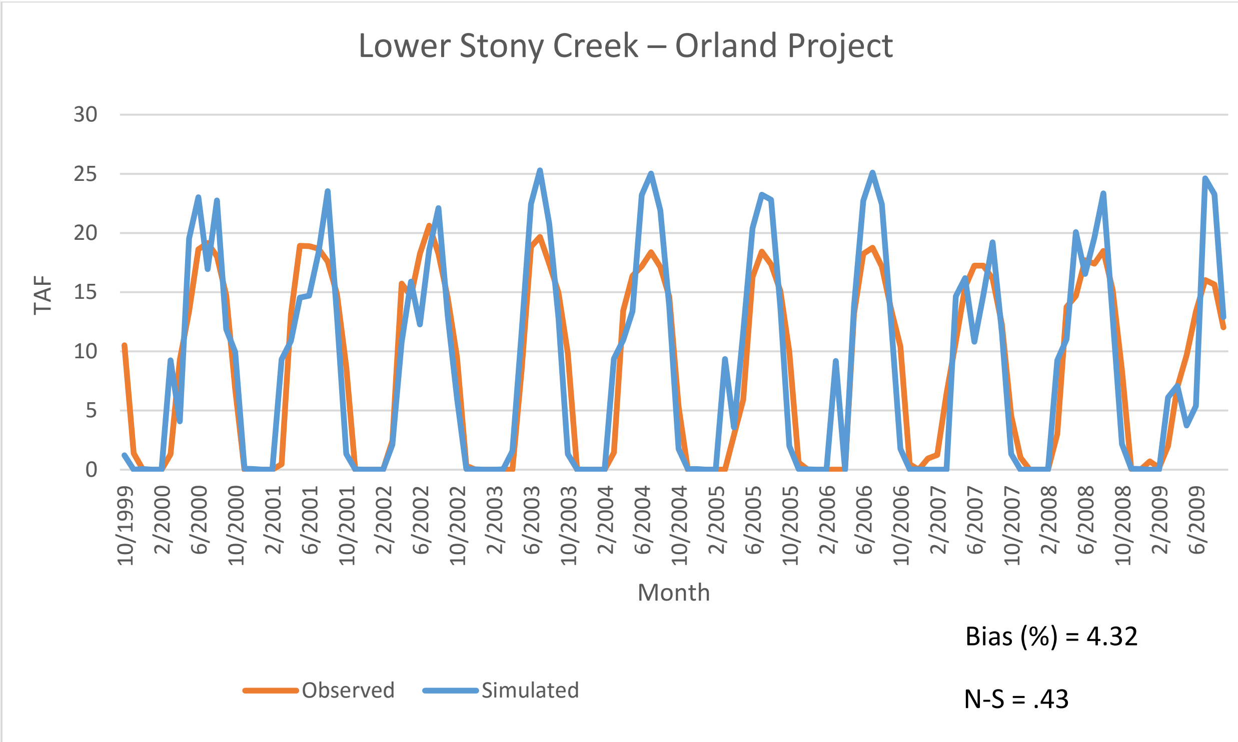

Figure B.3.15a Lower Stony Creek – Orland Project, Monthly 2000 to 2009

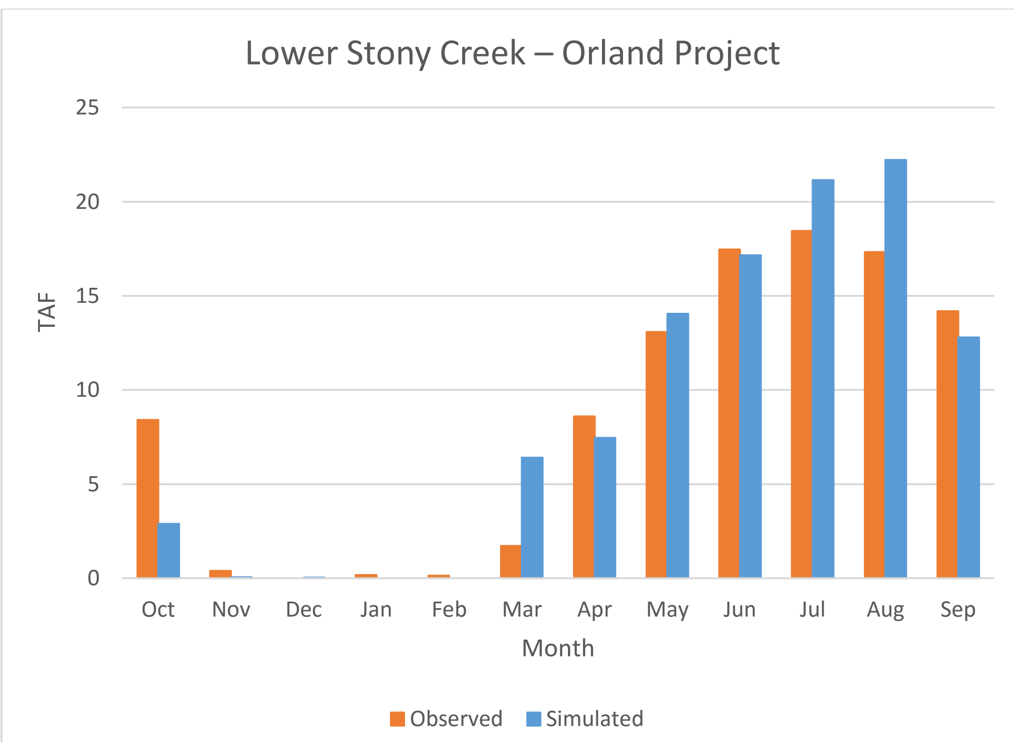

Figure B.3.15b Lower Stony Creek – Orland Project, Average Monthly

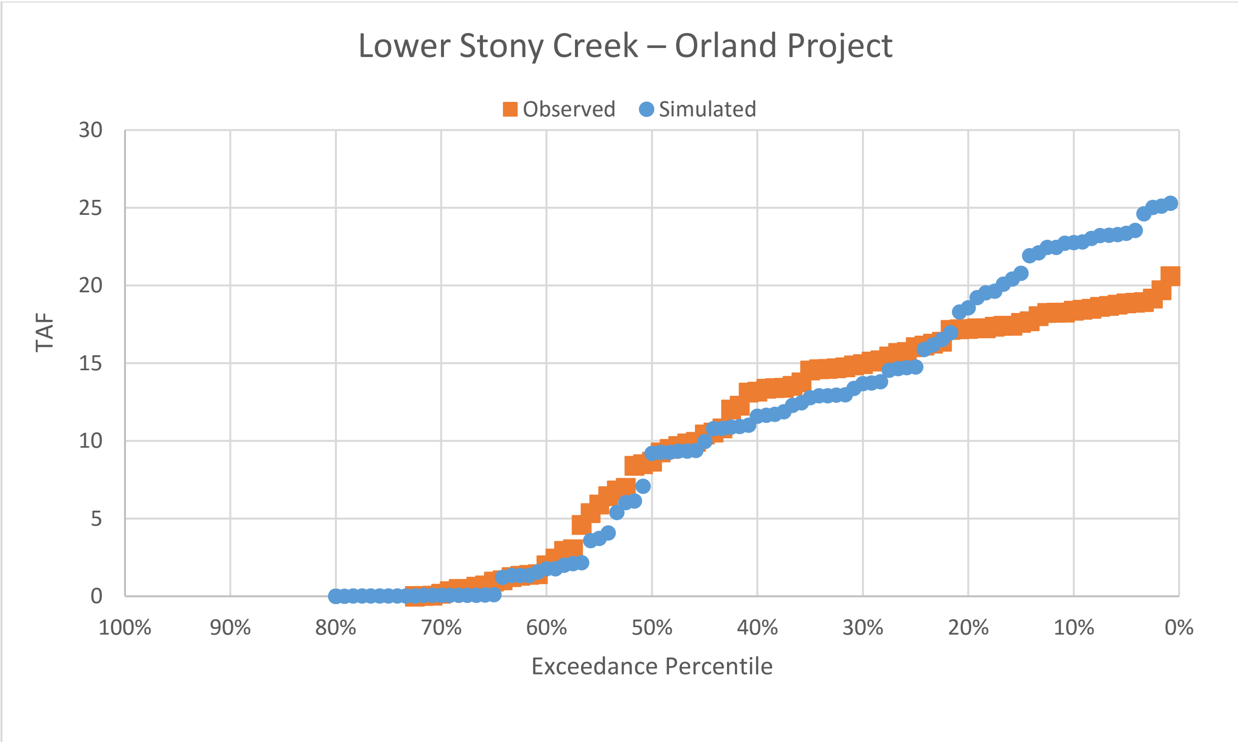

Figure B.3.15c Lower Stony Creek – Orland Project, Exceedance

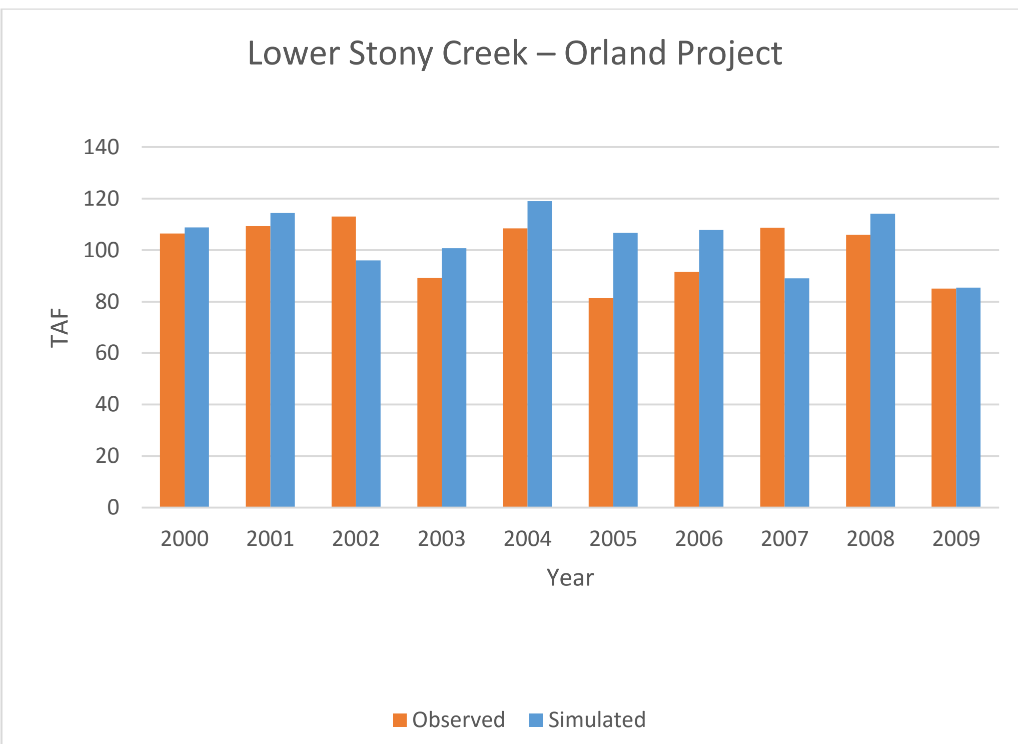

Figure B.3.15d Lower Stony Creek – Orland Project, Annual 2000 to 2009

Overall, the 15 diversions discussed in the previous paragraphs represent an annual average of 3,755,000 acre-feet. The simulated value is 3,732,000 which represents a bias of -1%. In general, the simulated values match the pattern of monthly diversions well. In some locations there are discrepancies which are largely due to incomplete information on rice management and the specifics of diversions from other sources of supply.

B.4 Rainfall Runoff Calibration

The next step in calibration was tuning the rainfall-runoff 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 1990-2009 matched. The comparison was made for the months of December 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 observed flow at Freeport. This calculation was not done for months in which the Fremont Weir was spilling in order to avoid errors caused by the inconsistent data related to Yolo Bypass flows during high flow events. For the simulated data, a modified version of SacWAM was developed in which the reservoirs were constrained to their observed storage values. This eliminated any error due to differences between simulated and observed reservoir operations. Similar to the historical accretions, the simulated accretions were calculated by subtracting simulated rim inflows from simulated flow at Freeport.

The initial literature values of the curve numbers for agricultural and native vegetation lands were adjusted on a monthly basis so that monthly average historical and simulated accretions more closely match (Table B-3). The resulting curve numbers increase in magnitude from December to March, which is 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.

Using the curve numbers shown in Table B-3 the average simulated monthly accretions for 1990 to 2009 match well with the observed accretions (Figure B.4–1). The average annual bias for the four months is -0.36%.

Another view of model performance that reflects the partitioning of precipitation into runoff and infiltration is the comparison of historical and simulated flow out of the Sacramento Valley, as represented by the sum of flows on the Sacramento River at Freeport and the Yolo Bypass. This is shown in Figure B.4–2. This graph indicates that generally the model is simulating the total flow from the valley with little bias. There is some under prediction of the largest wintertime flows. The discrepancies in the highest peak flows may be due to a) inaccuracies in the measurement of flow in the

Yolo Bypass, b) inaccuracies in the specified inflows used in the model, and/or c) inaccuracies in the model simulation of rainfall runoff.

Table B-3 Calibrated Curve Number Values Based on Matching Average Monthly Accretions, Sacramento Valley

		Calibrated Curve Numbers			
Land Cover Type	**Initial Curve Number**	**December**	**January**	**February**	**March**
Agriculture	86	91.5	91.8	99.2	100
Native Vegetation	79	84.0	84.4	91.2	94.8
Urban Outdoor	69	69	69	69	69
Refuge	46	46	46	46	46

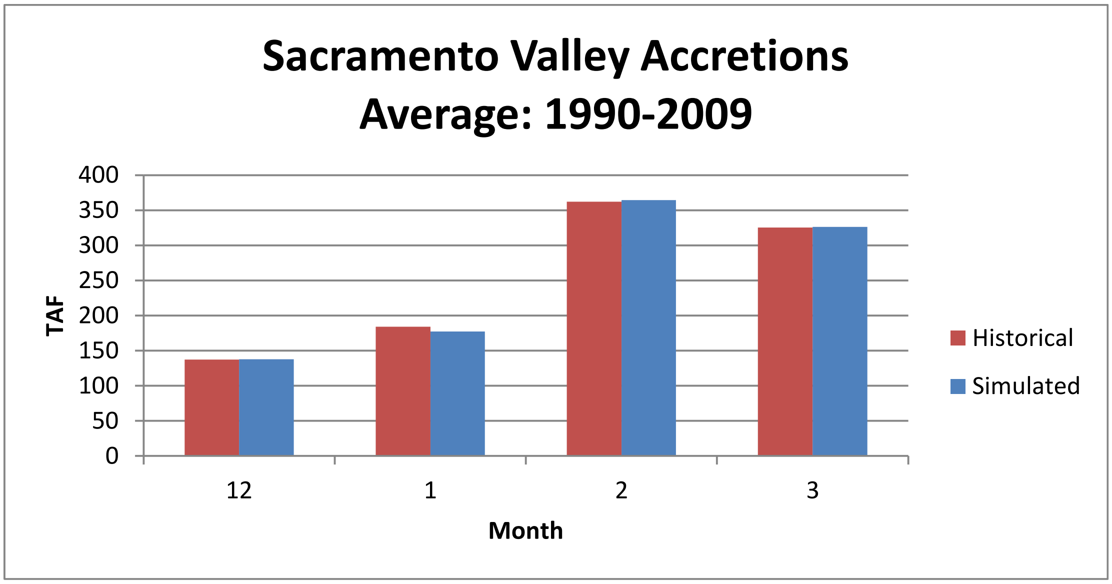

Figure B.4–1 Simulated and Historical Sacramento Valley Accretions (1990-2009)

Data represent months in which the Fremont Weir was not spilling

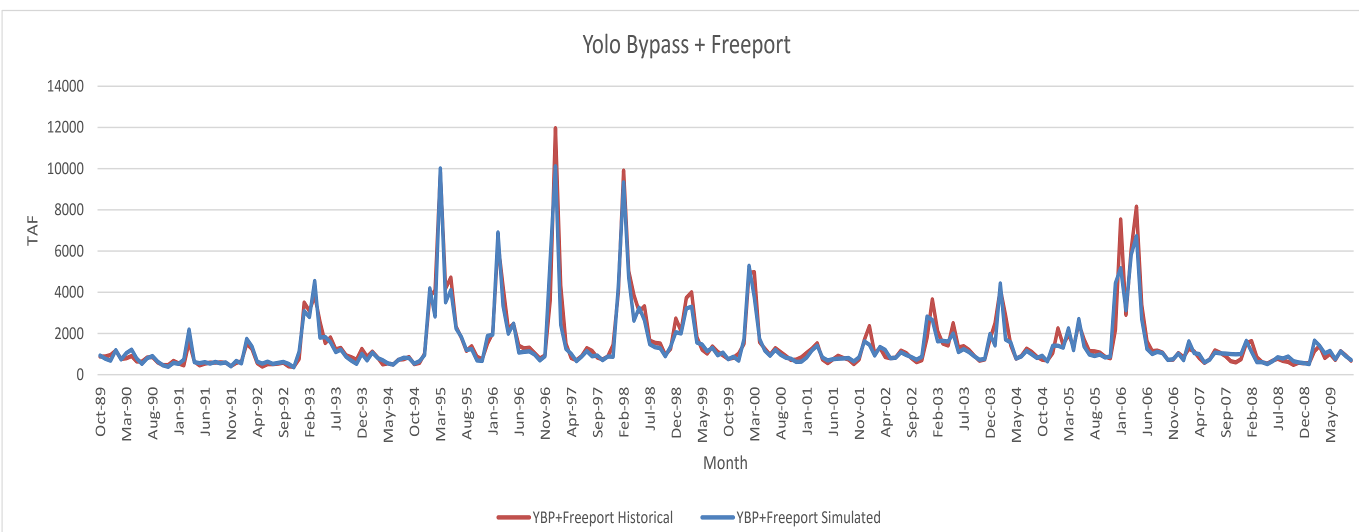

Figure B.4–2 Monthly Historical and Simulated Flows Out of the Sacramento Valley (Freeport + Yolo Bypass), 1990-2009

The **rainfall runoff calibration** spreadsheet contains the calculations and comparisons made during the calibration.

B.5 Stream Aquifer Interactions Calibration

The next step in the calibration process was to adjust the parameters governing stream-aquifer interactions. The initial parameterization of the stream – aquifer interactions are described in Section 6.3.1.3. During calibration the parameters that characterize the interactions between streams and aquifers were adjusted so that SacWAM more closely matched results from a "current conditions" model run in C2VSim for water years 1990-2009. This adjustment was done on the scale of each C2VSim stream reach. In this calibration the focus was on adjusting the parameters of Sacramento River tributaries in SacWAM until the average annual seepage for both models were within 5 TAF. The final step was to adjust all Sacramento River reaches until the average annual Sacramento River seepage in SacWAM was similar to the C2VSim Sacramento River seepage. For most streams little adjustment was needed, however on some streams and particularly on the Sacramento River it was necessary to modify the slope parameter to increase the volume of water that percolated to the groundwater system. The calibration factors are provided in Table 6-12. The average annual seepage values and the Bias are shown in Table B-4.

Table B-4 C2VSim and calibrated SacWAM average annual seepage values

C2VSim Reach #	Description	SacWAM Average Monthly Seepage (TAF)	C2VSim Average Monthly Seepage (TAF)	BIAS (%)
25	Calaveras R	53.5	54.8	-2.3
27	Mokelumne R	63.0	89.8	-29.8
29	Cosumnes R	1.4	3.3	-56.7
33	Cow Ck	12.2	12.2	0.0
35	Cottonwood Ck	9.4	7.2	31.2
36	Battle Ck	-9.4	-10.2	8.4
38	Paynes Ck	-11.9	-13.5	11.6
40	Antelope Ck	-14.7	-14.3	-3.0
42	Elder Ck	-2.9	-3.7	20.9
43	Mill Ck	-2.7	-2.5	-10.7
45	Thomes Ck	17.1	15.9	8.0
47	Deer Ck	0.6	1.3	-52.3
49	Stony Ck	63.9	68.7	-6.9
50	Big Chico Ck	0.3	0.4	-34.7
52	Butte Ck	123.2	119.3	3.3
58	Sutter Bypass	44.6	42.0	6.32
59,61,64	Feather R	41.3	36.0	14.81
60	Yuba R	15.5	20.2	-23.17
62	Bear R	39.8	40.8	-2.53
66	American R	49.9	49.7	0.44
68	Cache C	89.2	86.2	3.54
69	Putah C	45.9	50.5	-9.2
32,34,37,39, 41,44,46,48, 51,53,57,65,67	Sacramento R	321.0	279.6	14.83
TOTAL		**991.8**	**948.1**	**4.6**

B.6 Project Operations Validation

An extensive set algorithms were developed to represent the operations of the CVP and SWP in SacWAM. A description of the algorithms is found in Chapters 7 and 8. In this section comparisons between SacWAM and a CalSim II study (2015 SWP Delivery Capability Report – Existing Conditions) are provided as a validation of the logic used in SacWAM to represent project operations. Comparisons were not made to historical data because the operations logic in SacWAM reflect current project operations rules that were not in force in earlier decades. The focus of the analysis presented here is on these main components:

1. Trinity River imports through the Clear Creek Tunnel
2. CVP storage north of the Delta
3. SWP storage north of the Delta
4. Feather River flows
5. American River flows
6. Sacramento River flows
7. Delta inflow
8. Delta required outflow
9. CVP and SWP exports

In each of the comparisons provided below, graphs of monthly, average monthly, annual, and monthly exceedance for flow/storage are provided for the water years 1922-2003. Values for Bias and the Nash-Sutcliffe efficiency are also provided. Positive values of bias correspond with an over prediction by SacWAM in comparison to CalSim.

Simulated Trinity River imports through the Clear Creek Tunnel are 12.5% larger than those simulated by CalSim. This represents an average of 71 TAF/year. Most of the differences between the models occur during winter months in which the Sacramento Valley is in flood conditions. CalSim has additional logic that restricts imports when the Sacramento Valley is in flood conditions, and directs flood releases from the Trinity Dam down the Trinity River. This logic could be added to SacWAM in the future.

North-of-Delta CVP and SWP storage as simulated by SacWAM and CalSim are in fair agreement. The most notable difference between the models occurs during the drought of 1977. In SacWAM, Lake Oroville is drained while in CalSim storage does not drop below 600 TAF. In CalSim II there are rules that restrict deliveries to the Feather River Service Area when Oroville storage is below 852 TAF. Similar logic could be added to SacWAM that would restrict reservoir releases during periods of low storage. Another difference of note is that on average SacWAM has more storage in north-of-Delta CVP and SWP reservoirs. The bias is 6.63% for the CVP and 4.37% for the SWP. A potential reason for this will be provided in the discussion on Delta Inflow (below).

River flows at the confluences of the Feather and American Rivers with the Sacramento River and on the Sacramento River at Freeport show general agreement between the two models. Notable differences are seen on the American River during summer months. This is likely due to differences in how demands have been specified in the models and how withdrawals during low flow conditions on the American River are simulated. In CalSim, contracts are used as surrogates for water demands which results in higher diversions than have recently occurred. SacWAM matches recent historical diversions.

On the Feather River SacWAM and CalSim are in good agreement at locations upstream from the mouth. At the confluence, flows are different in the winter months because of an accretions/depletions term that has been added in the CalSim model at this location. This term has been calculated using a historical water balance on the Feather River watershed which includes uncertainties in actual evapotranspiration and groundwater pumping rates. River flows on the Sacramento River at Freeport are in close agreement between the models

A comparison of flows in and out of the Delta largely show good agreement between SacWAM and CalSim. Delta inflow, which represents all flows into the Delta including the Sacramento River, the San Joaquin River and the Eastside streams has a bias of 2.98%. This represents an average of 688 TAF/yr. Closer inspection of the two models revealed that SacWAM has an average of approximately 326 TAF/yr more water flowing out of the Mokelumne River downstream of the Cosumnes confluence than CalSim. SacWAM also has an average of approximately 362 TAF/yr flowing into the Delta from regions outside of the Delta which are not directly represented in CalSim (e.g. Yolo County south of the Putah Creek watershed). Additional investigations into the cause of these differences may be warranted.

Combined CVP/SWP Delta exports, through the Delta Mendota Canal and California Aqueduct, show similar model performance. However, inspection of the individual exports to the Delta-Mendota Canal and California aqueduct indicate a closer match for the CVP exports than the SWP exports. The positive bias in exports is possibly due to the additional 688 TAF/yr of water that is available in SacWAM in comparison to CalSim.

Delta outflows are simulated as flow requirements for salinity control, X2, and MRDO and as surplus Delta outflow, which typically occurs during wet periods. In both cases the models are in good agreement. Operations of San Luis reservoir are somewhat different between SacWAM and CalSim with the operations of the SWP portion of San Luis Reservoir being less similar. Operations of San Luis Reservoir may require additional refinement.

B.6.1 Trinity River Imports

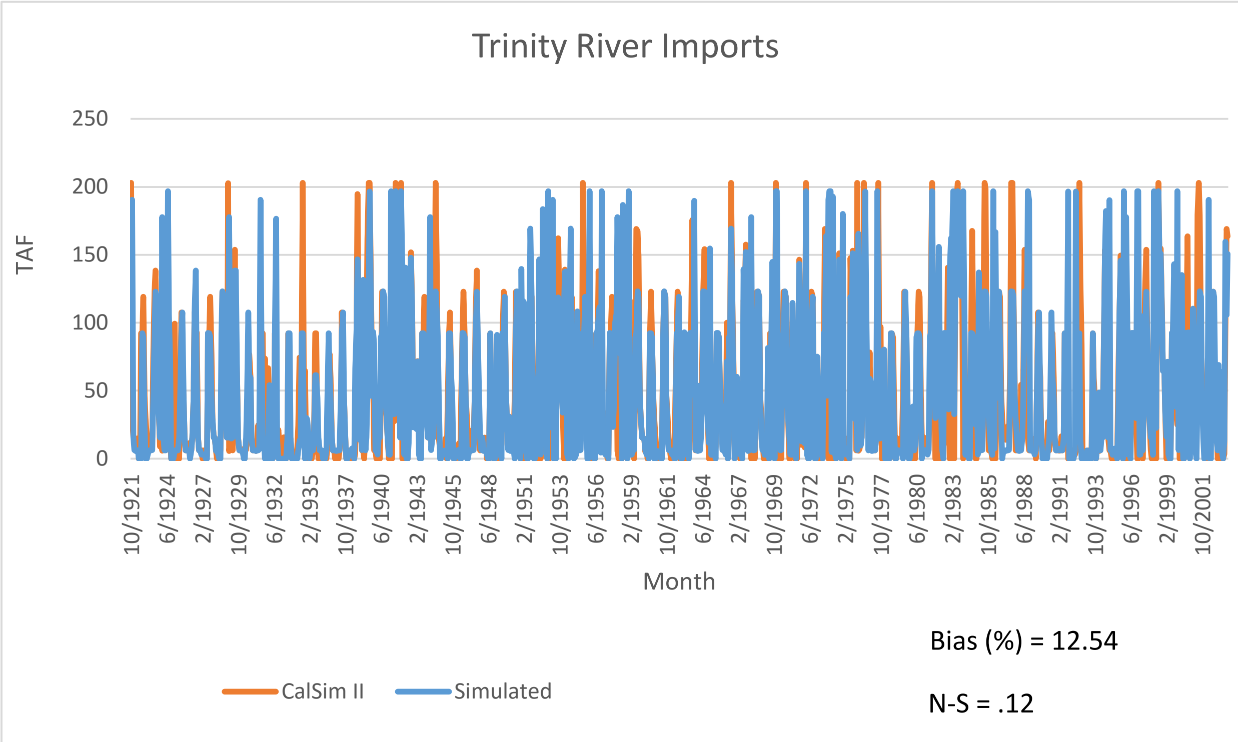

Figure B.6.1a Trinity River Imports, Monthly 1922 to 2003

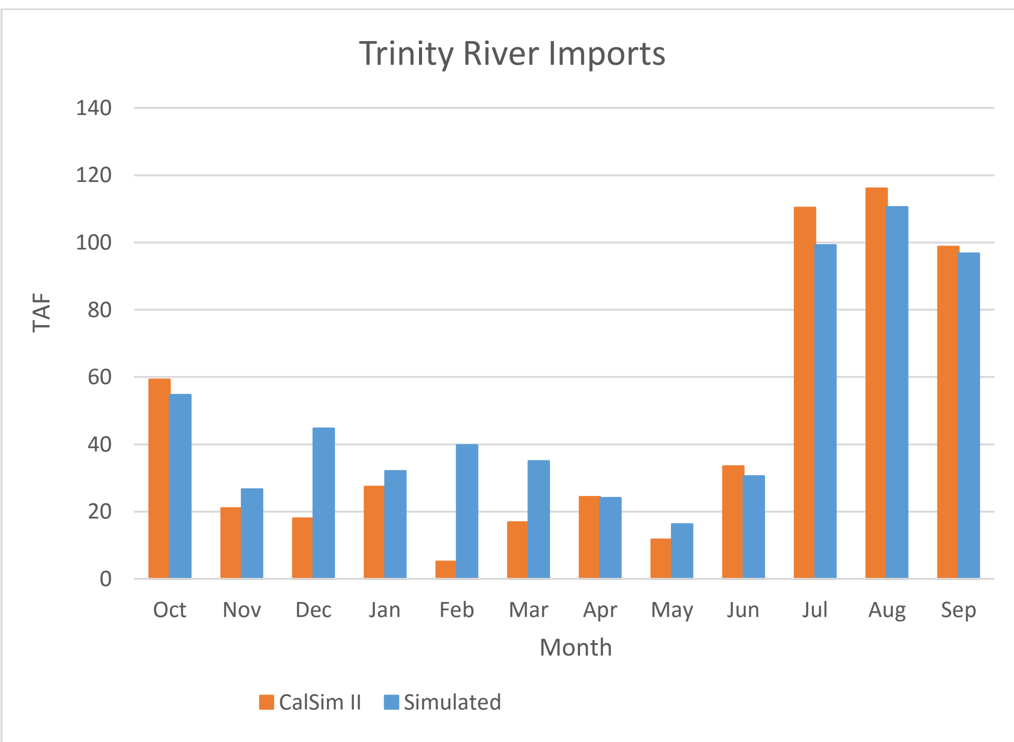

Figure B.6.1b Trinity River Imports, Average Monthly

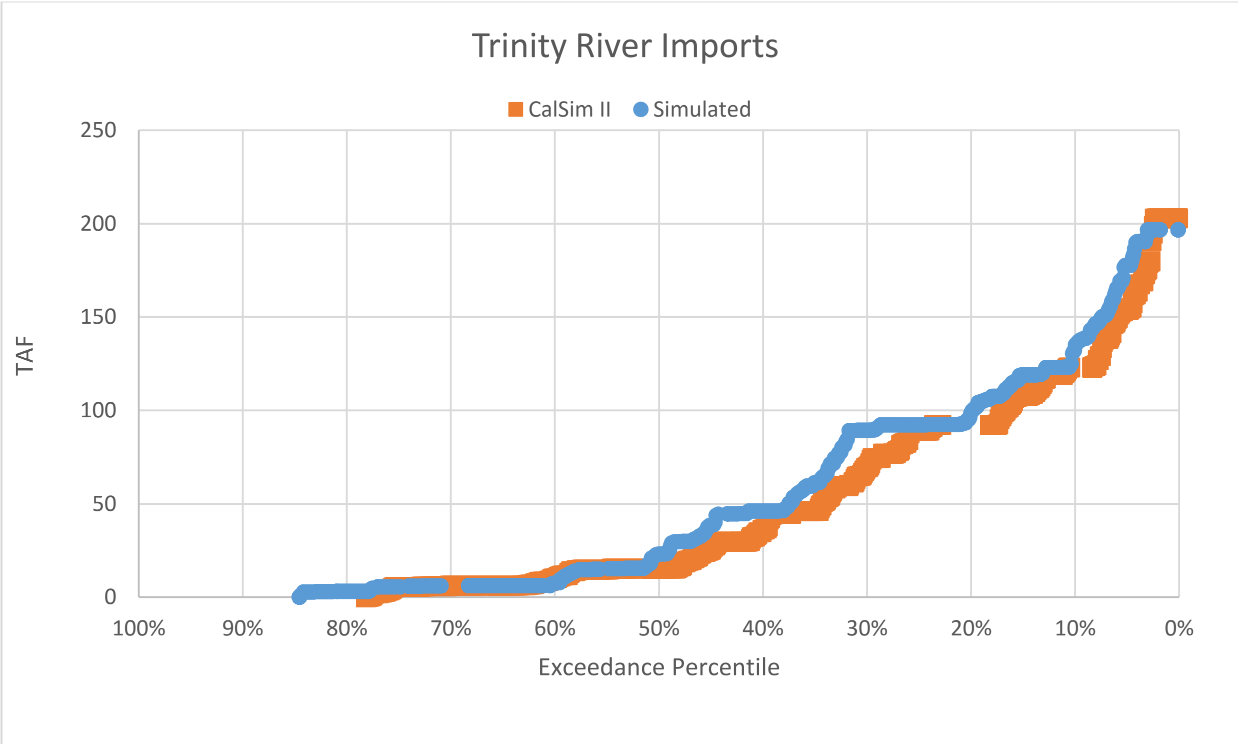

Figure B.6.1c Trinity River Imports, Exceedance

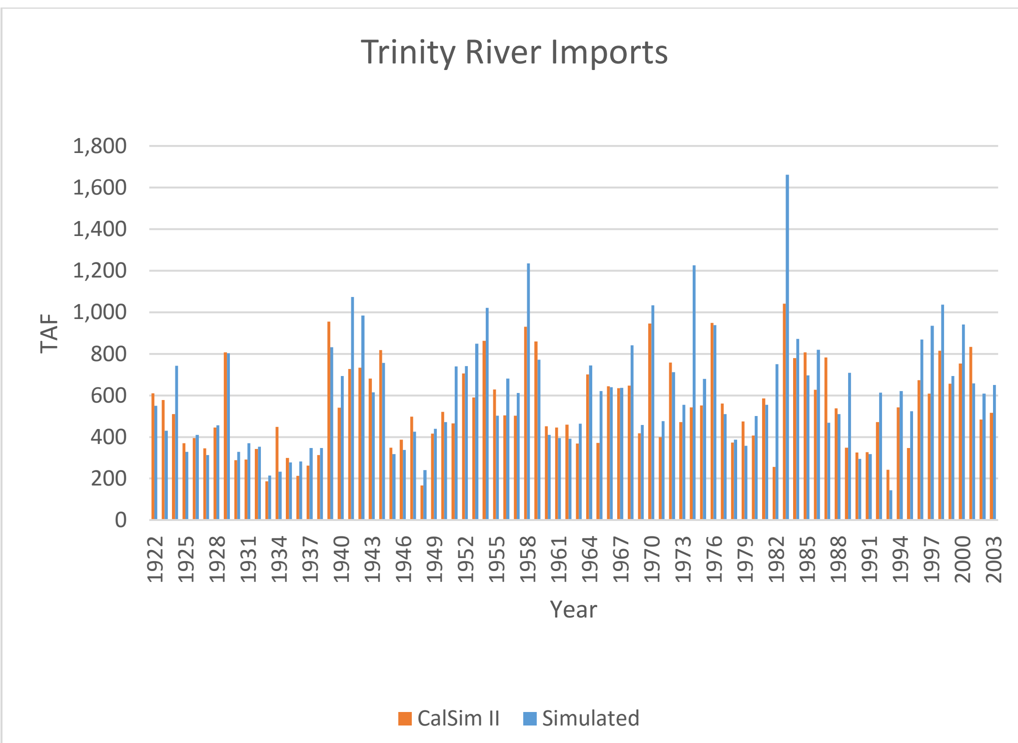

Figure B.6.1d Trinity River Imports, Annual 1922 to 2003

B.6.2 CVP NOD Storage

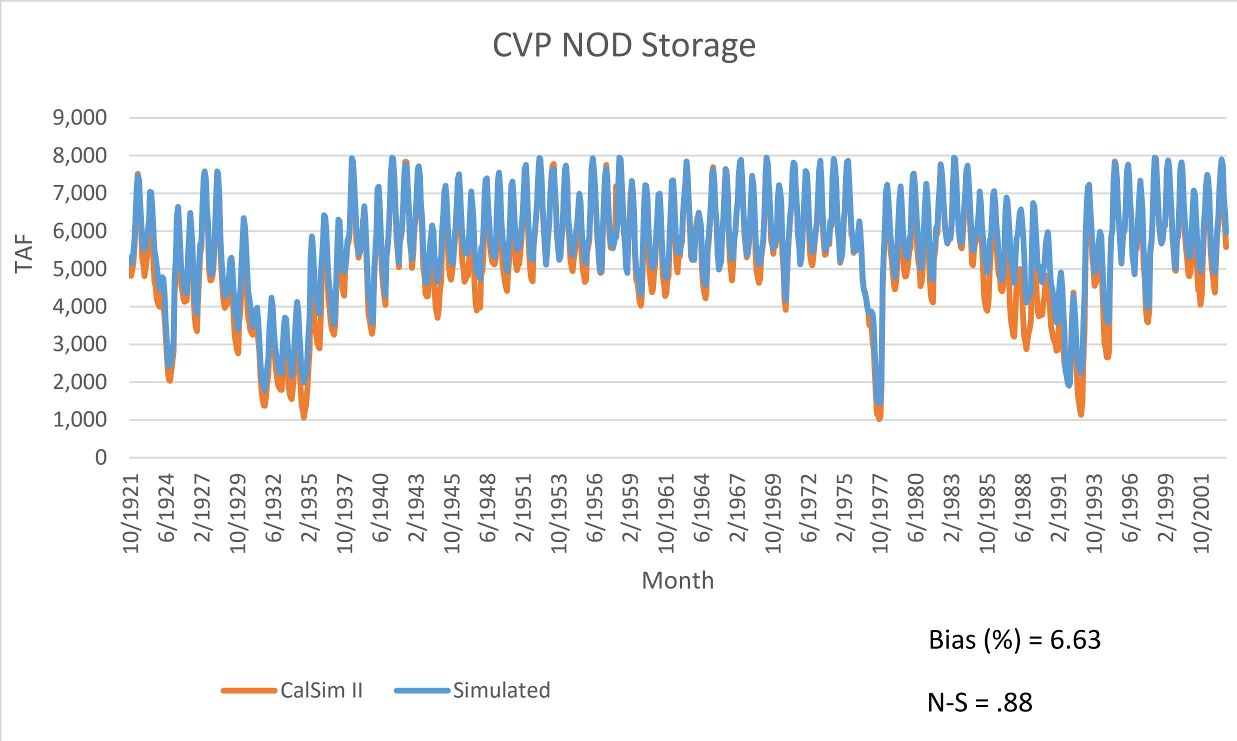

Figure B.6.2a CVP NOD Storage, Monthly 1922 to 2003

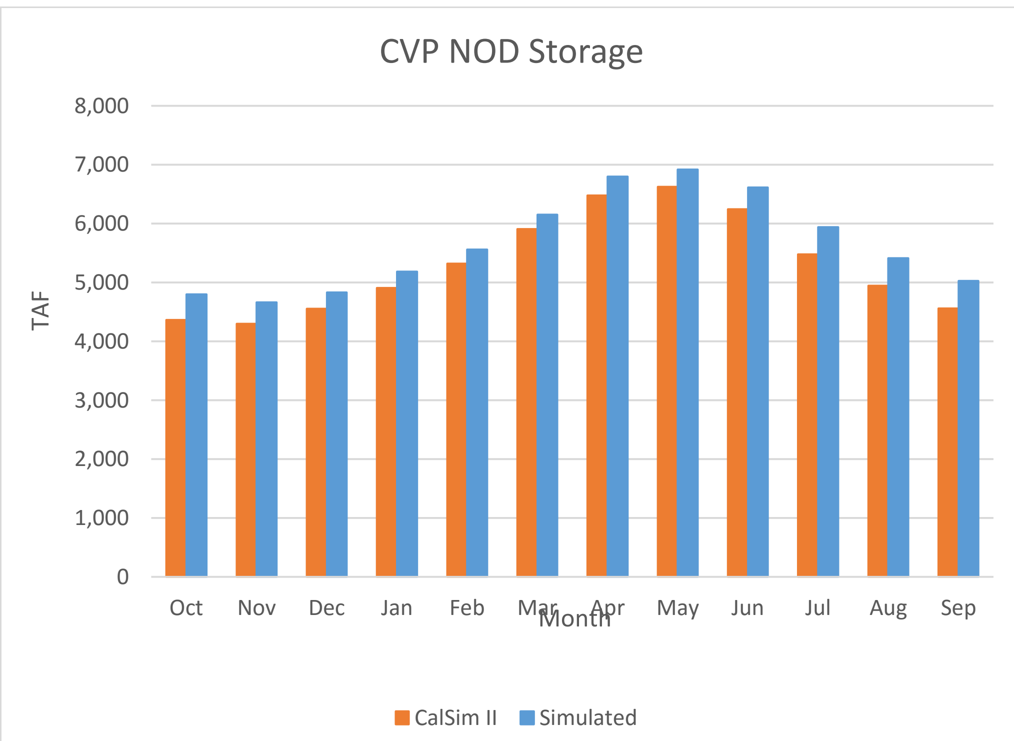

Figure B.6.2b CVP NOD Storage, Average Monthly

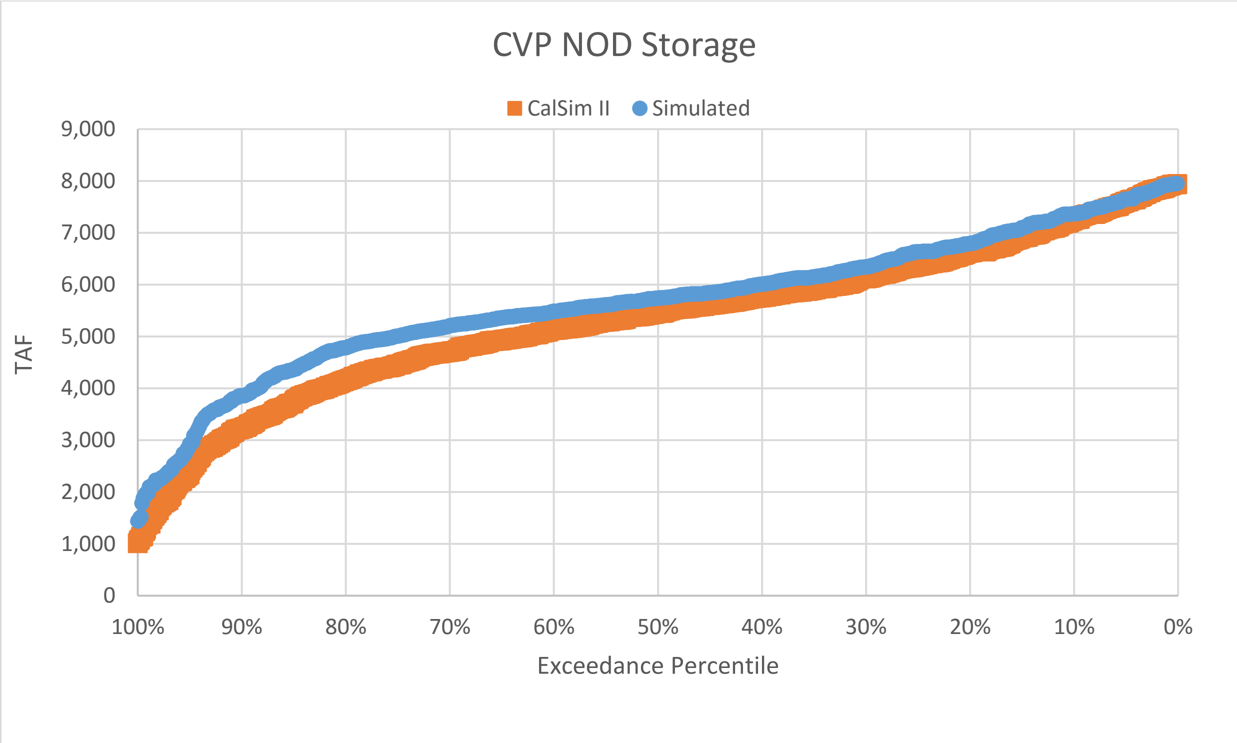

Figure B.6.2c CVP NOD Storage, Exceedance

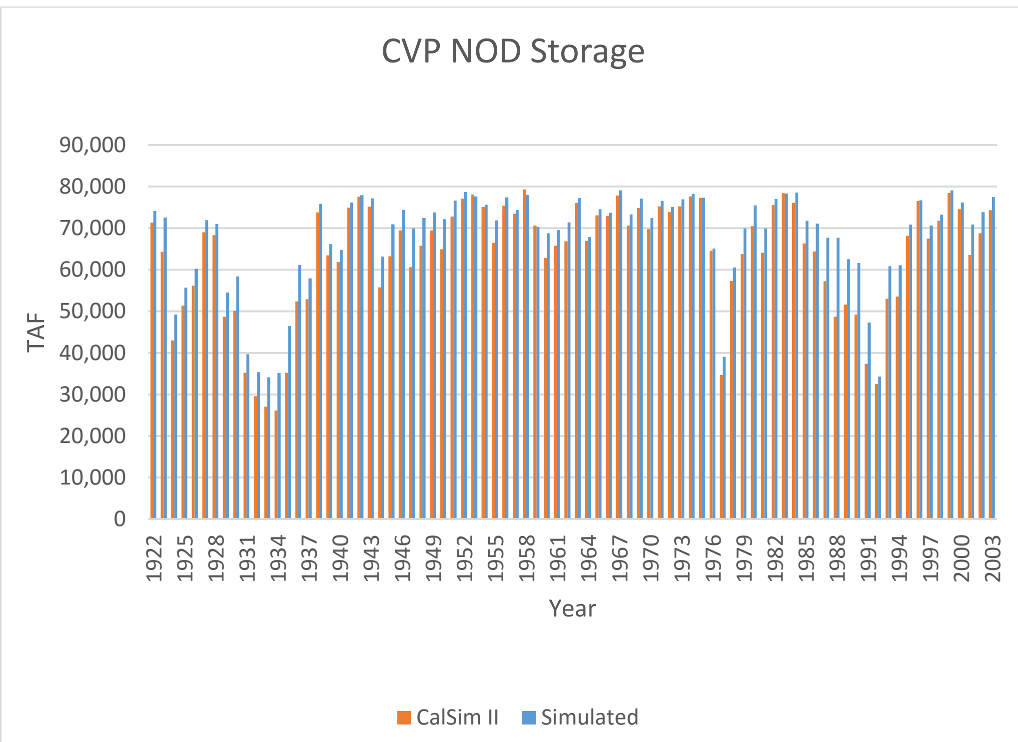

Figure B.6.2d CVP NOD Storage, Annual 1922 to 2003

B.6.3 SWP NOD Storage

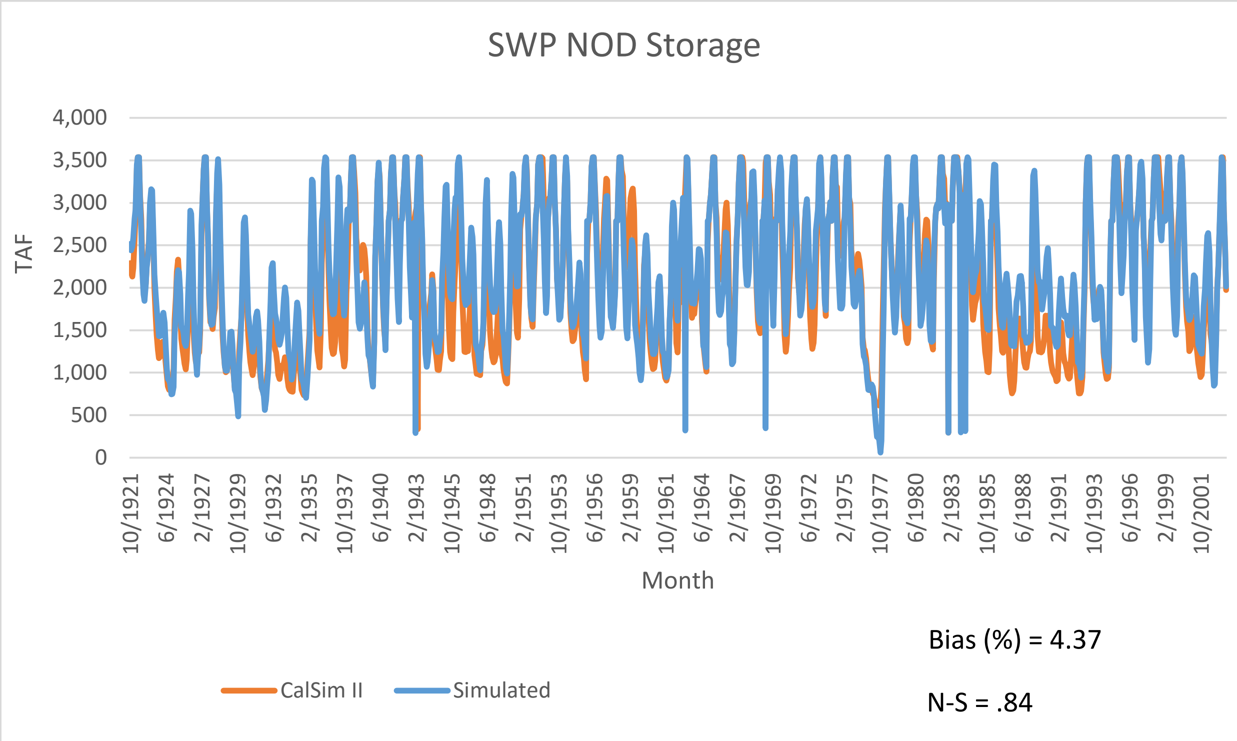

Figure B.6.3a SWP NOD Storage, Monthly 1922 to 2003

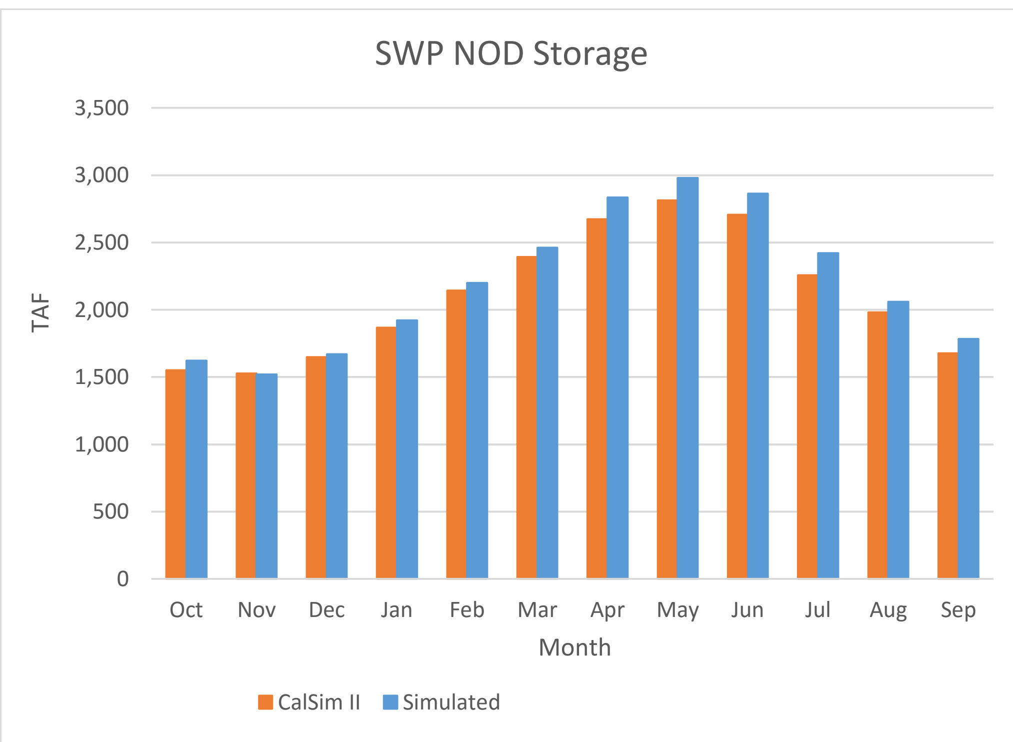

Figure B.6.3b SWP NOD Storage, Average Monthly

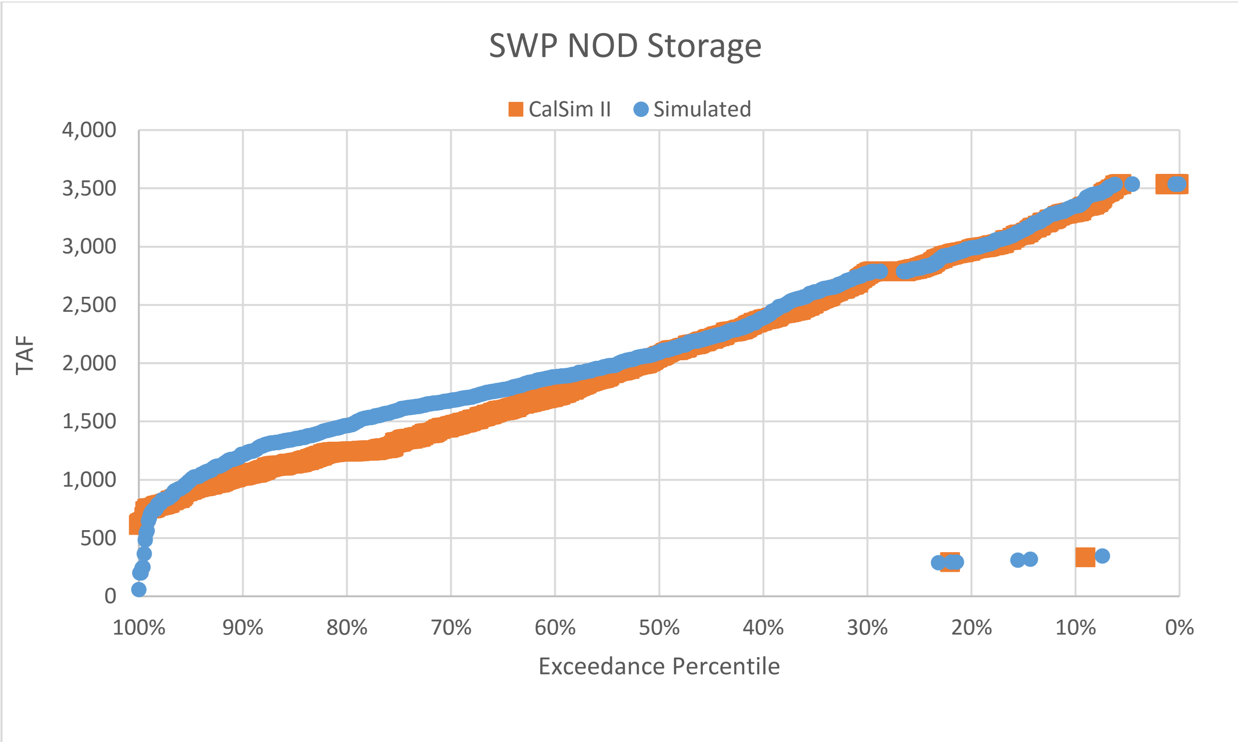

Figure B.6.3c SWP NOD Storage, Exceedance

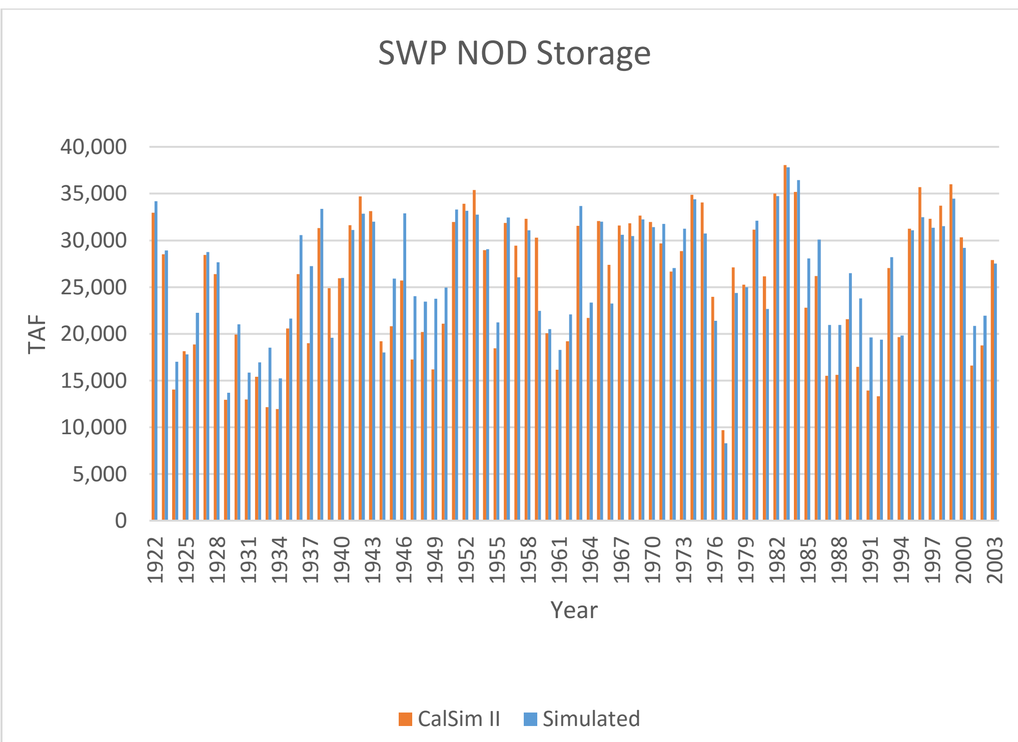

Figure B.6.3d SWP NOD Storage, Annual 1922 to 2003

B.6.4 Feather River at Confluence

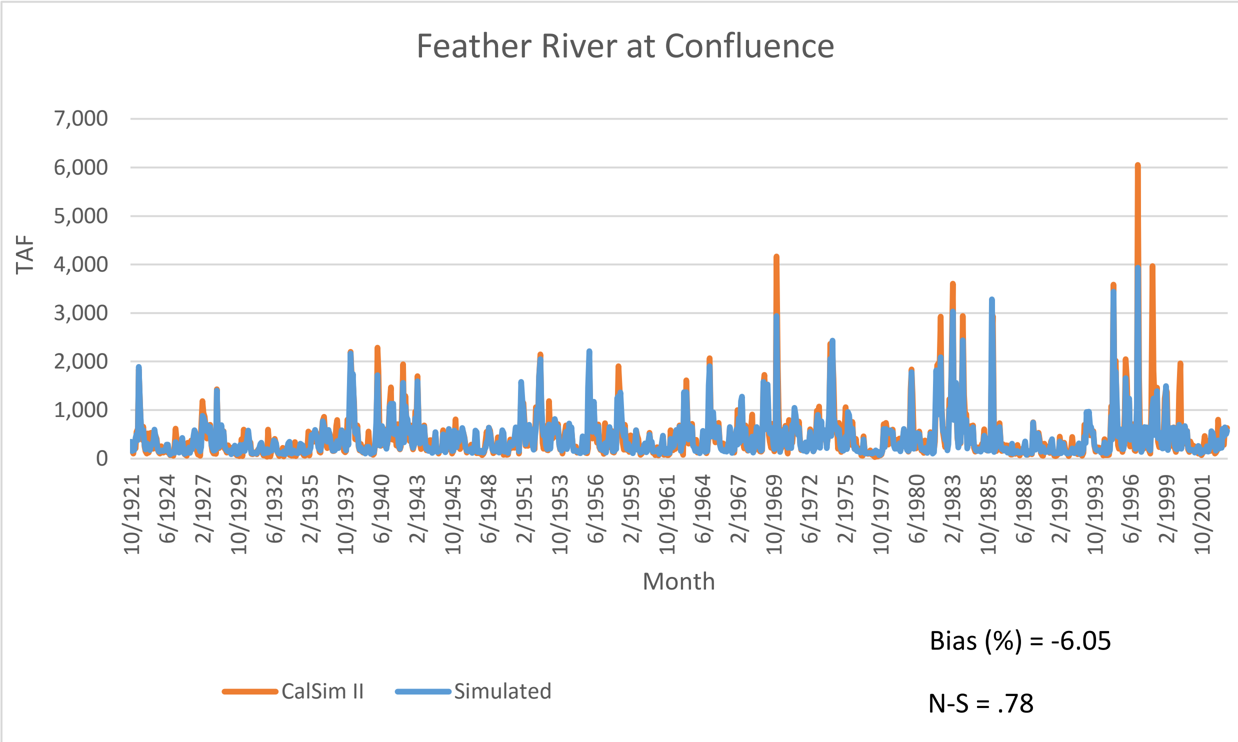

Figure B.6.4a Feather River at Confluence, Monthly 1922 to 2003

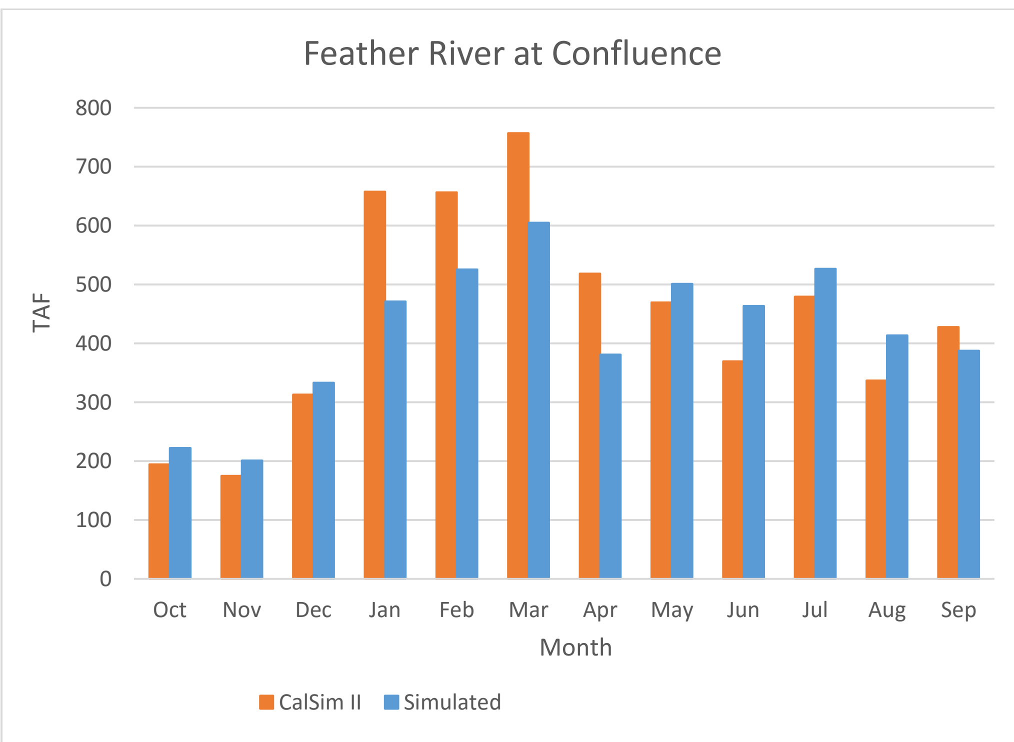

Figure B.6.4b Feather River at Confluence, Average Monthly

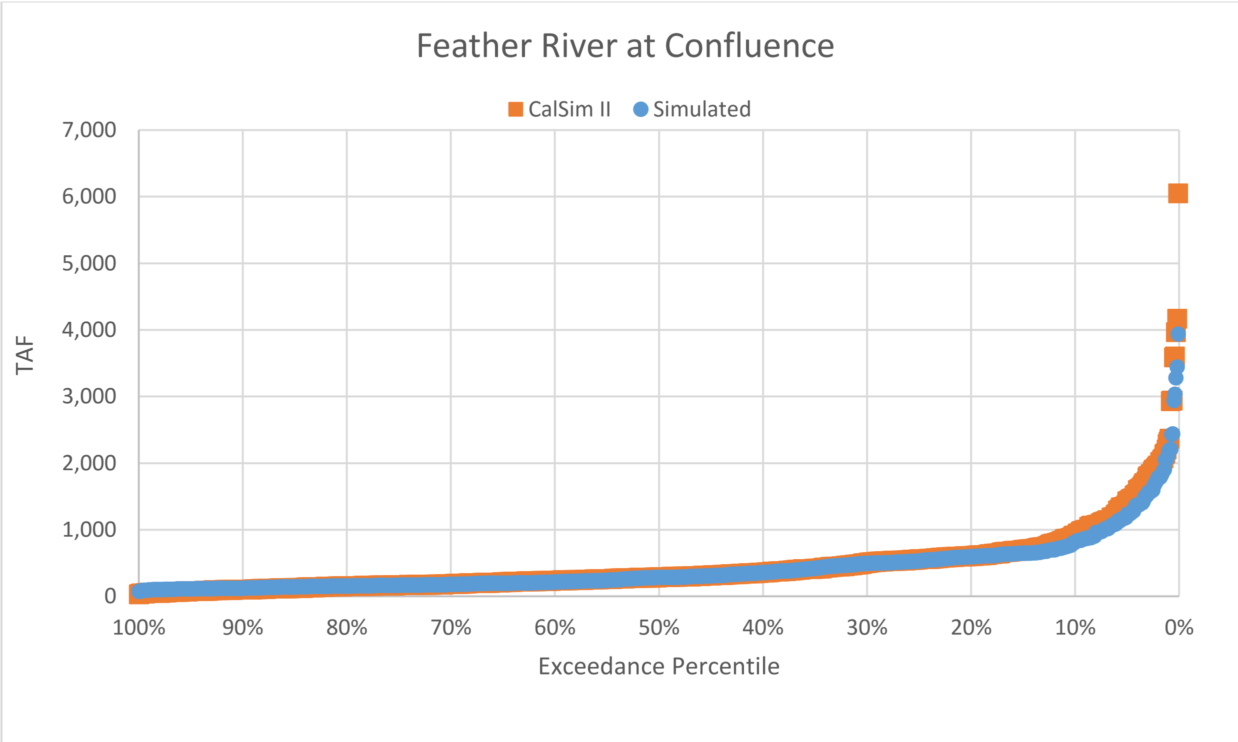

Figure B.6.4c Feather River at Confluence, Exceedance

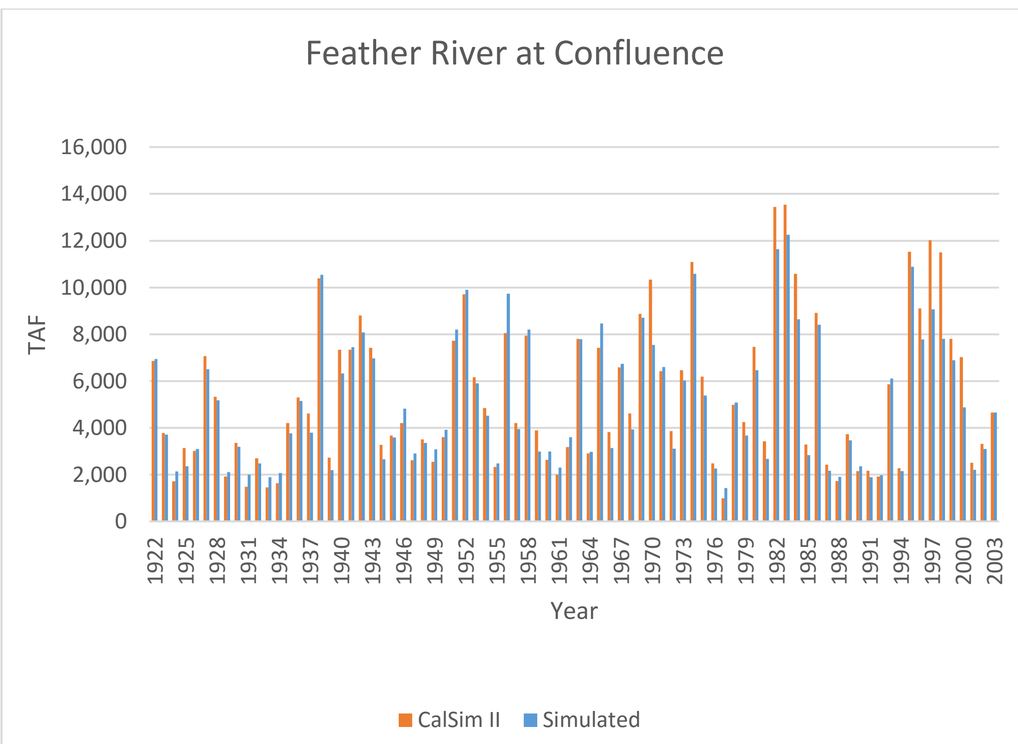

Figure B.6.4d Feather River at Confluence, Annual 1922 to 2003

B.6.5 American River at Confluence

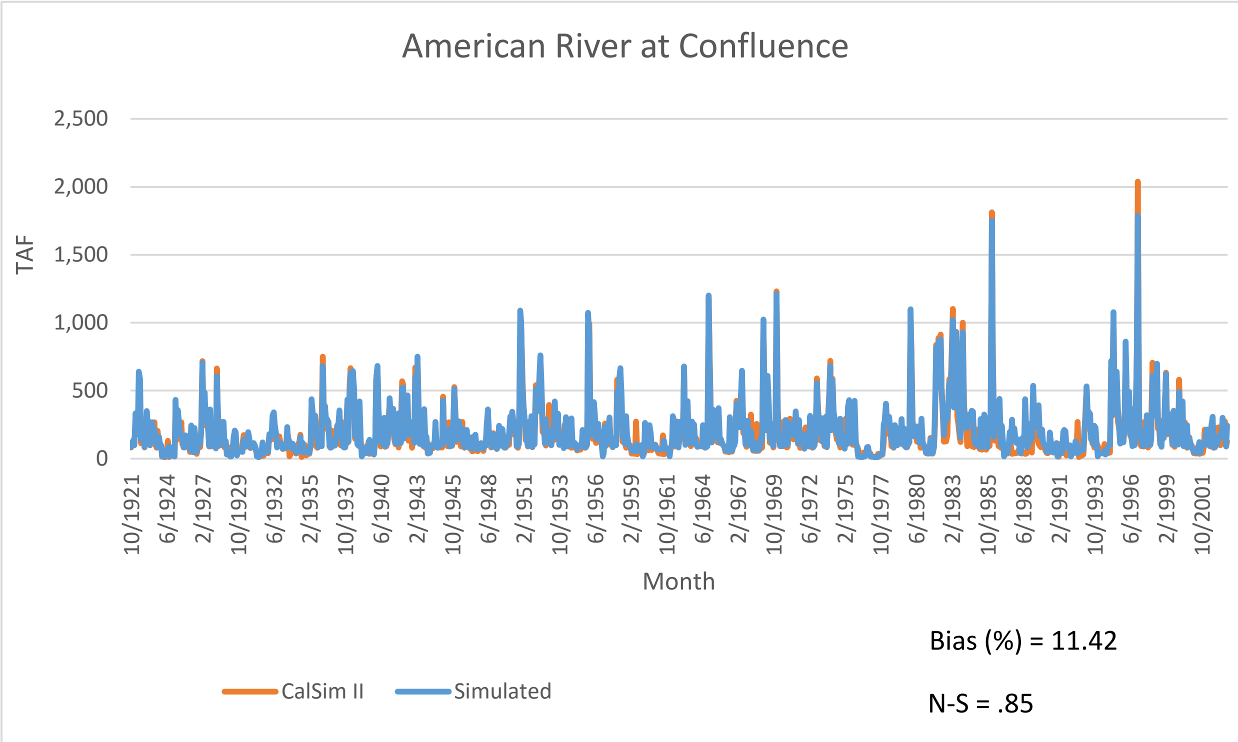

Figure B.6.5a American River at Confluence, Monthly 1922 to 2003

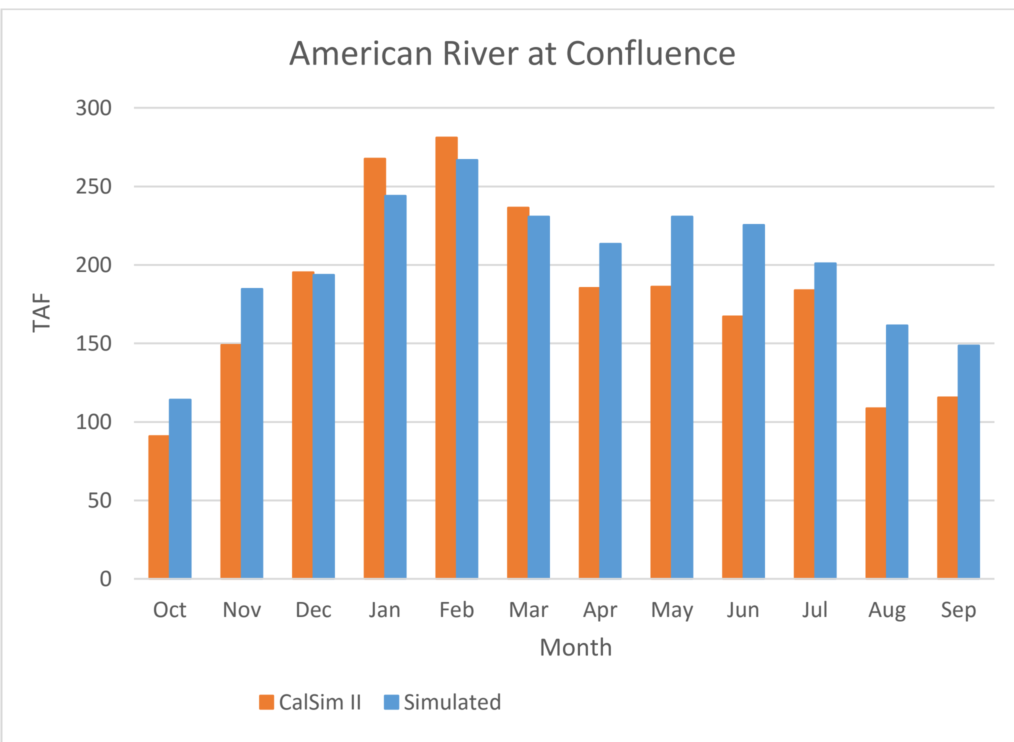

Figure B.6.5b American River at Confluence, Average Monthly

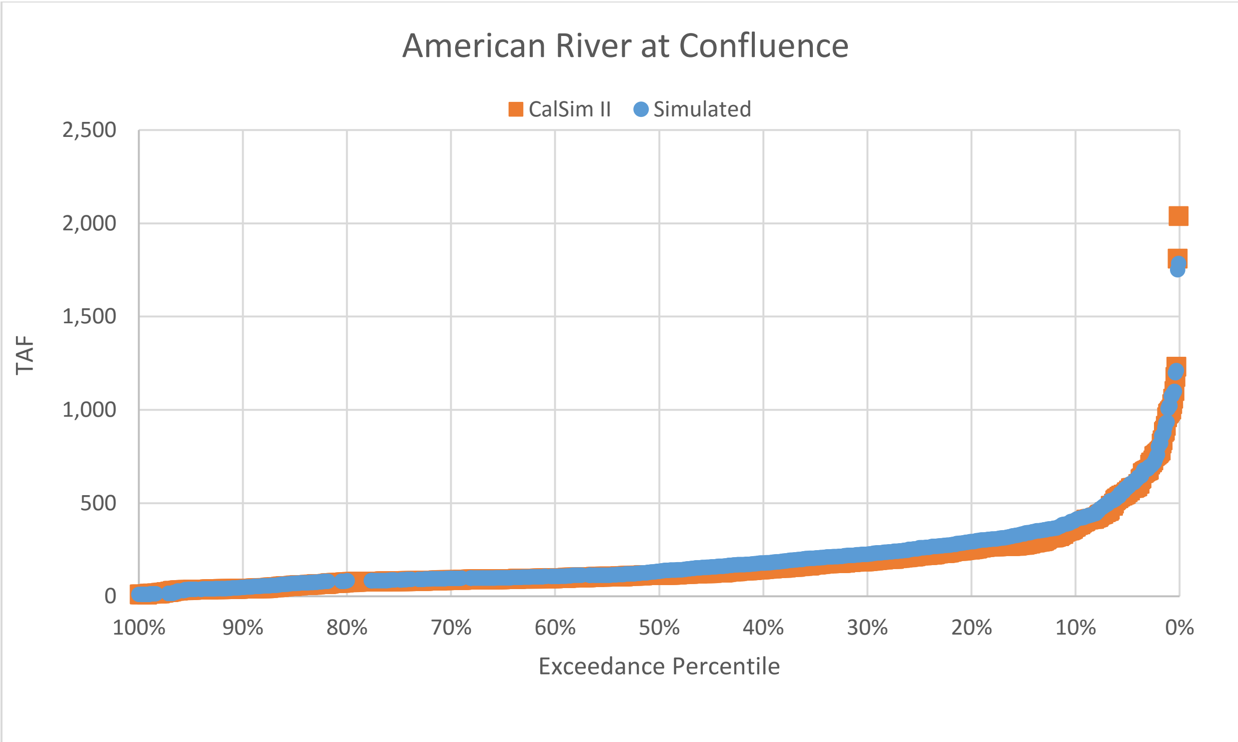

Figure B.6.5c American River at Confluence, Exceedance

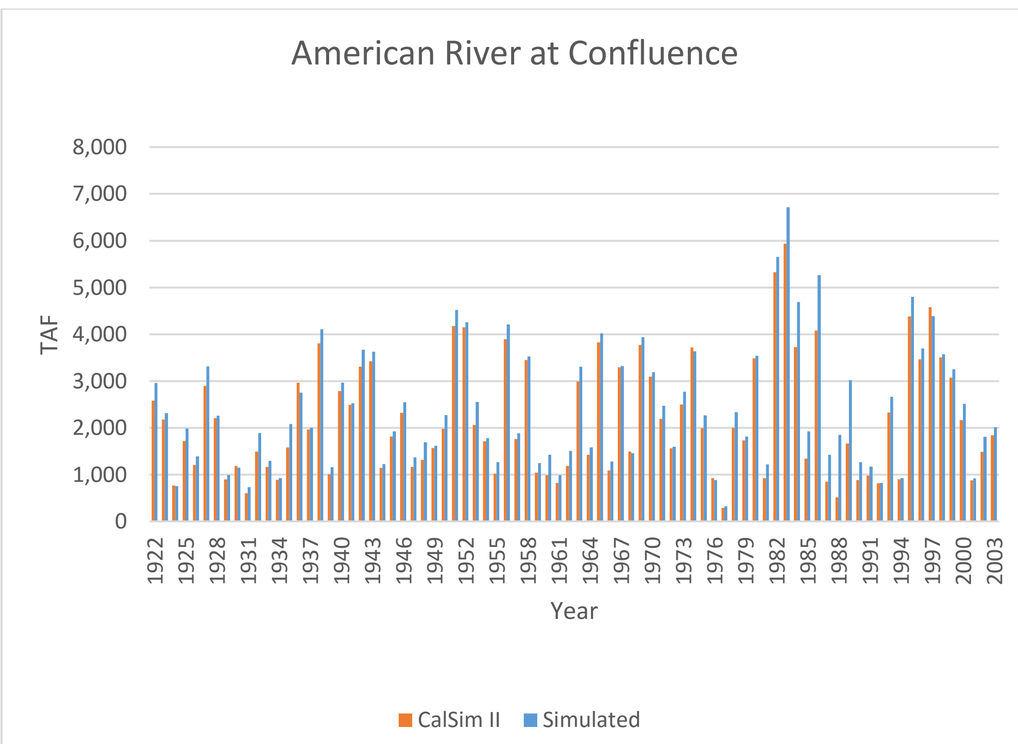

Figure B.6.5d American River at Confluence, Annual 1922 to 2003

B.6.6 Sacramento River at Freeport

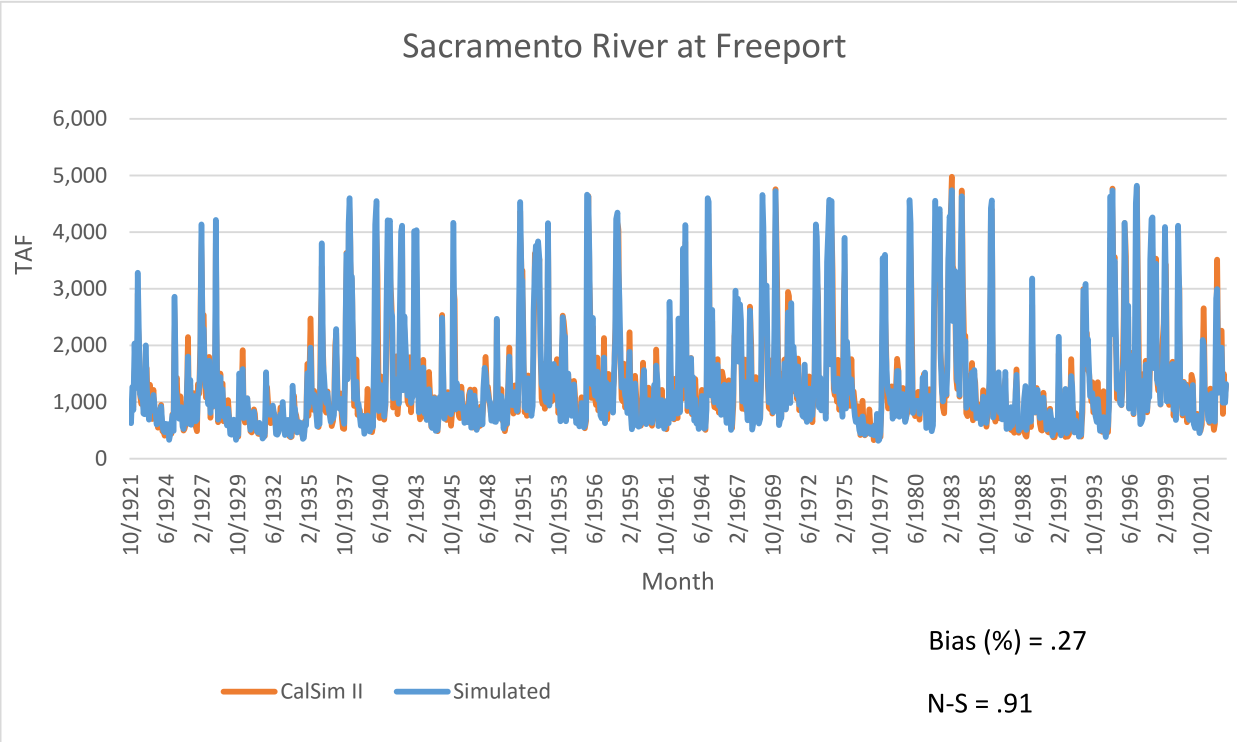

Figure B.6.6a Sacramento River at Freeport, Monthly 1922 to 2003

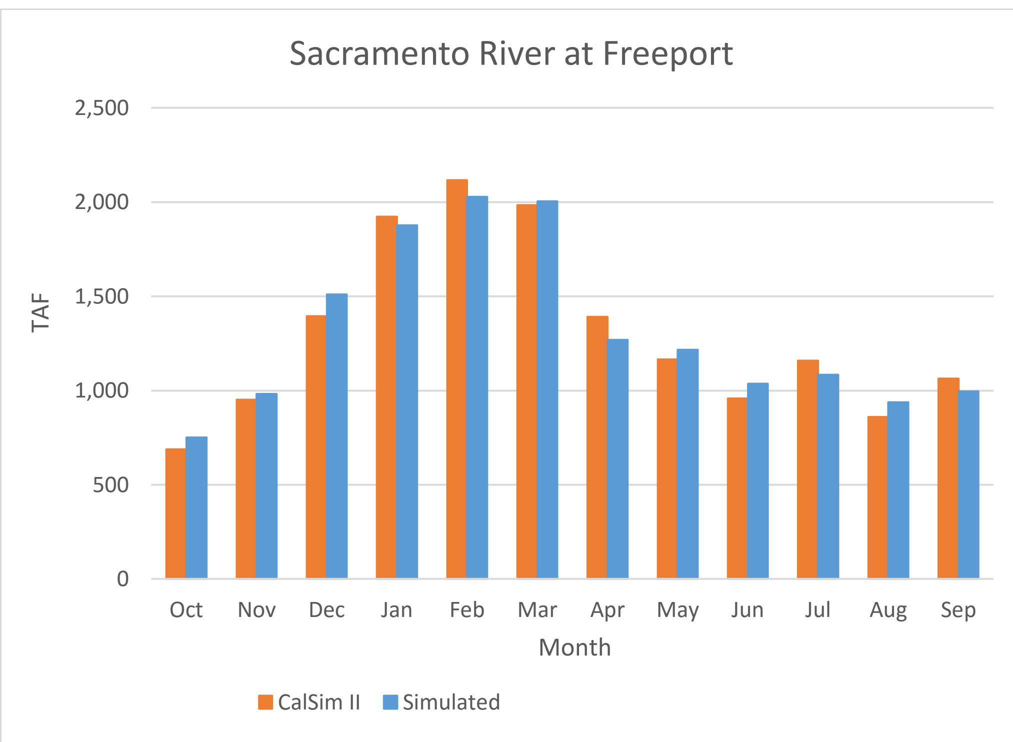

Figure B.6.6b Sacramento River at Freeport, Average Monthly

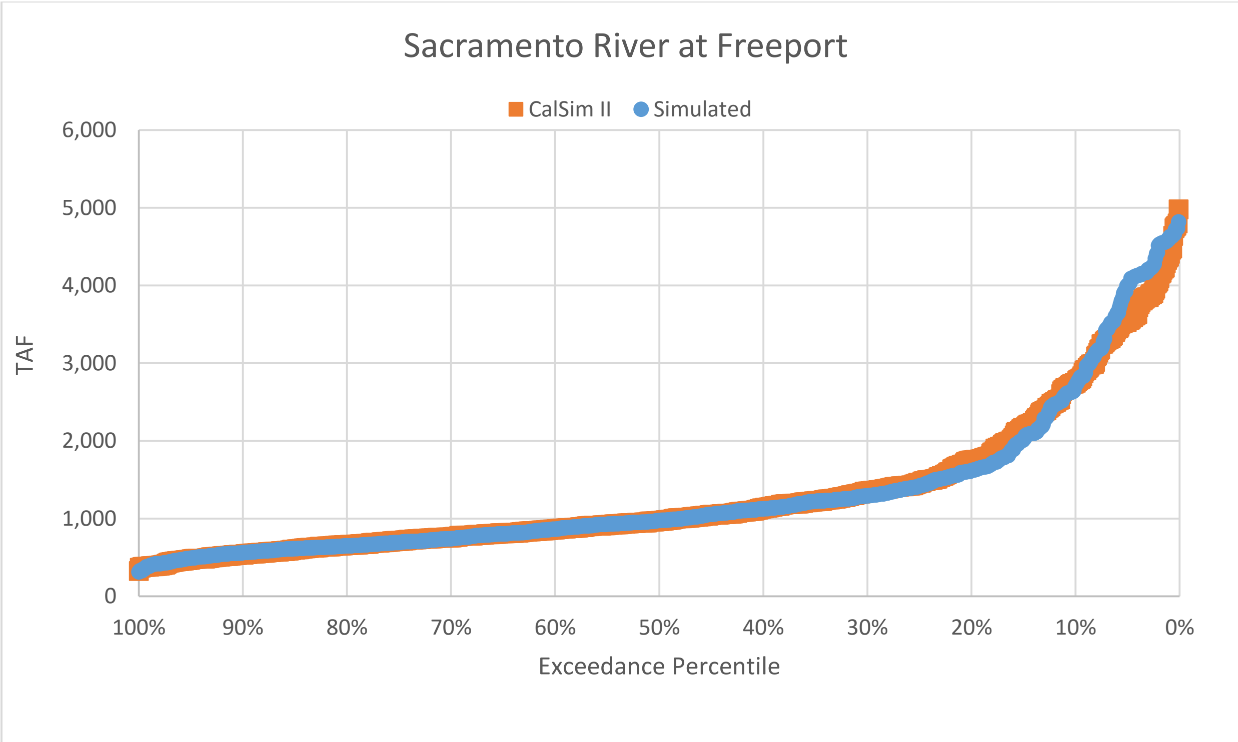

Figure B.6.6c Sacramento River at Freeport, Exceedance

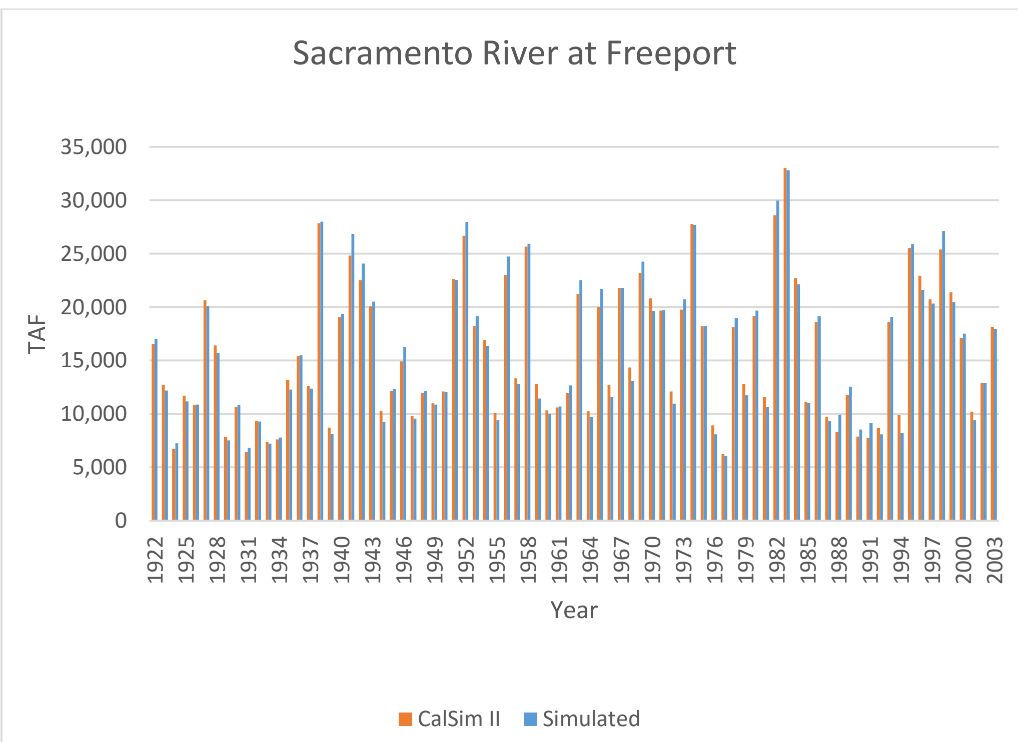

Figure B.6.6d Sacramento River at Freeport, Annual 1922 to 2003

B.6.7 Delta Inflow

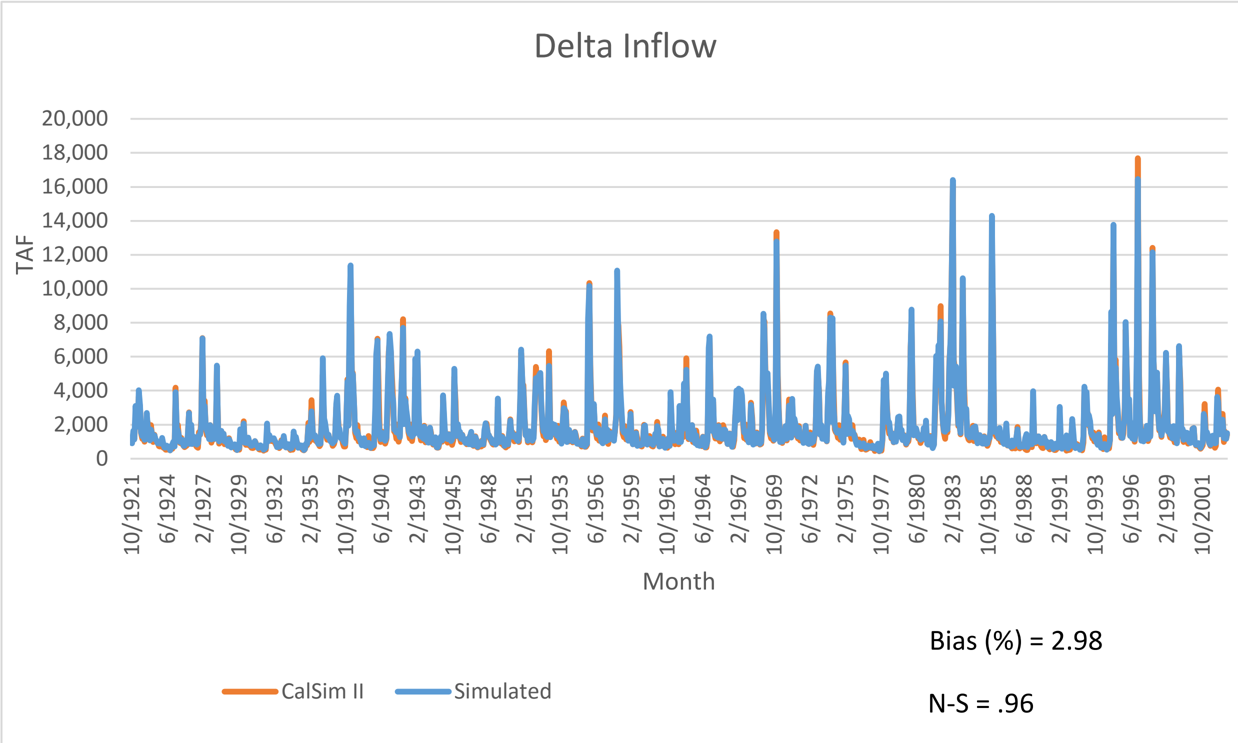

Figure B.6.7a Delta Inflow, Monthly 1922 to 2003

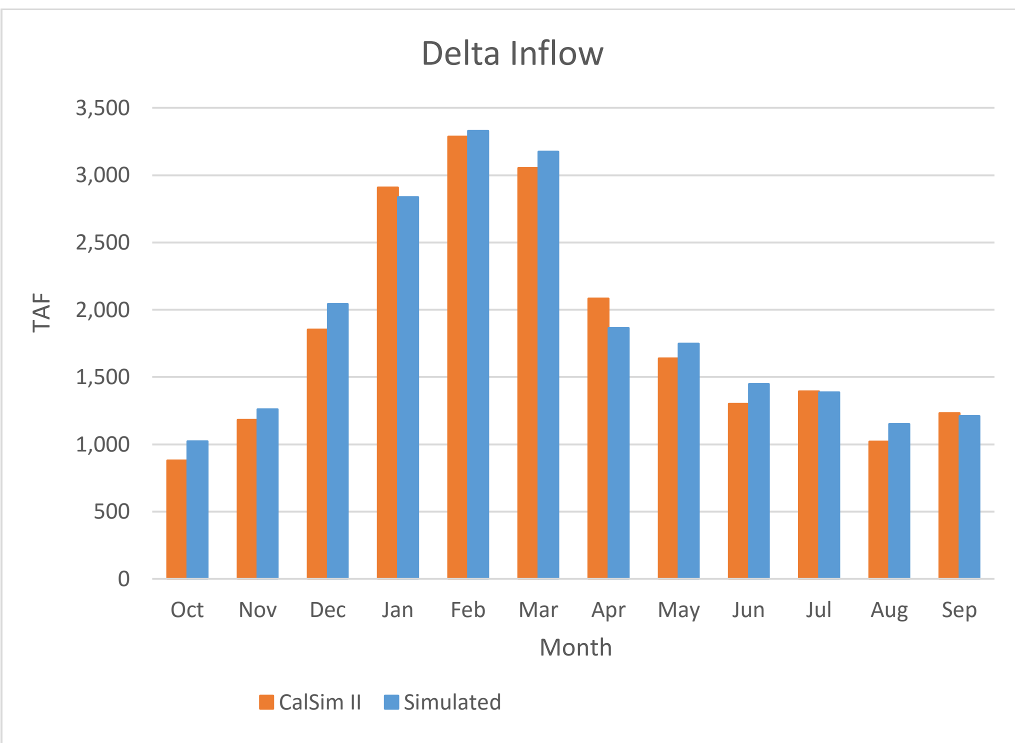

Figure B.6.7b Delta Inflow, Average Monthly

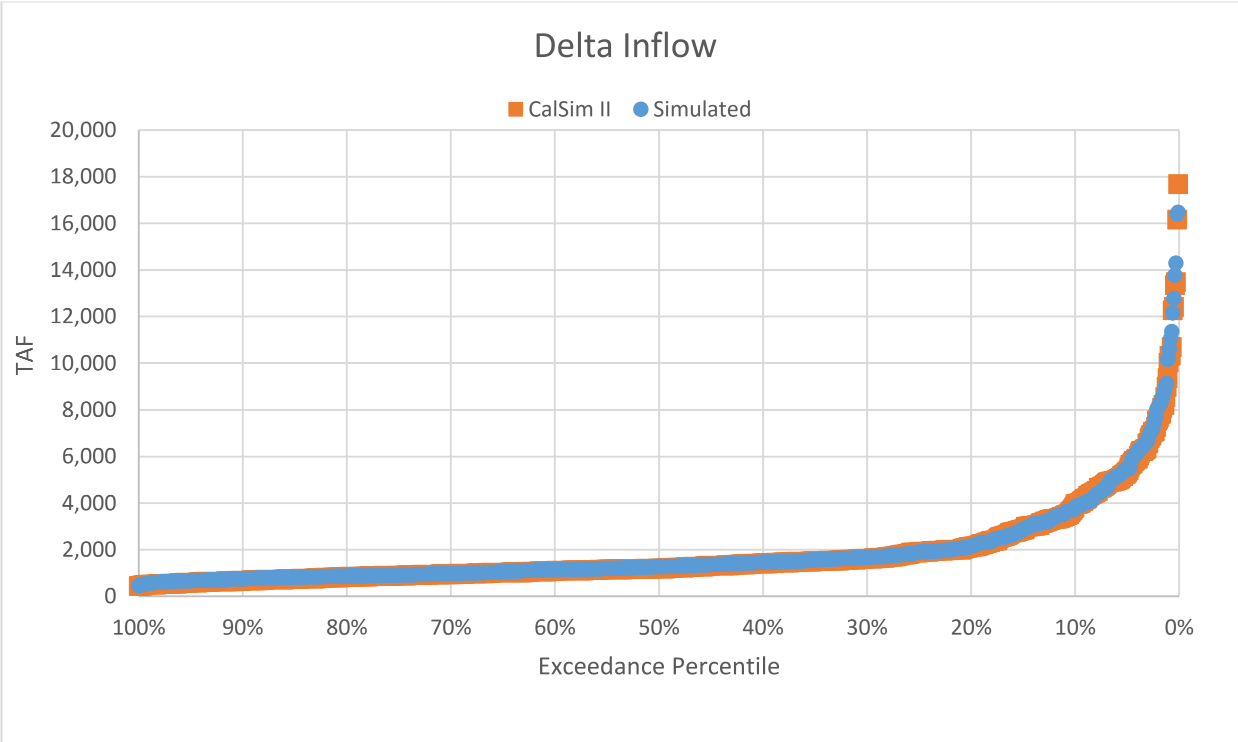

Figure B.6.7c Delta Inflow, Exceedance

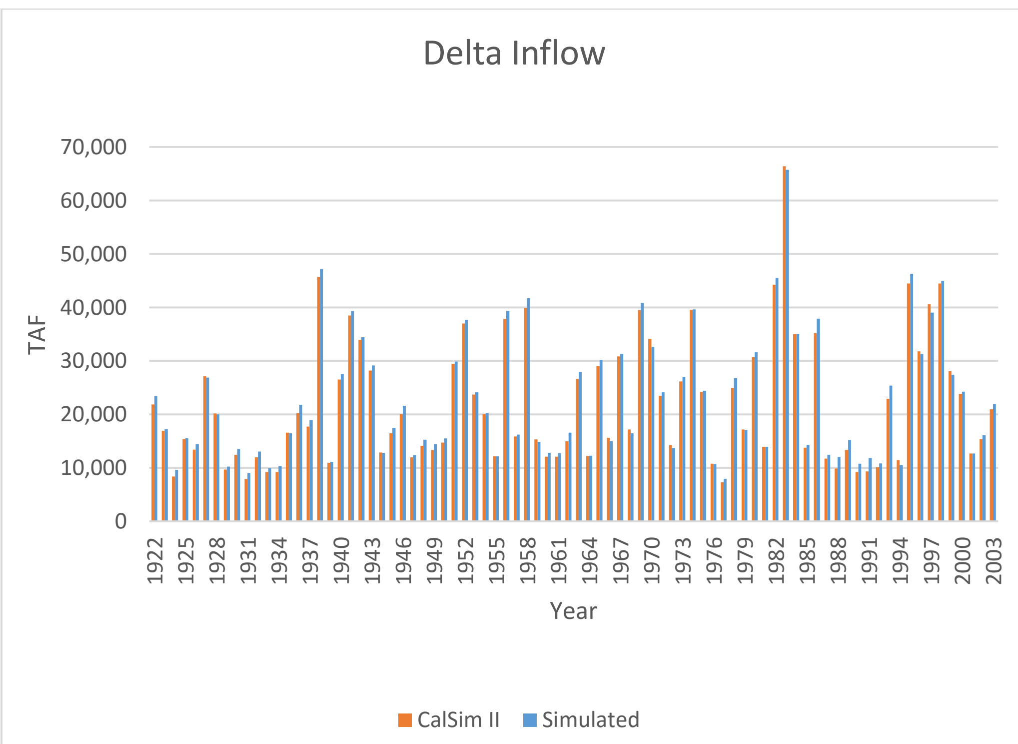

Figure B.6.7d Delta Inflow, Annual 1922 to 2003

B.6.8 Combined Delta Exports

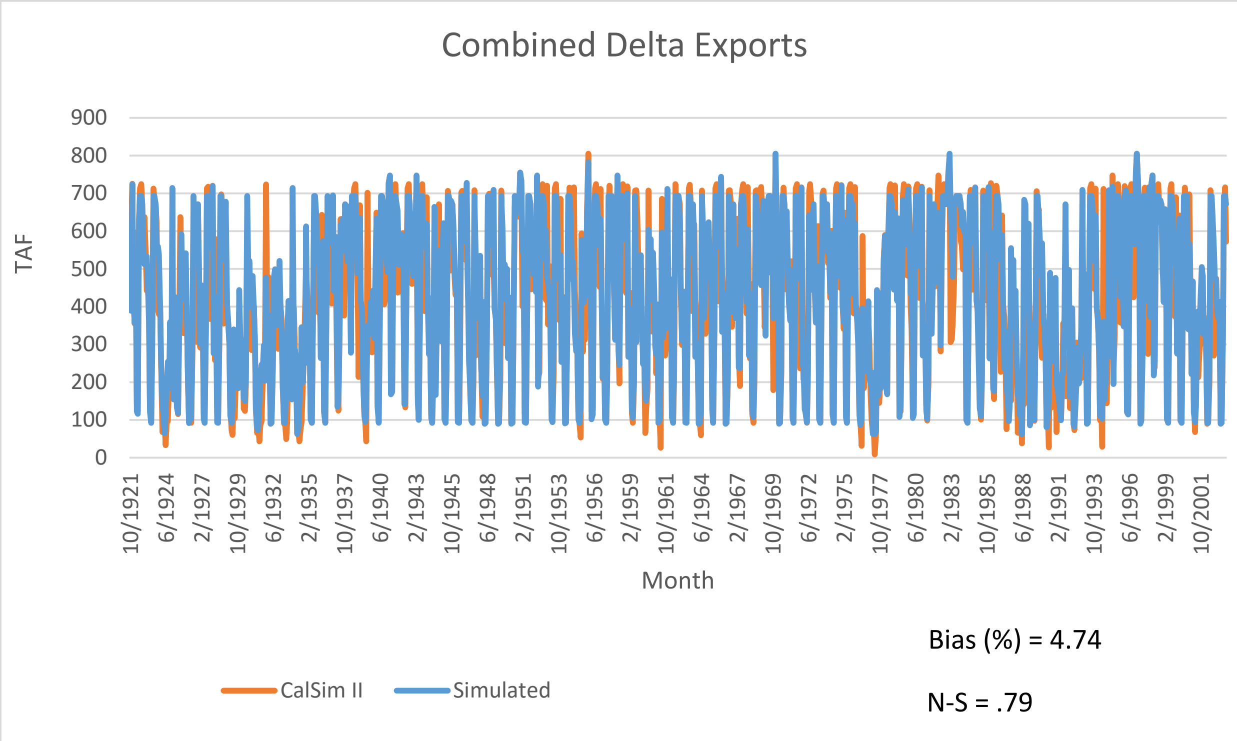

Figure B.6.8a Combined Delta Exports, Monthly 1922 to 2003

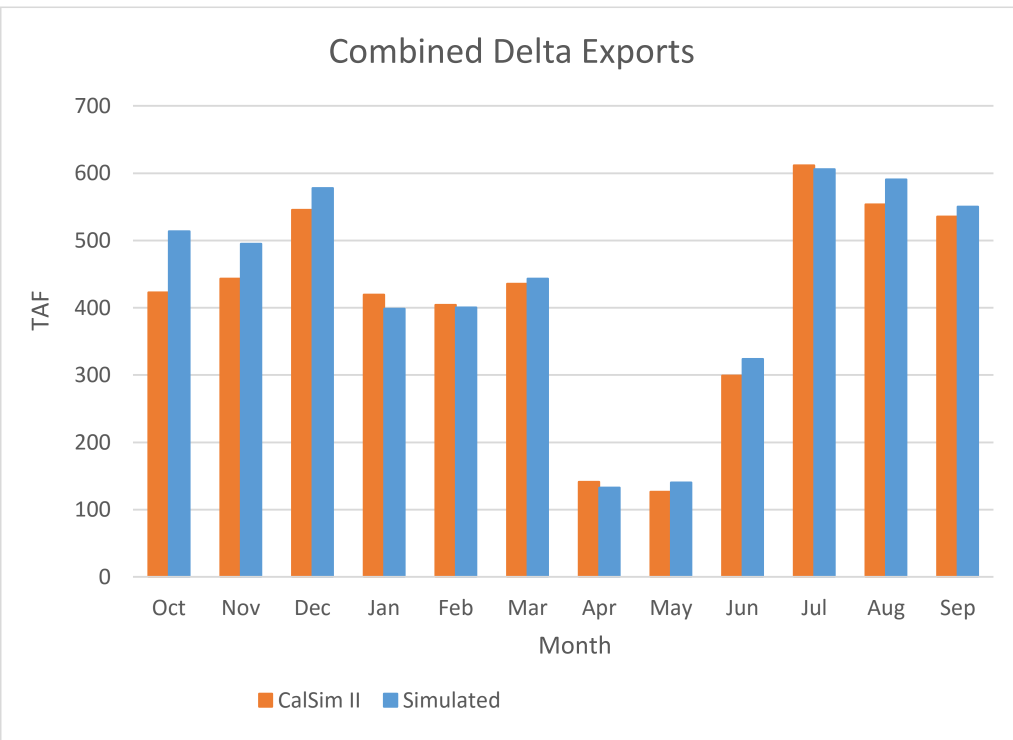

Figure B.6.8b Combined Delta Exports, Average Monthly

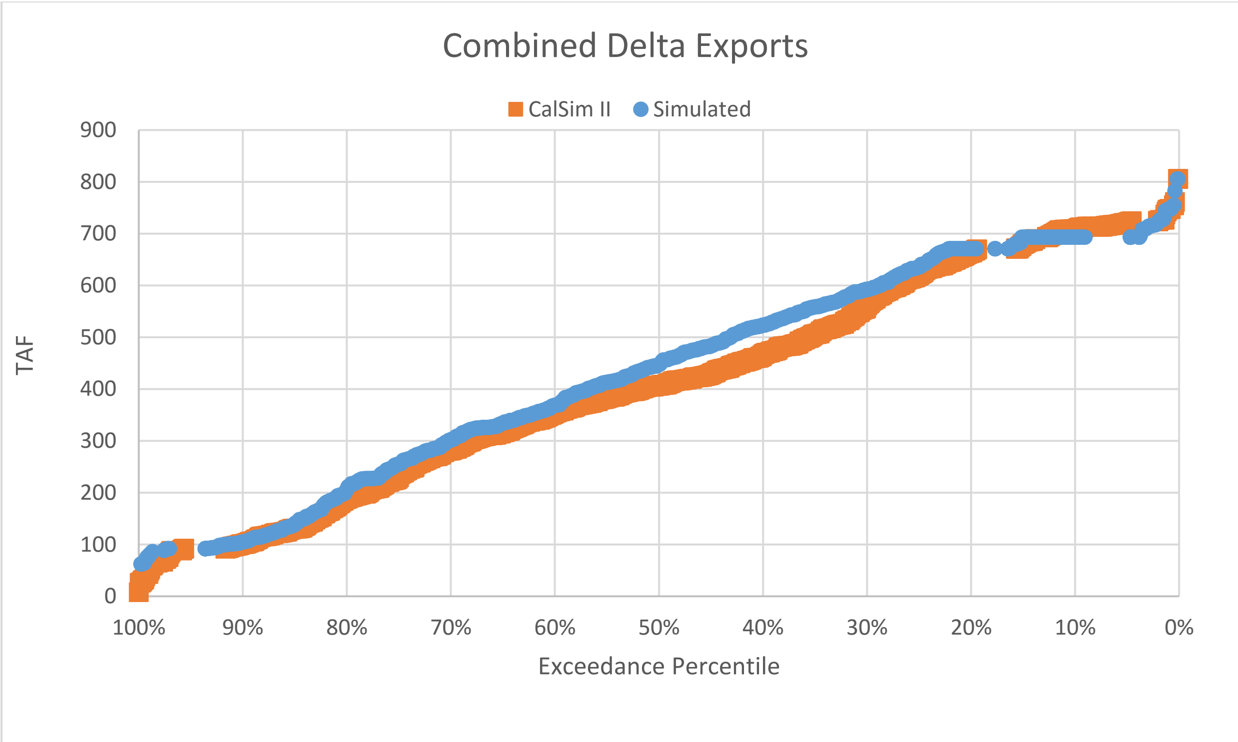

Figure B.6.8c Combined Delta Exports, Exceedance

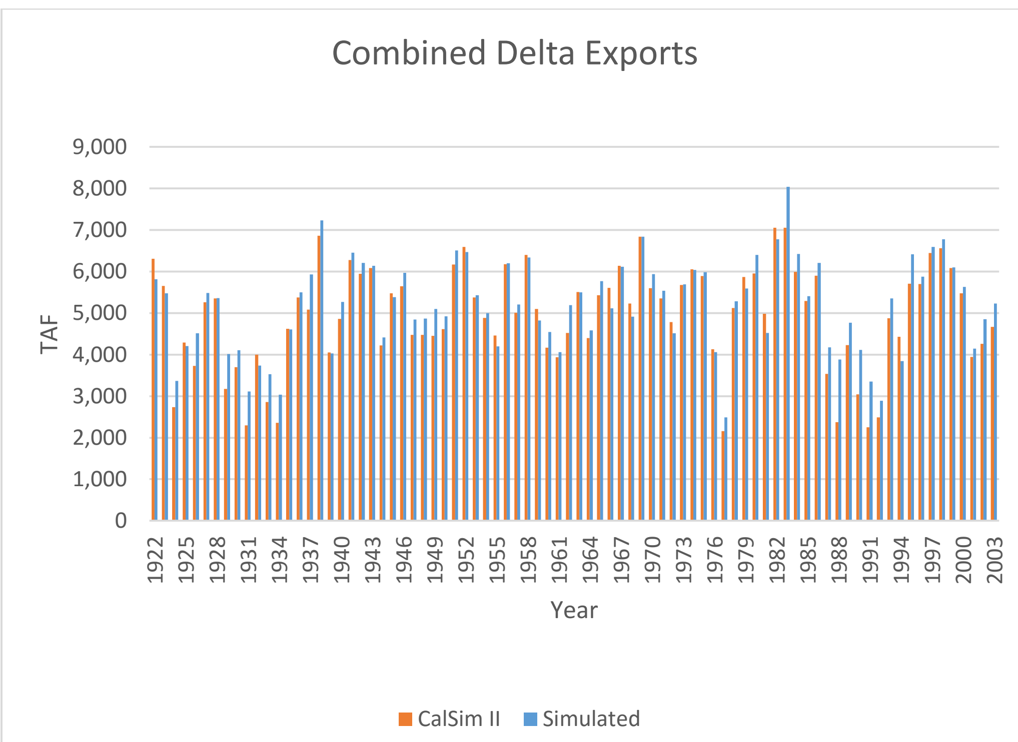

Figure B.6.8d Combined Delta Exports, Annual 1922 to 2003

B.6.9 CVP Delta Exports

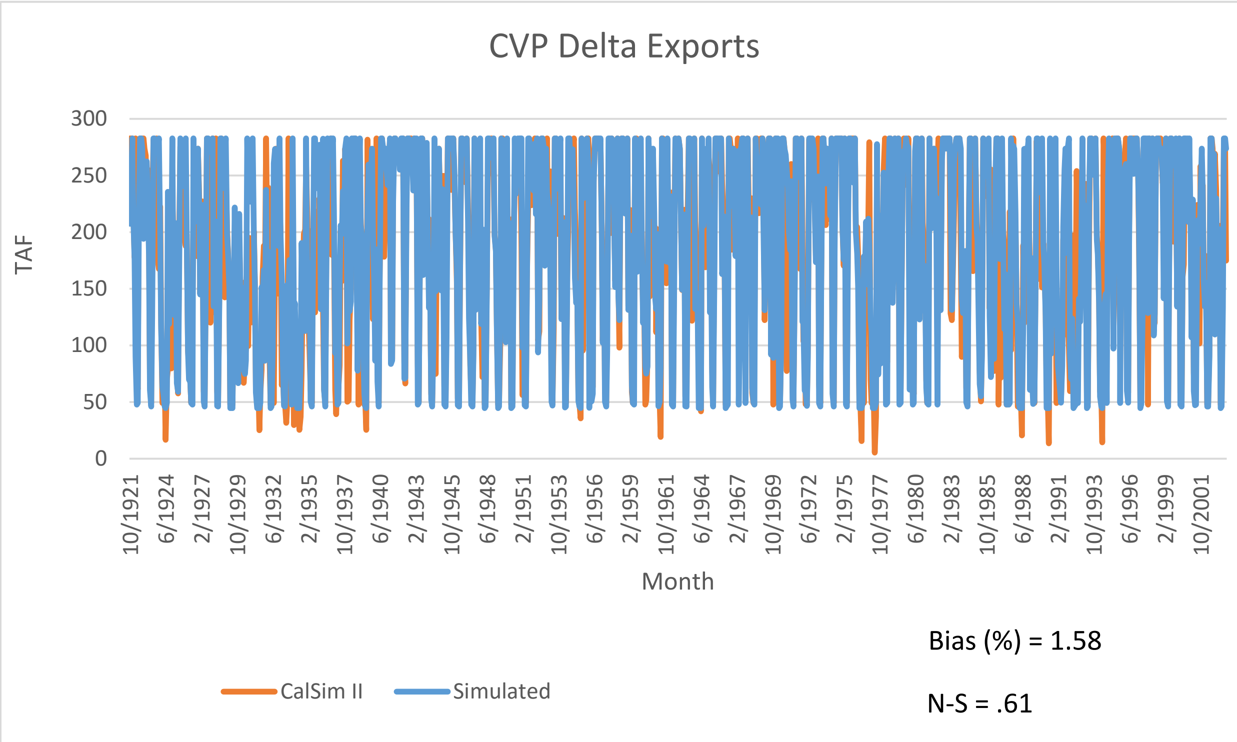

Figure B.6.9a CVP Delta Exports, Monthly 1922 to 2003

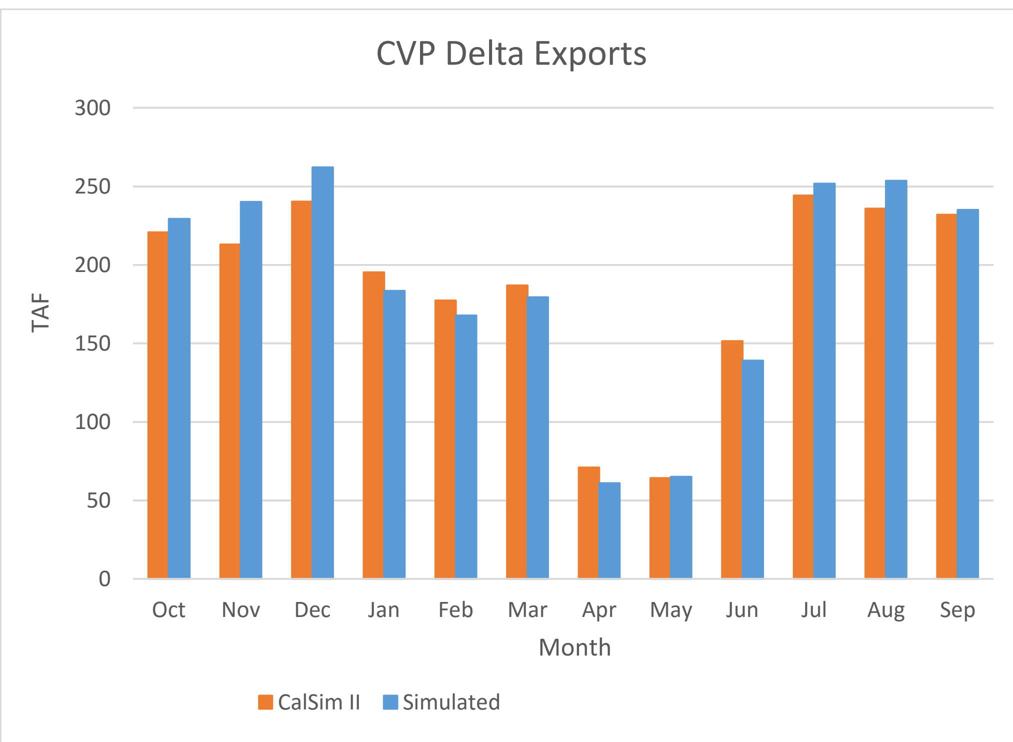

Figure B.6.9b CVP Delta Exports, Average Monthly

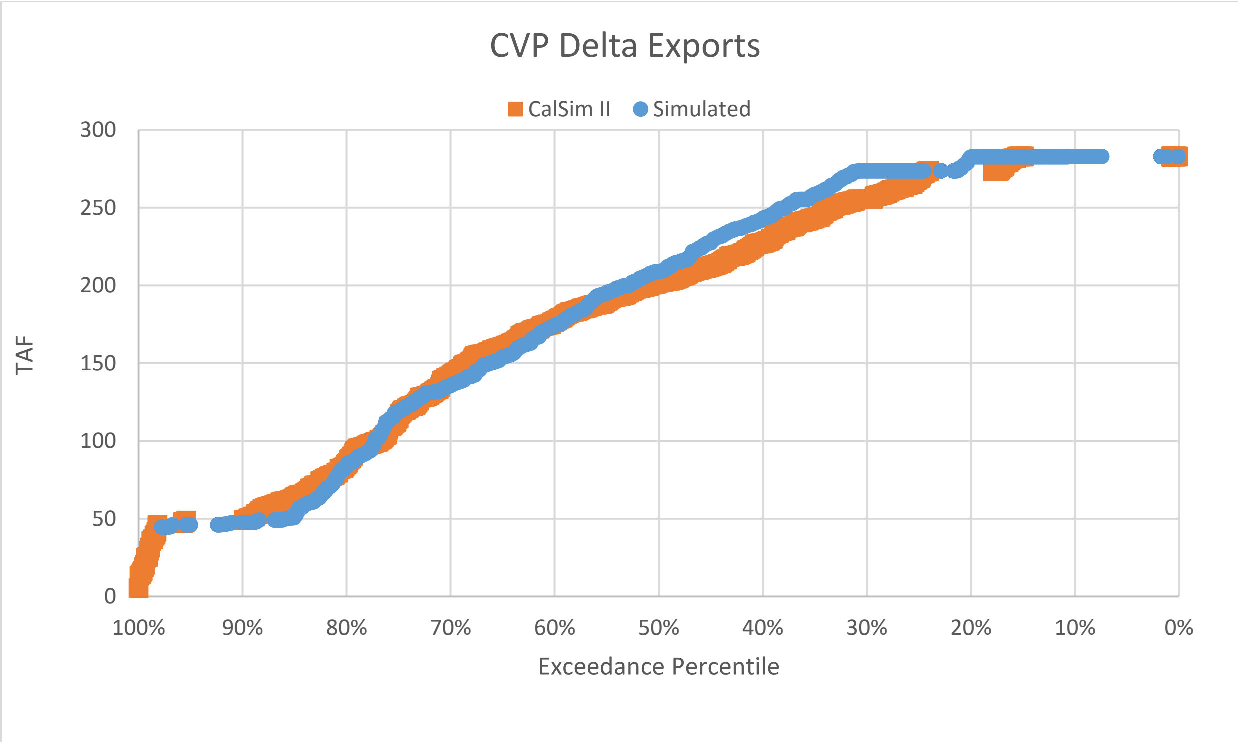

Figure B.6.9c CVP Delta Exports, Exceedance

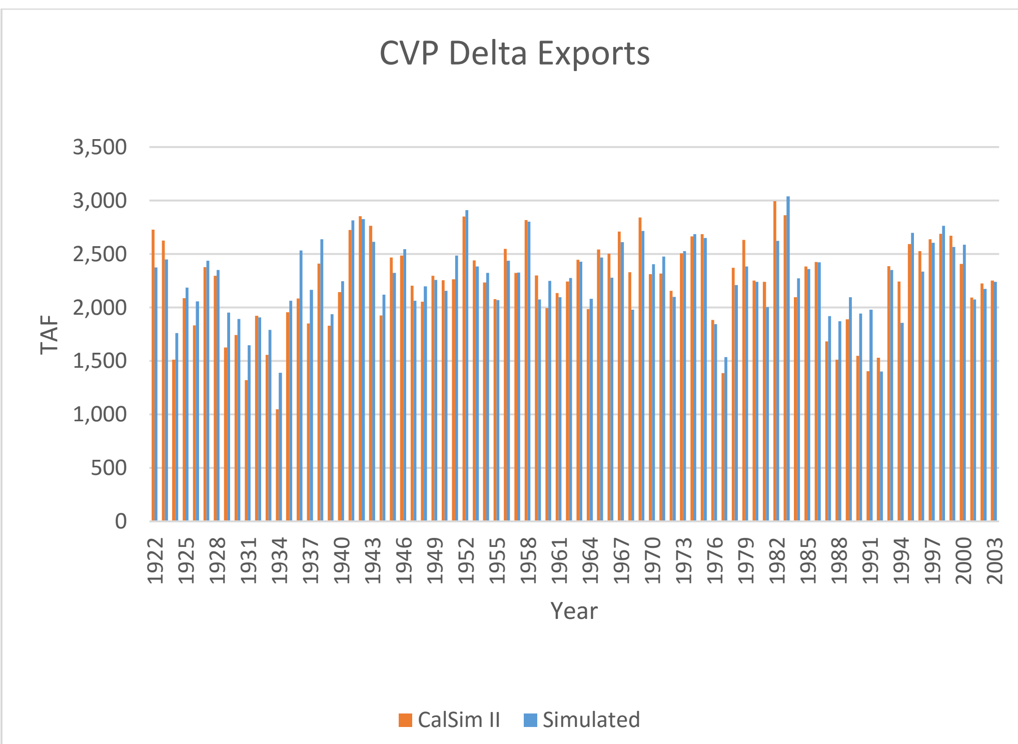

Figure B.6.9d CVP Delta Exports, Annual 1922 to 2003

B.6.10 SWP Delta Exports

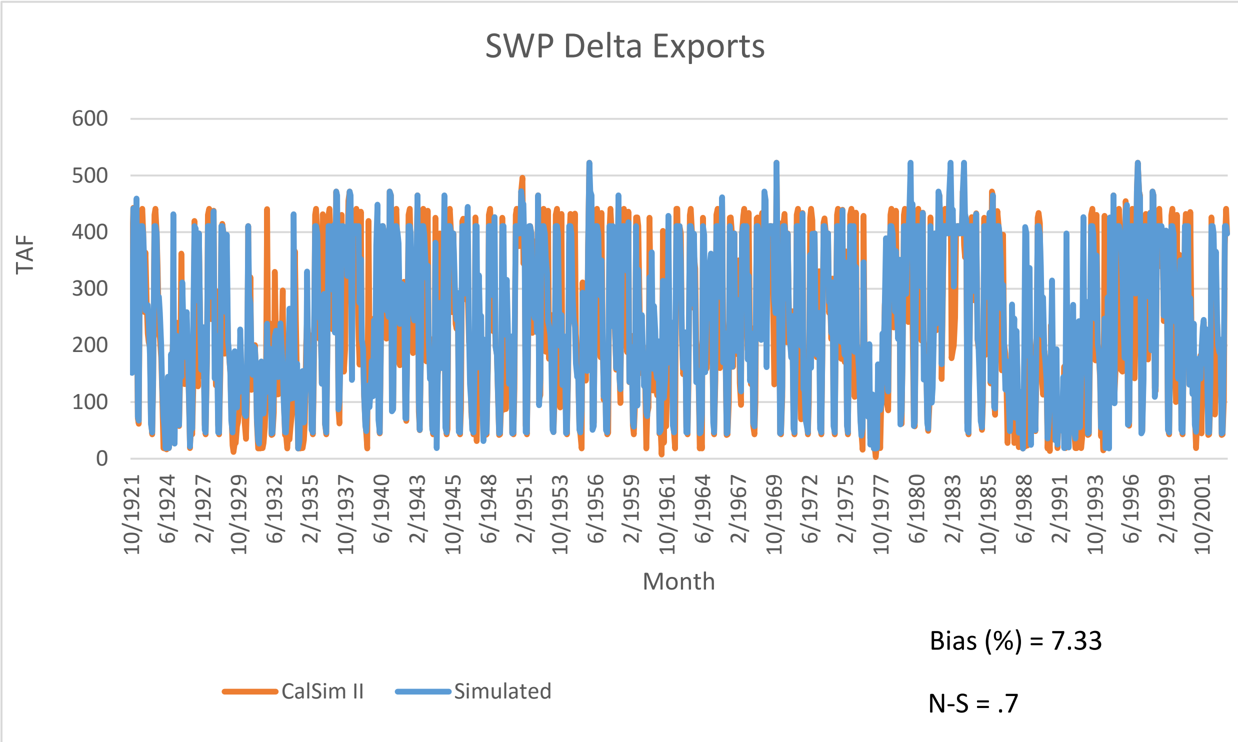

Figure B.6.10a SWP Delta Exports, Monthly 1922 to 2003

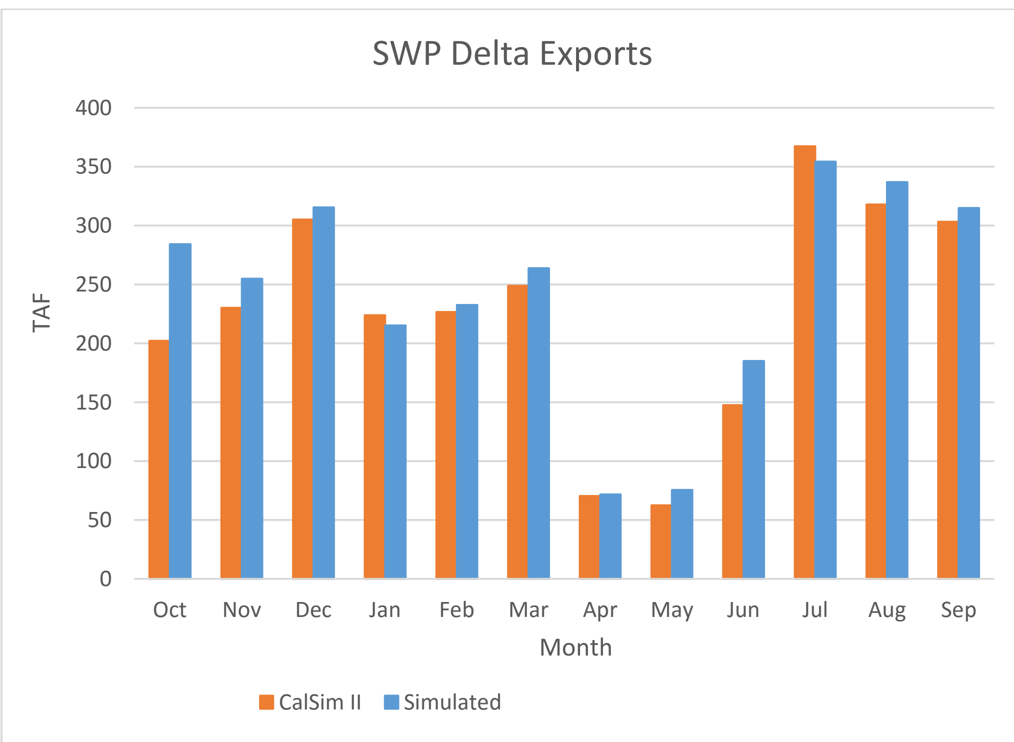

Figure B.6.10b SWP Delta Exports, Average Monthly

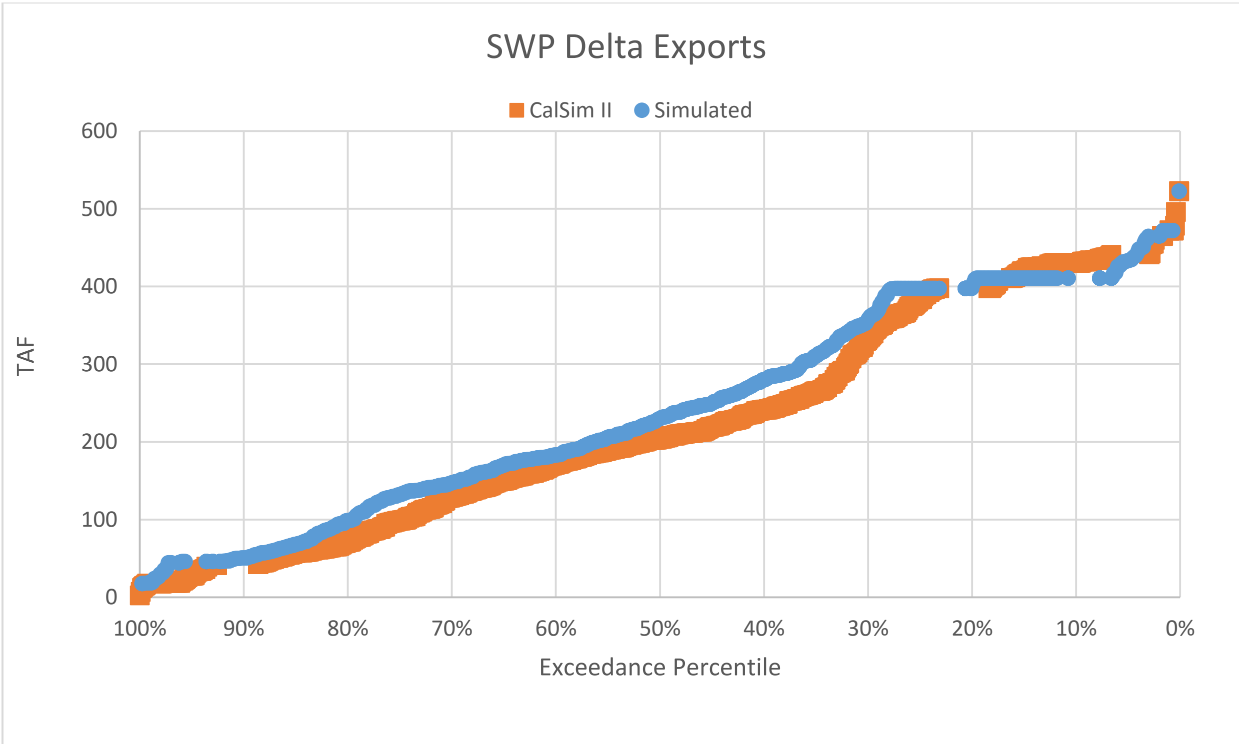

Figure B.6.10c SWP Delta Exports, Exceedance

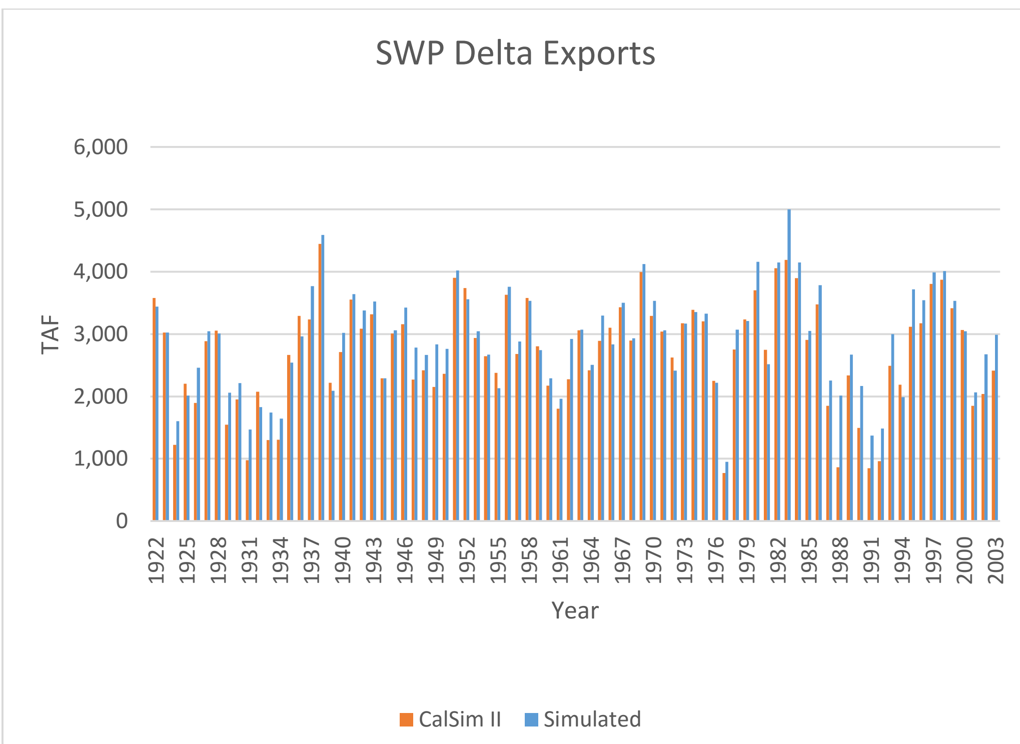

Figure B.6.10d SWP Delta Exports, Annual 1922 to 2003

B.6.11 Required Delta Outflow (Salinity, X2, MRDO)

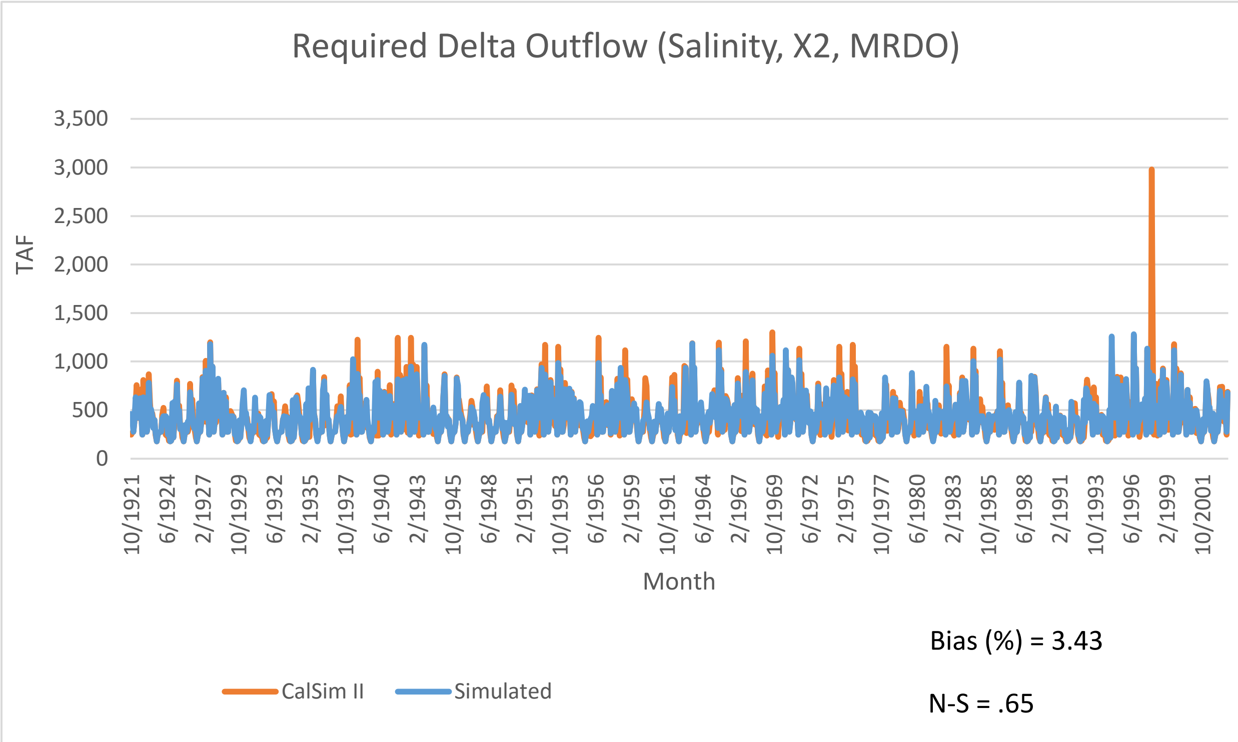

Figure B.6.11a Required Delta Outflow (salinity, X2, MRDO), Monthly 1922 to 2003

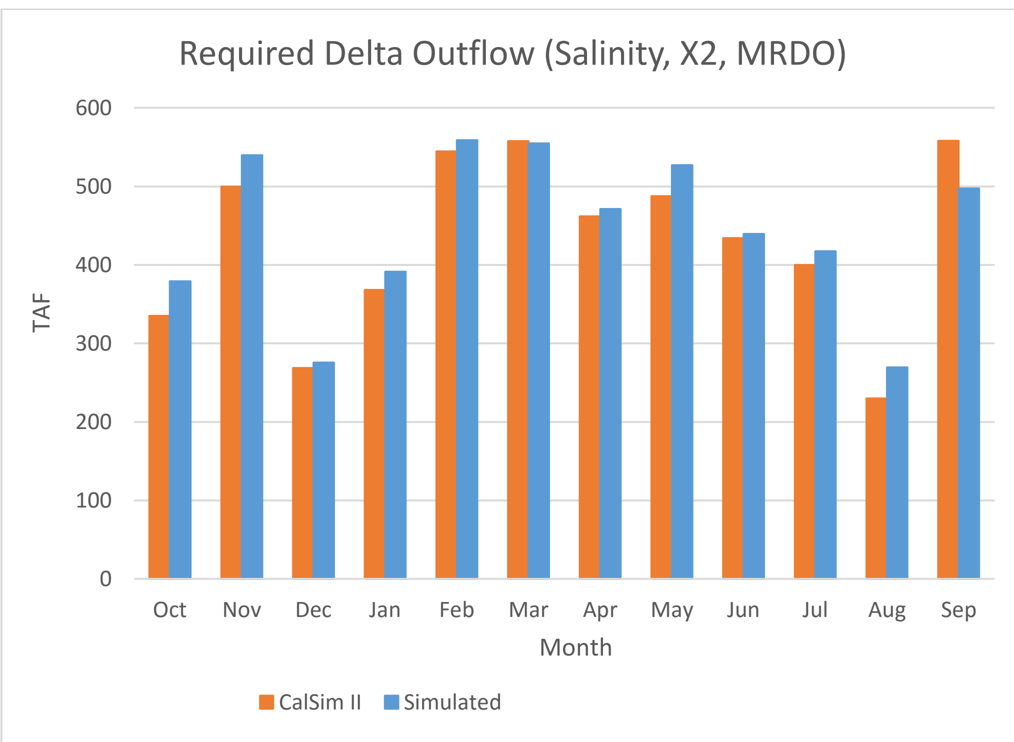

Figure B.6.11b Required Delta Outflow (salinity, X2, MRDO), Average Monthly

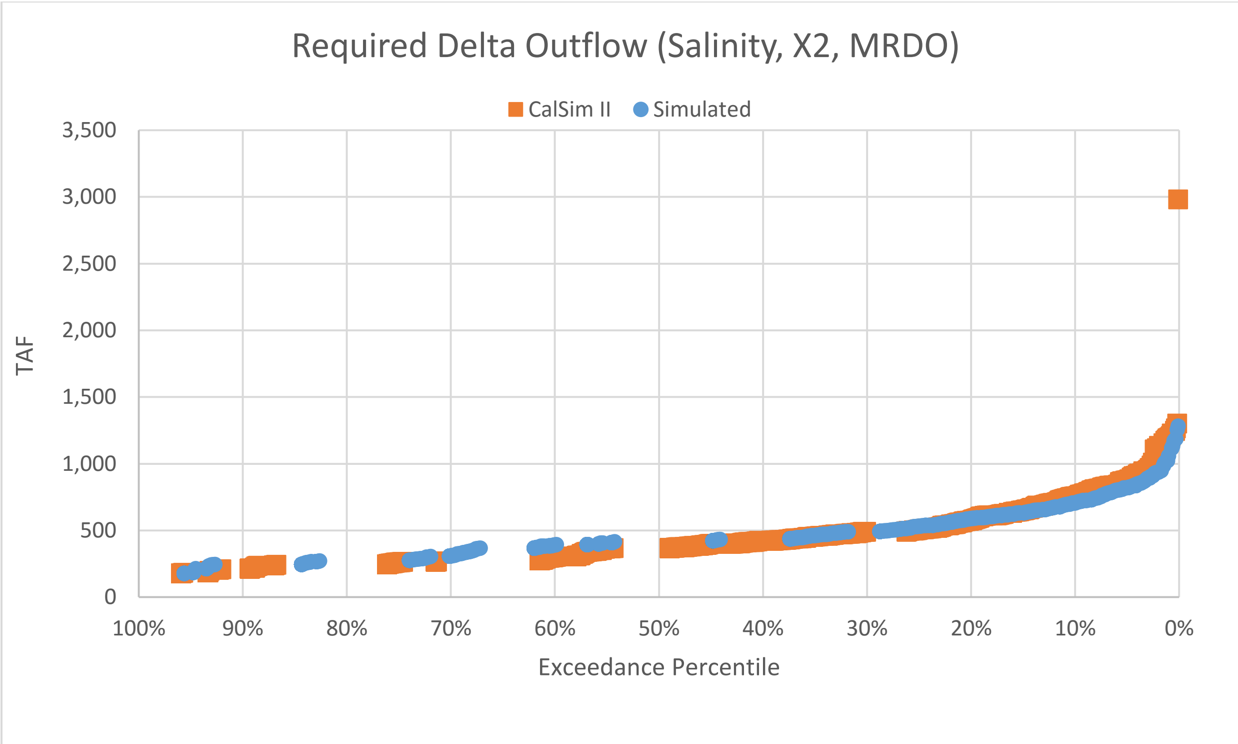

Figure B.6.11c Required Delta Outflow (salinity, X2, MRDO), Exceedance

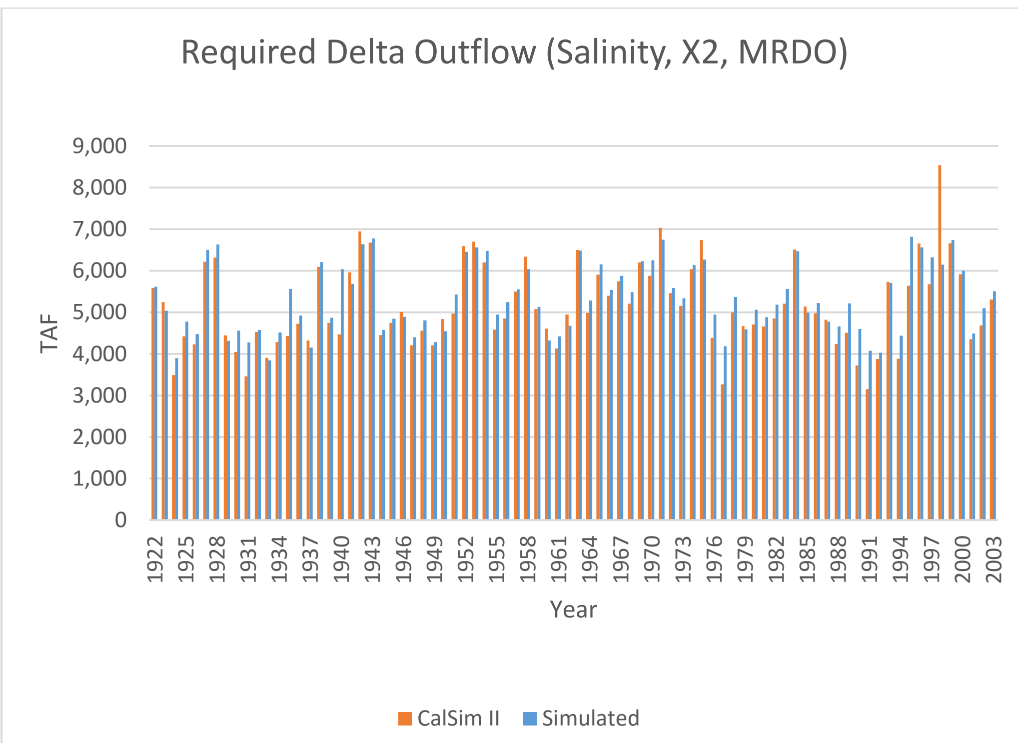

Figure B.6.11d Required Delta Outflow (salinity, X2, MRDO), Annual 1922 to 2003

B.6.12 Surplus Delta Outflow

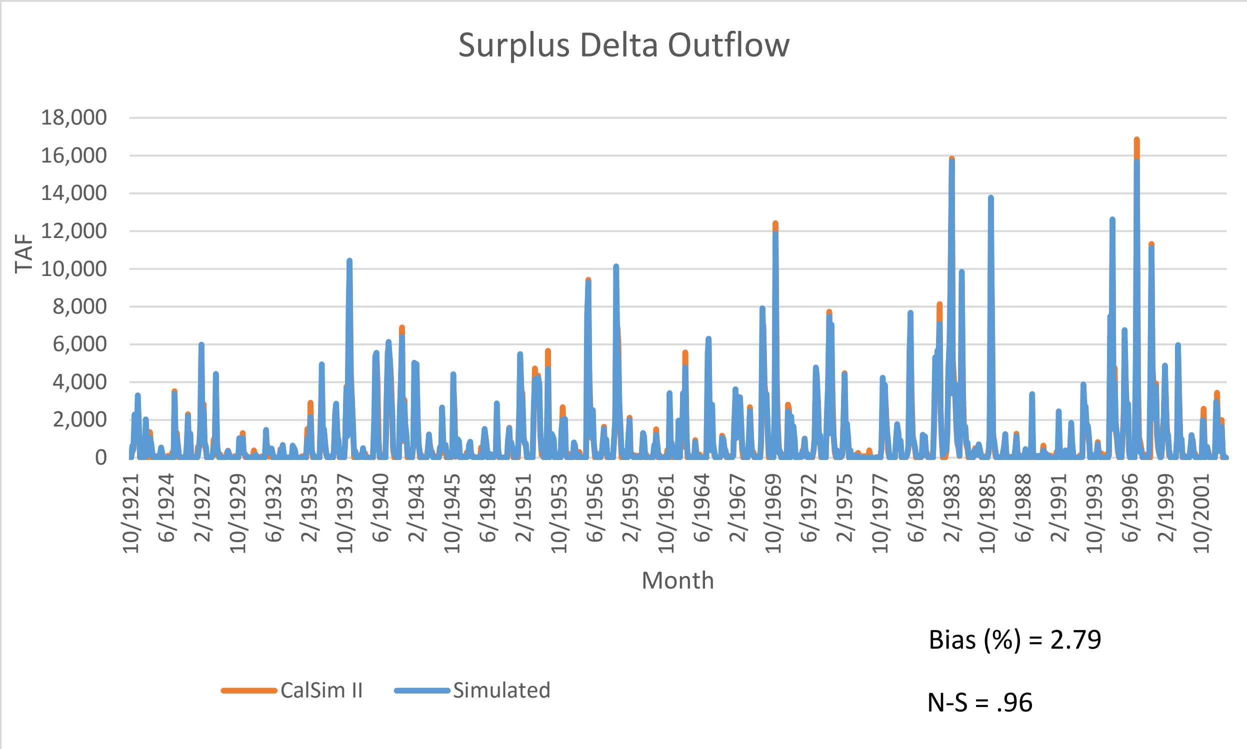

Figure B.6.12a Surplus Delta Outflow, Monthly 1922 to 2003

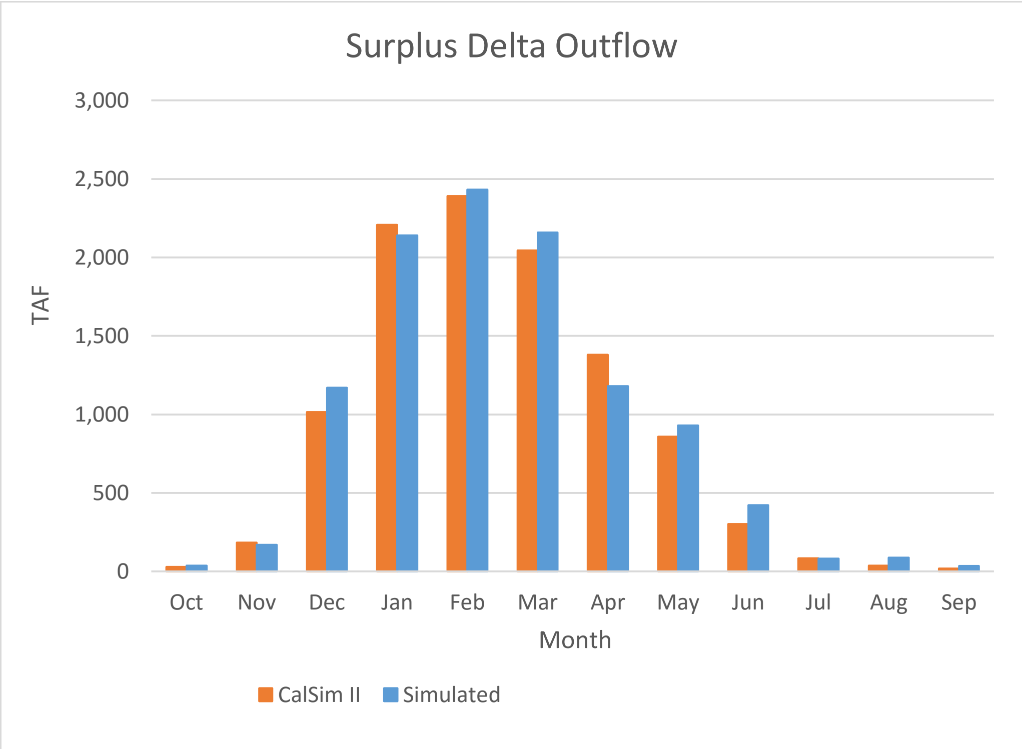

Figure B.6.12b Surplus Delta Outflow, Average Monthly

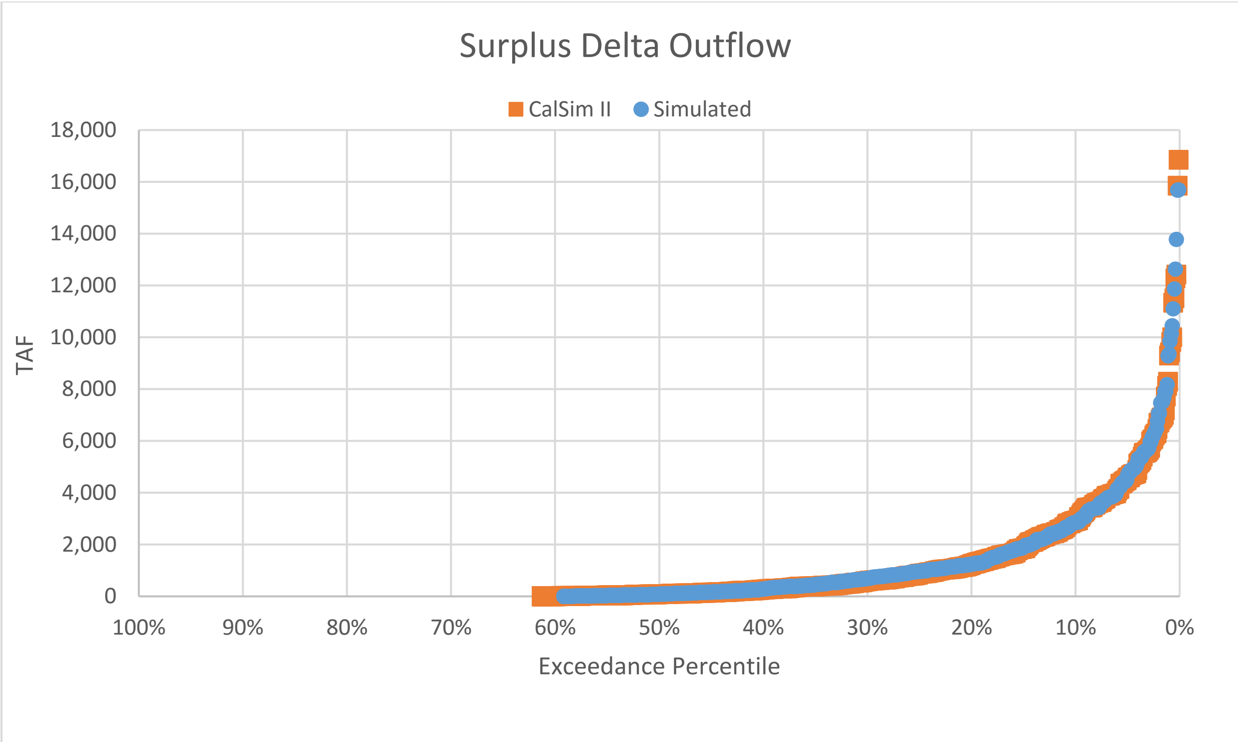

Figure B.6.12c Surplus Delta Outflow, Exceedance

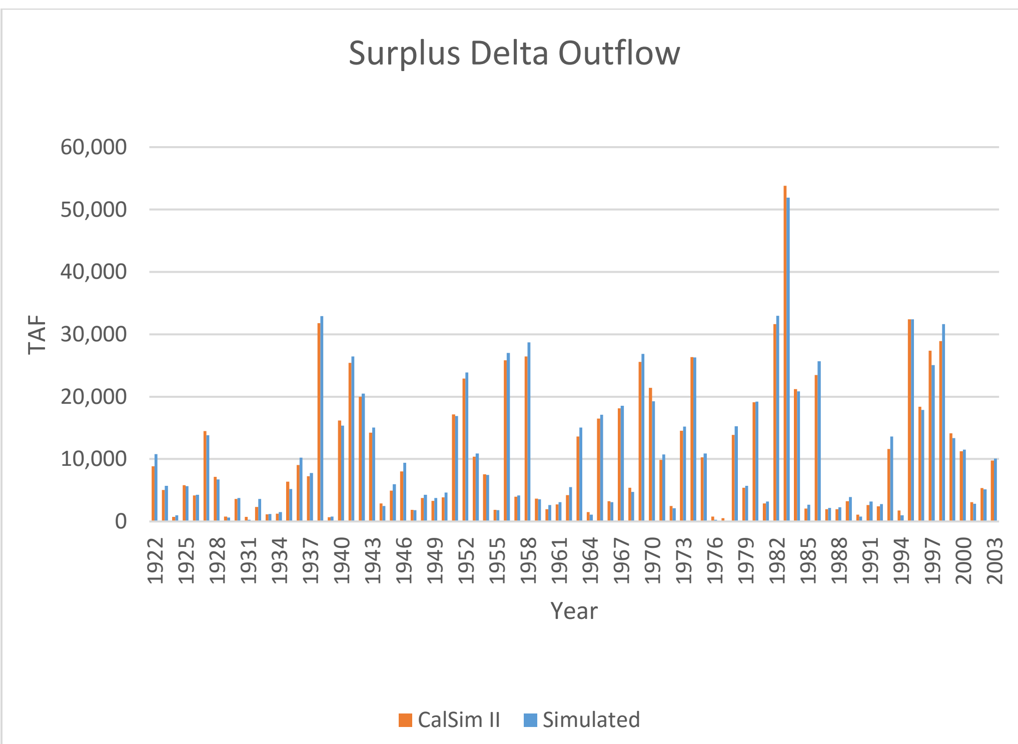

Figure B.6.12d Surplus Delta Outflow, Annual 1922 to 2003

B.6.13 CVP San Luis Storage

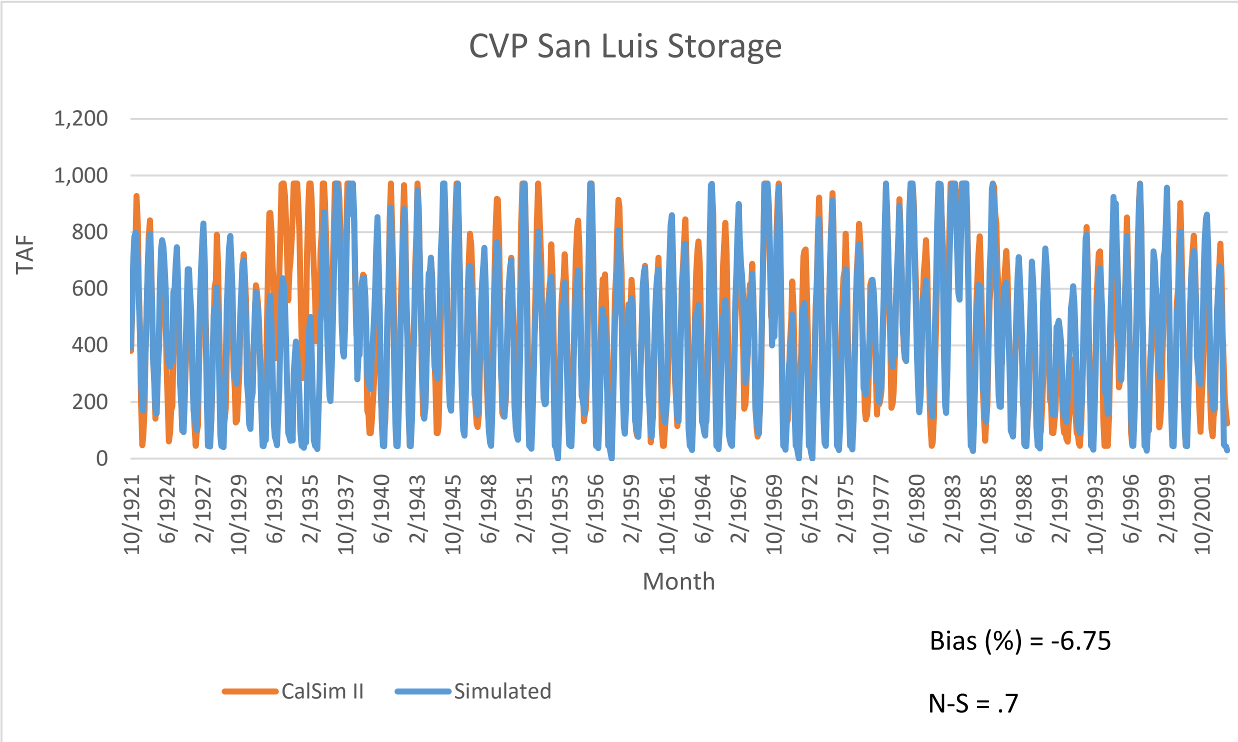

Figure B.6.13a CVP San Luis Storage, Monthly 1922 to 2003

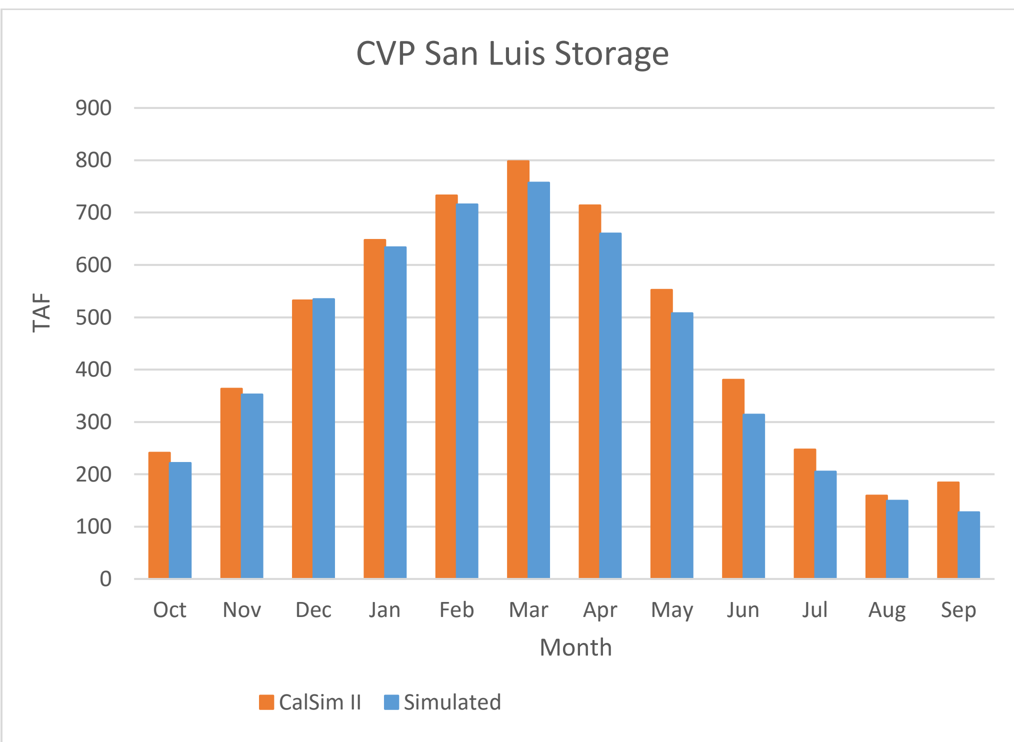

Figure B.6.13b CVP San Luis Storage, Average Monthly

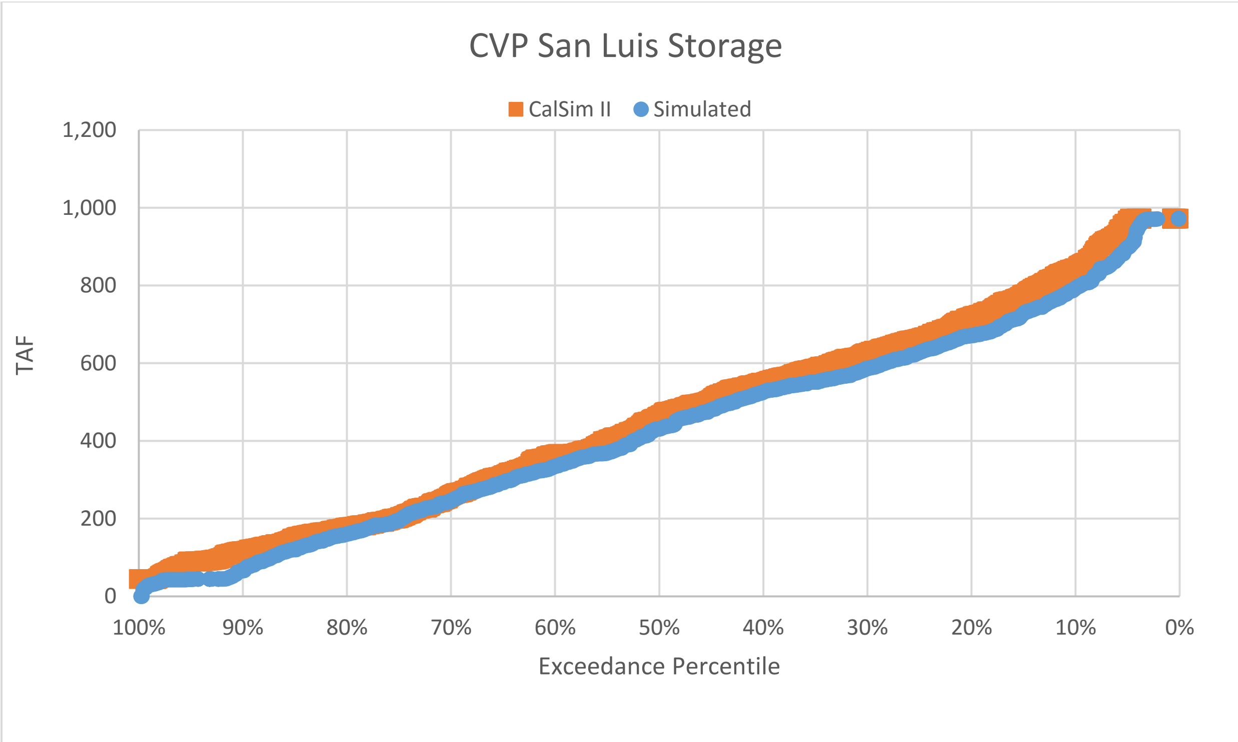

Figure B.6.13c CVP San Luis Storage, Exceedance

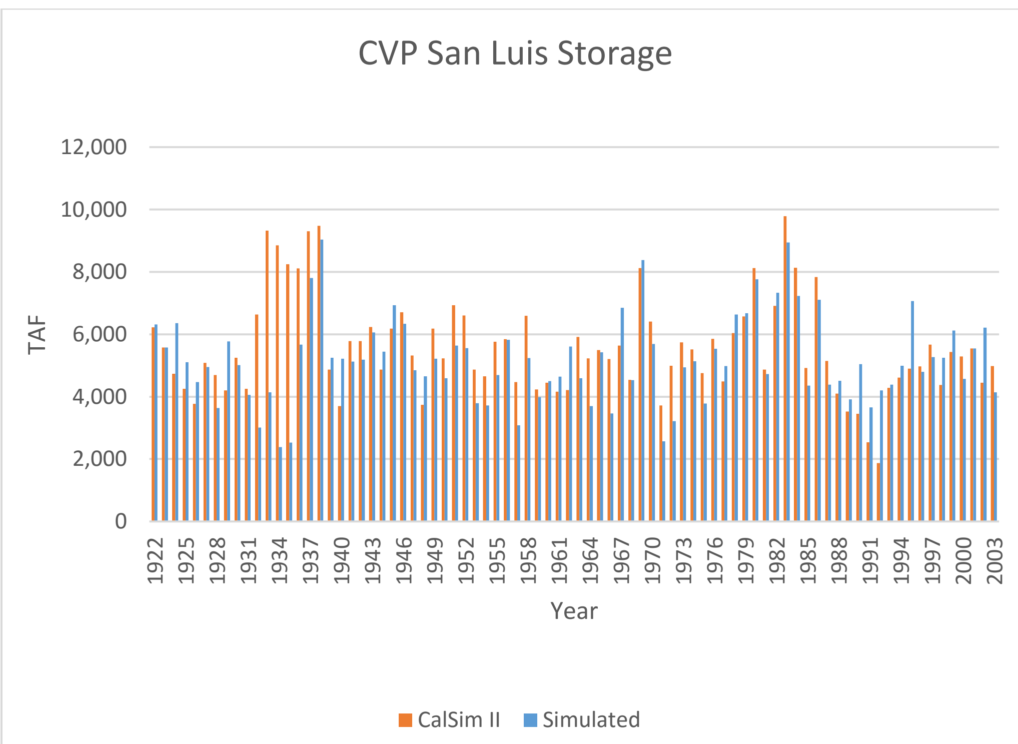

Figure B.6.13d CVP San Luis Storage, Annual 1922 to 2003

B.6.14 SWP San Luis Storage

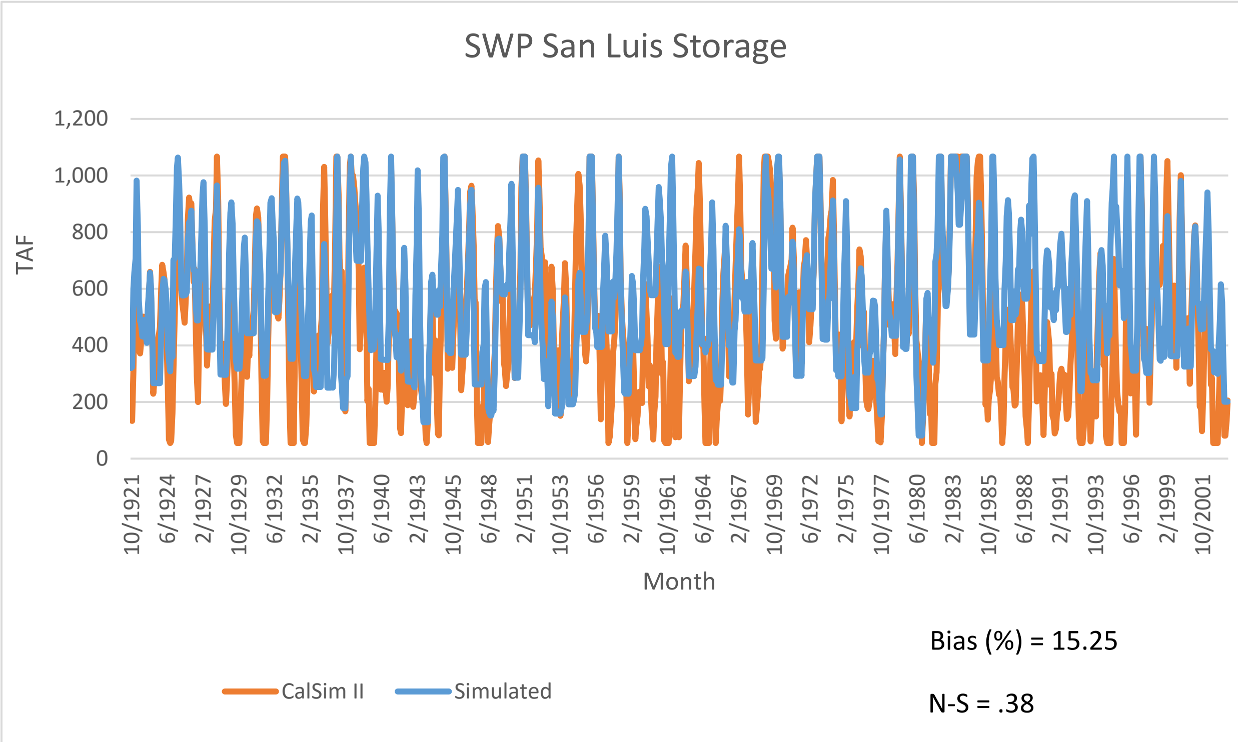

Figure B.6.14a SWP San Luis Storage, Monthly 1922 to 2003

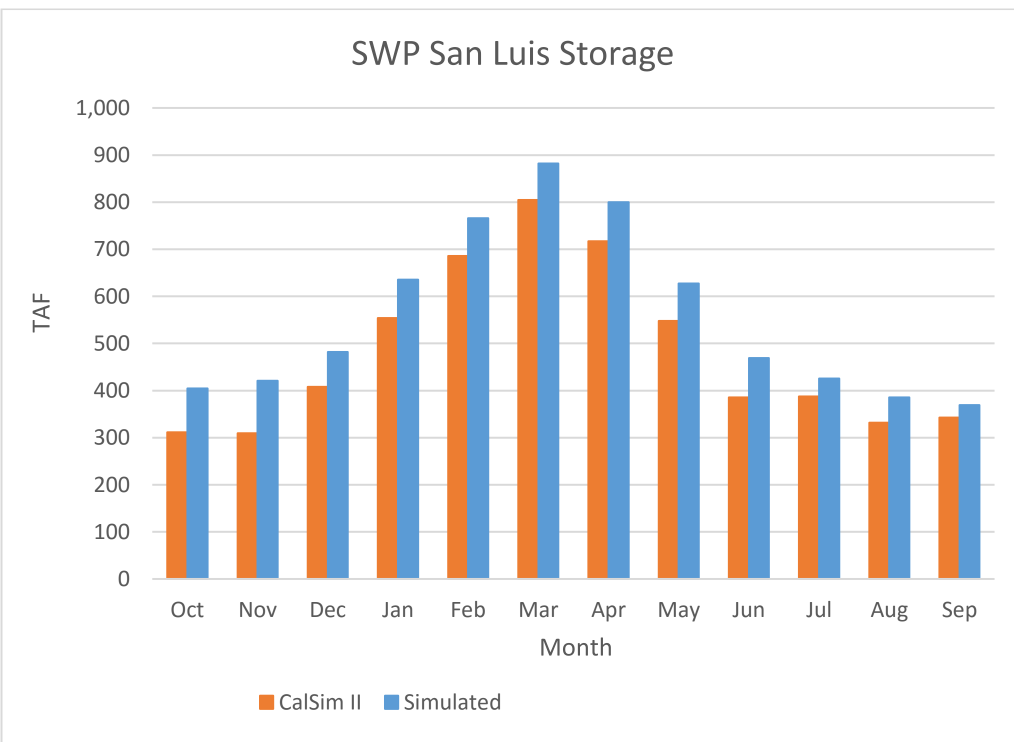

Figure B.6.14b SWP San Luis Storage, Average Monthly

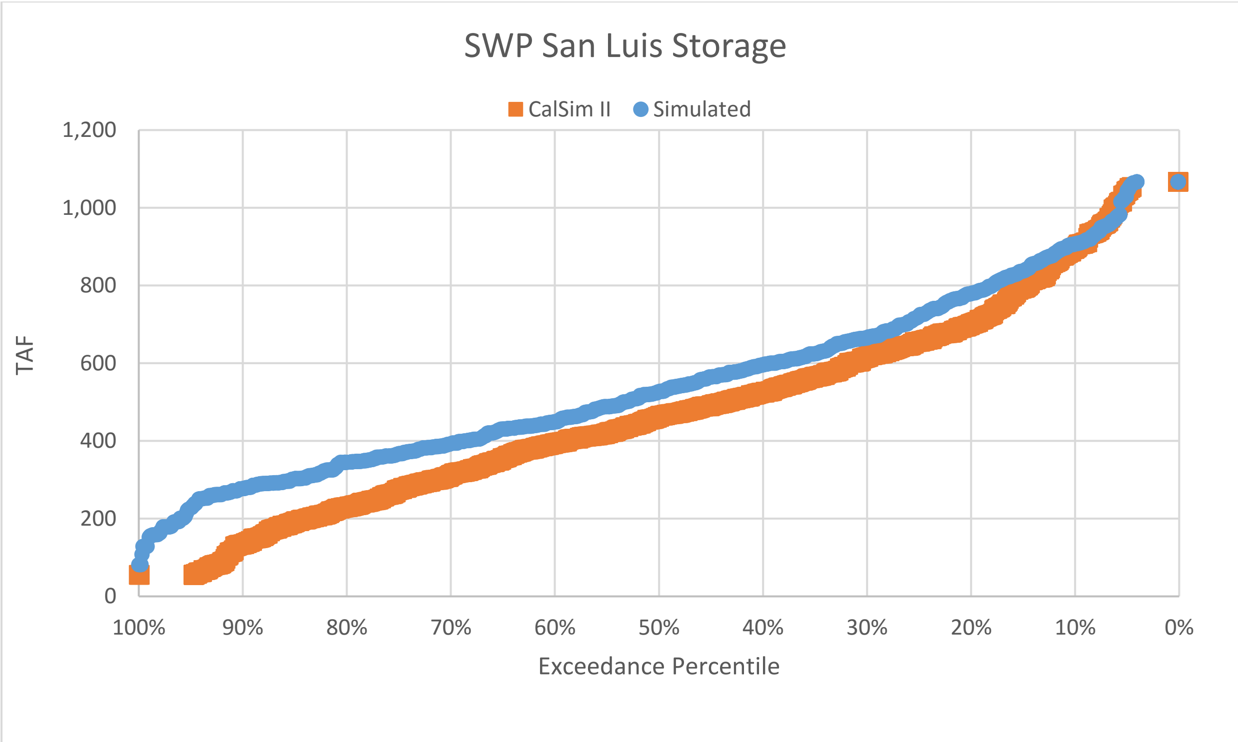

Figure B.6.14c SWP San Luis Storage, Exceedance

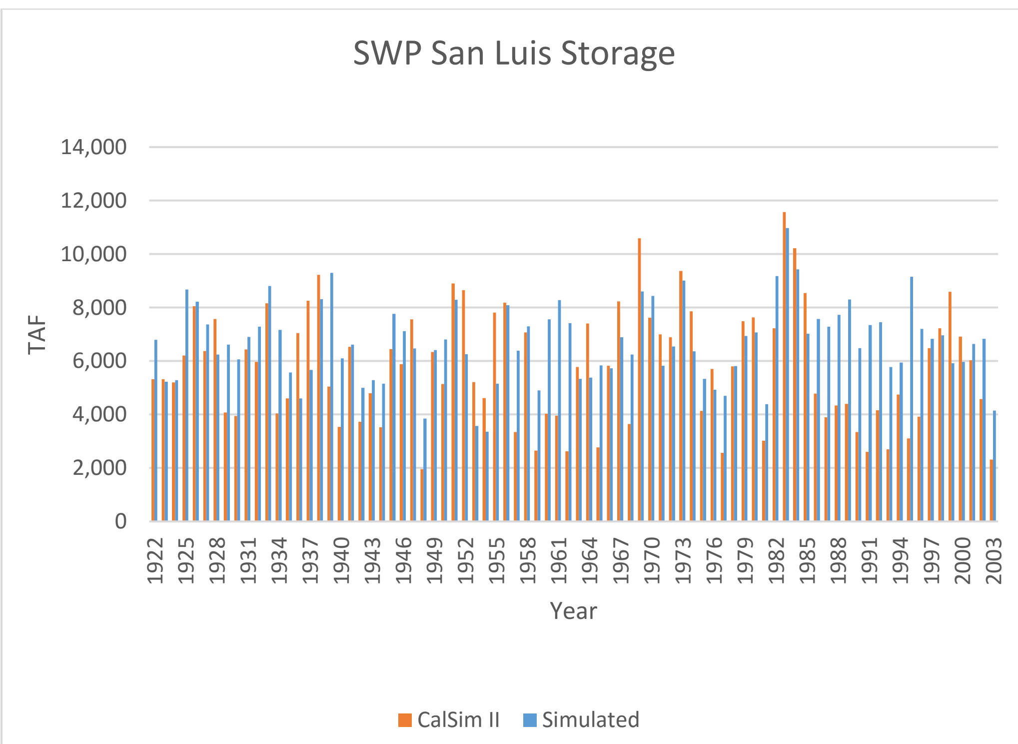

Figure B.6.14d SWP San Luis Storage, Annual 1922 to 2003

B.7 Non-Project Streamflow Validation

The performance of the model for streams and facilities that are not part of the CVP and SWP are presented in this section (stream flows) and the next (reservoir storage). Streamflow and reservoir storage are compared to historical observations for 1990 – 2009 as this period provides a range of hydrologic conditions and contains the period from which demands were derived for SacWAM.

Stream flows on the Yuba River at Marysville are under predicted by 7.4%. The streamflow at Marysville represents the aggregate of operations in the upper Yuba River, including export to the Bear River and agricultural diversions on the lower Yuba. Analysis of the monthly flows indicates that much of the difference between simulated and historical values occurs in the peak flow months. The inflow hydrology may underestimate high flows during flood events. Operations on the lower Yuba River have changed significantly since the implementation of the lower Yuba River Accord in 2008 and may explain the negative bias in New Bullards Bar Reservoir storage (bias = - 11%).

Stream flows on Bear River at Wheatland show the influence of operations at Camp Far West Reservoir with very low flows during most periods and higher flows during the winter months. Inflows to Camp Far West Reservoir are also influenced by imports from the Yuba River system, PG&E diversions to the Bear River Canal, and diversions to the Nevada Irrigation District for agricultural and M&I purposes. Given the complexity of upstream operations, the SacWAM simulation of the Bear River seems reasonable in capturing winter flood releases and summertime minimum in-stream flows

The simulated values of flow on Butte Creek near Durham are in good agreement with observed values. The bias is 6.3% with the over prediction mostly happening during the spring and summer months. This may be caused by groundwater losses, which are significant, but which are aggregated in SacWAM at a point downstream from this gauge.

Simulated values of stream flow in Cache Creek at Rumsey reflect the operations of Clear Lake and Indian Valley Reservoir. Operations on Clear Lake are controlled by logic in the model that implements the Solano Decree. Storage values for Clear Lake show that the model is performing that task well. Storage in Indian Valley Reservoir is not simulated as well. The reservoir remains too full for most of the validation period. This is also reflected in the under simulation of flows on the Cache Creek at Rumsey. One potential reason for this is that in SacWAM the simulated diversions on Cache Creek have been adjusted to match the diversions at the Capay Diversion Dam which does not represent all the diversions off of Cache Creek, particularly in the Capay Valley. Another potential reason is that the groundwater interaction has been lumped into one reach on Cache Creek located downstream of Rumsey gauge while in reality losses to the groundwater system may occur upstream of the gauge.

On Putah Creek, the SacWAM model does a good job of simulating the storage in Lake Berryessa as well as the flows on the lower Putah Creek downstream of the Solano Diversion Dam. The flows below the diversion dam have a bias of -7.7%.

Stream flows on the Mokelumne River at Camanche are within 2.8% of historical observations. Downstream at Woodbridge SacWAM over estimates flows by 14.7%. It is likely that the differences are due to poor simulation of groundwater losses.

There are no publicly available gauge data on the lower reaches of the Calaveras River, therefore, the point of comparison is immediately below New Hogan Dam. The bias is 0.1% with an under prediction of flows during the winter months and an over prediction during the summer months. Storage at New Hogan is generally under predicted.

B.7.1 Yuba River near Marysville

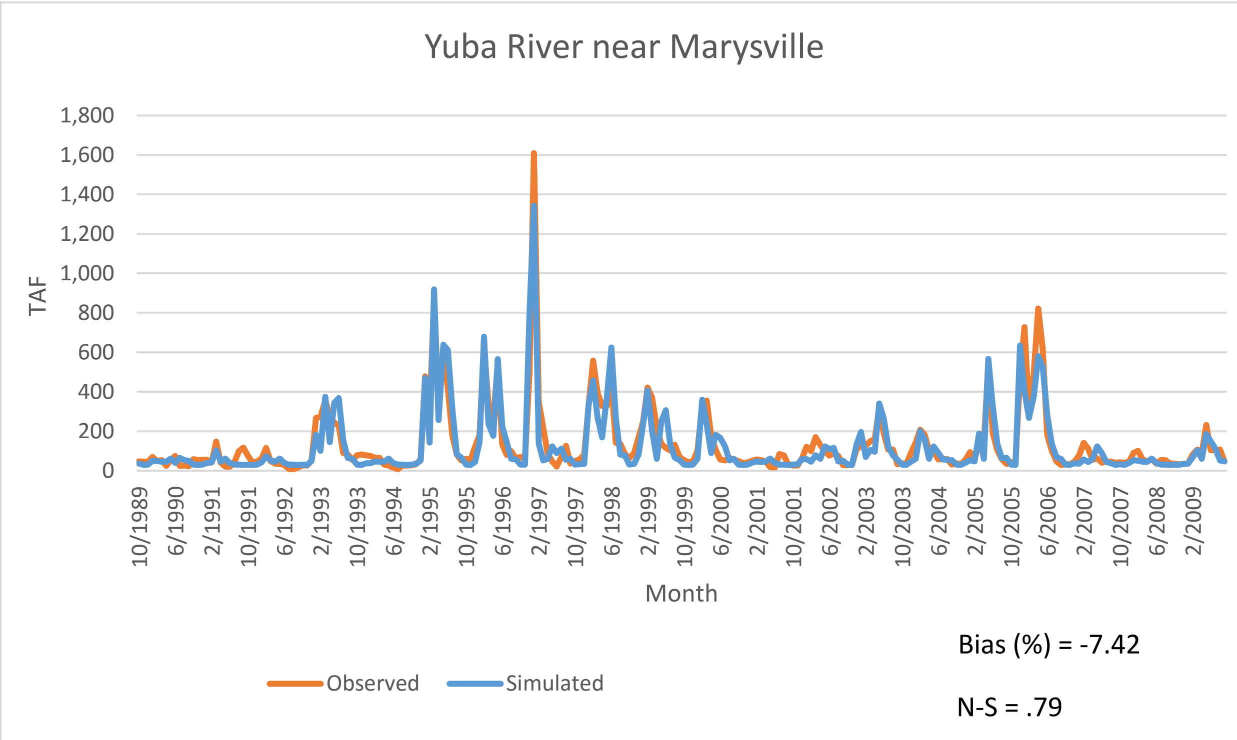

Figure B.7.1a Yuba River near Marysville, Monthly 1990 to 2009

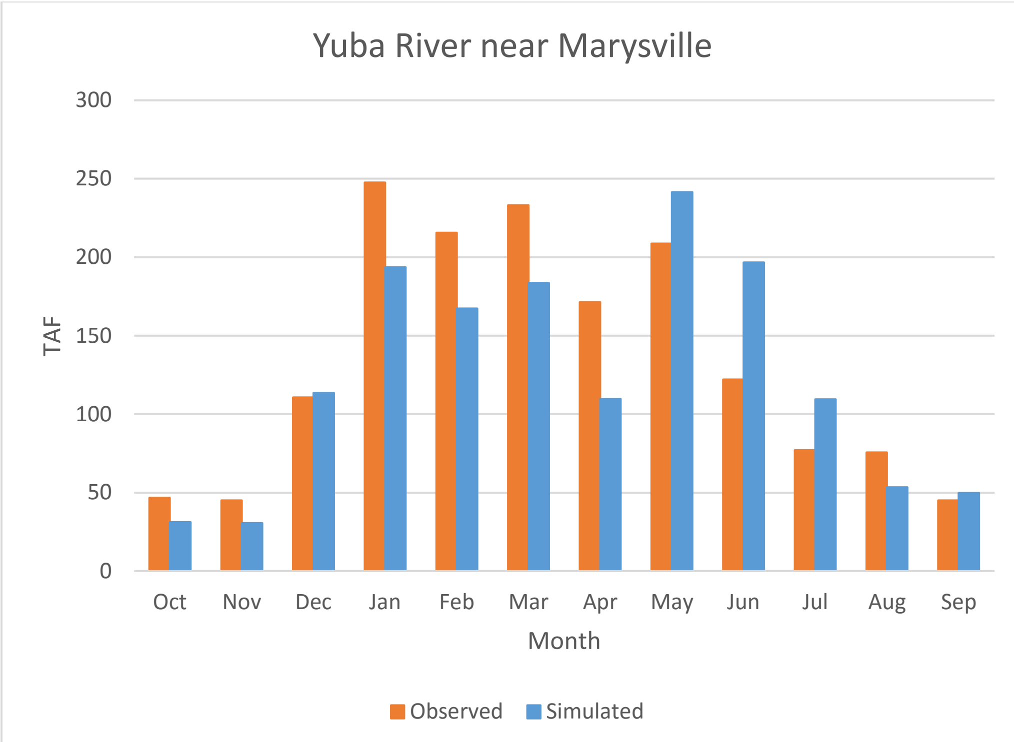

Figure B.7.1b Yuba River near Marysville, Average Monthly

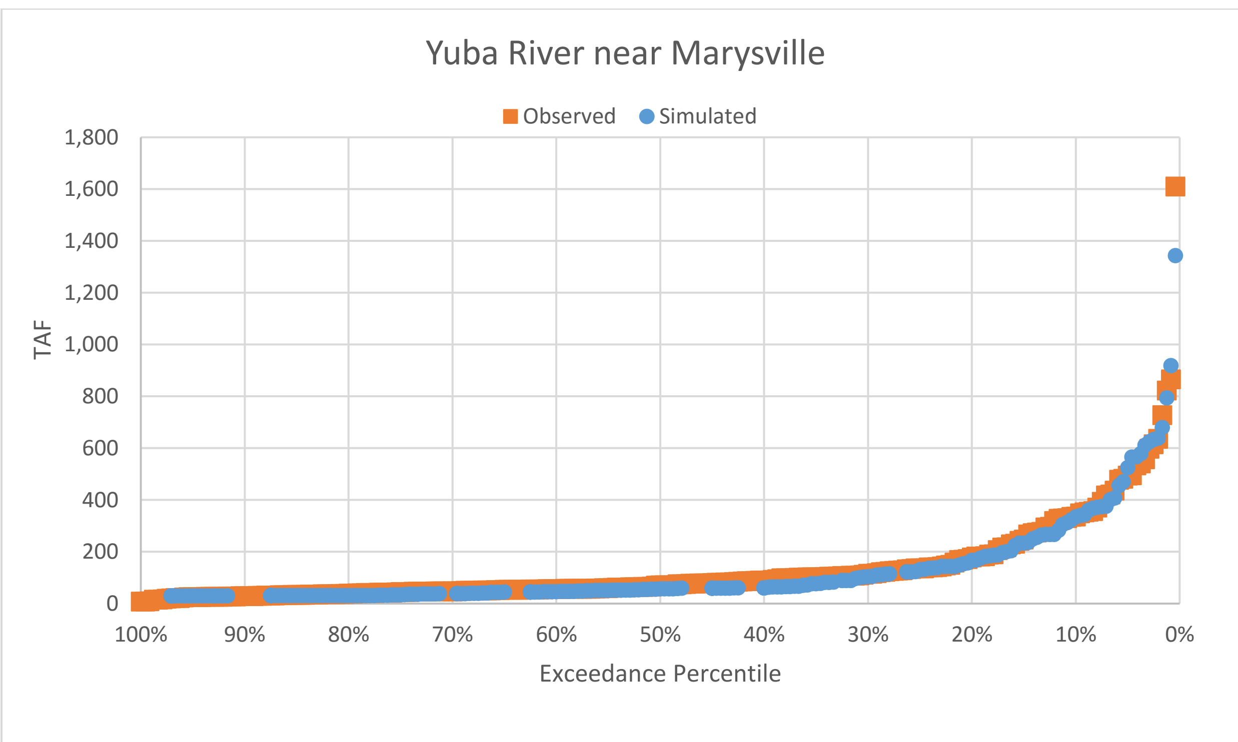

Figure B.7.1c Yuba River near Marysville, Exceedance

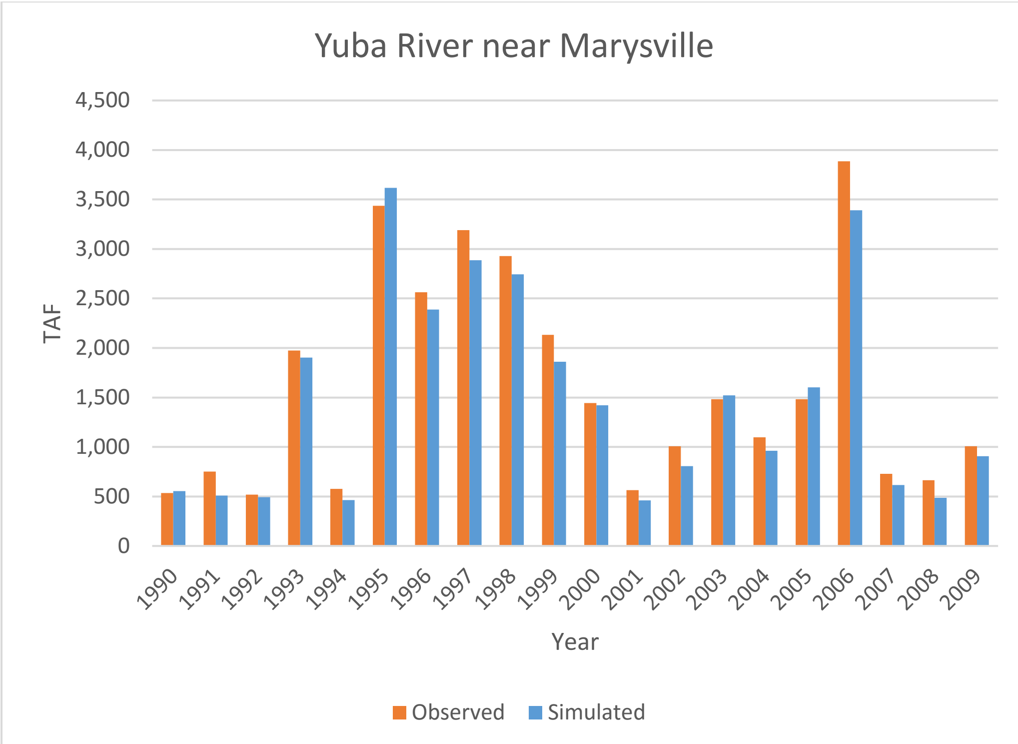

Figure B.7.1d Yuba River near Marysville, Annual 1990 to 2009

B.7.2 Bear River near Wheatland

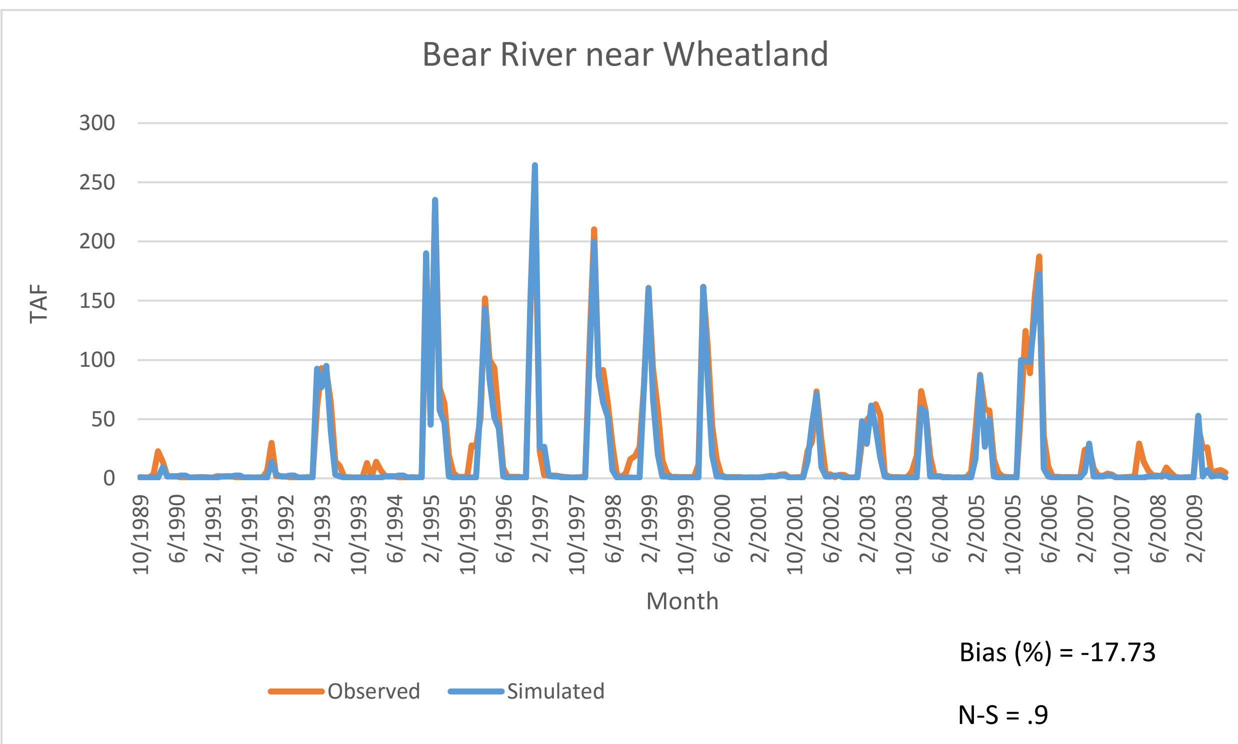

Figure B.7.2a Bear River near Wheatland, Monthly 1990 to 2009

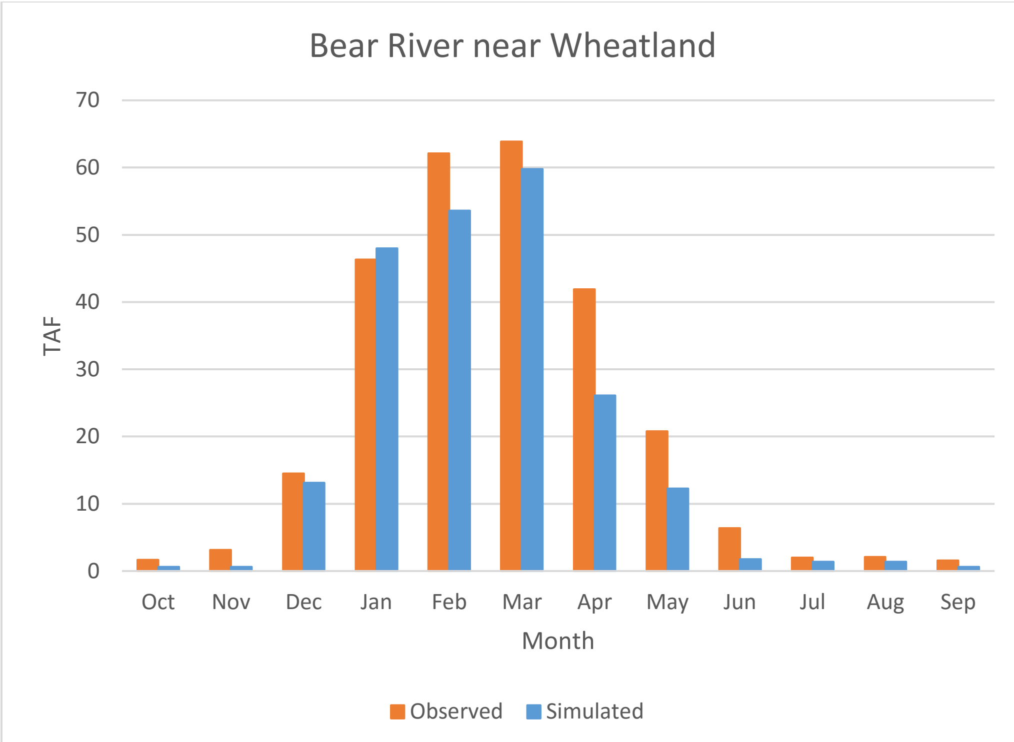

Figure B.7.2b Bear River near Wheatland, Average Monthly

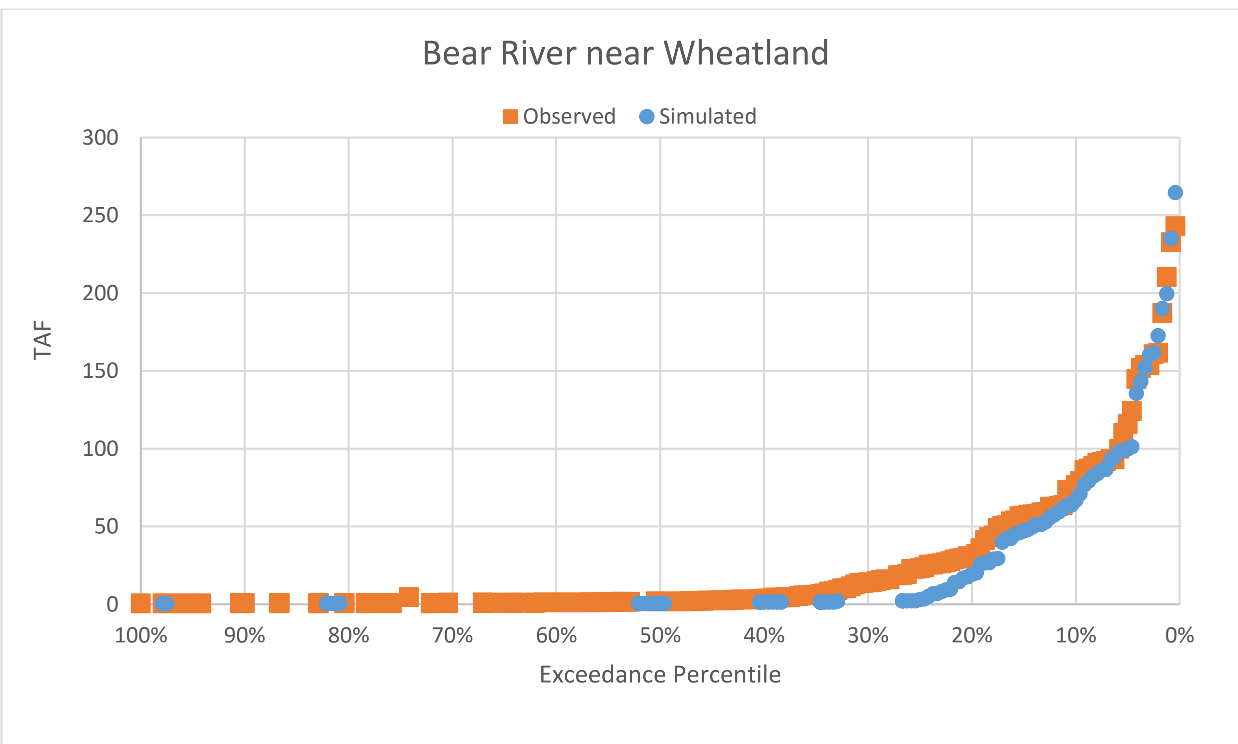

Figure B.7.2c Bear River near Wheatland, Exceedance

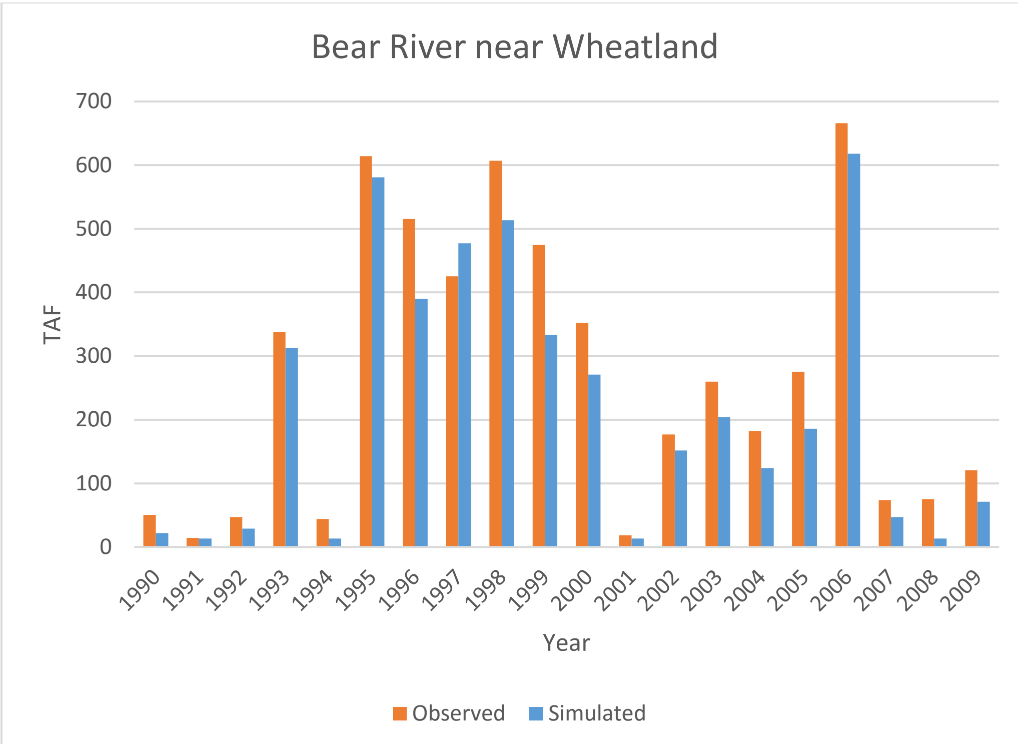

Figure B.7.2d Bear River near Wheatland, Annual 1990 to 2009

B.7.3 Butte Creek near Durham

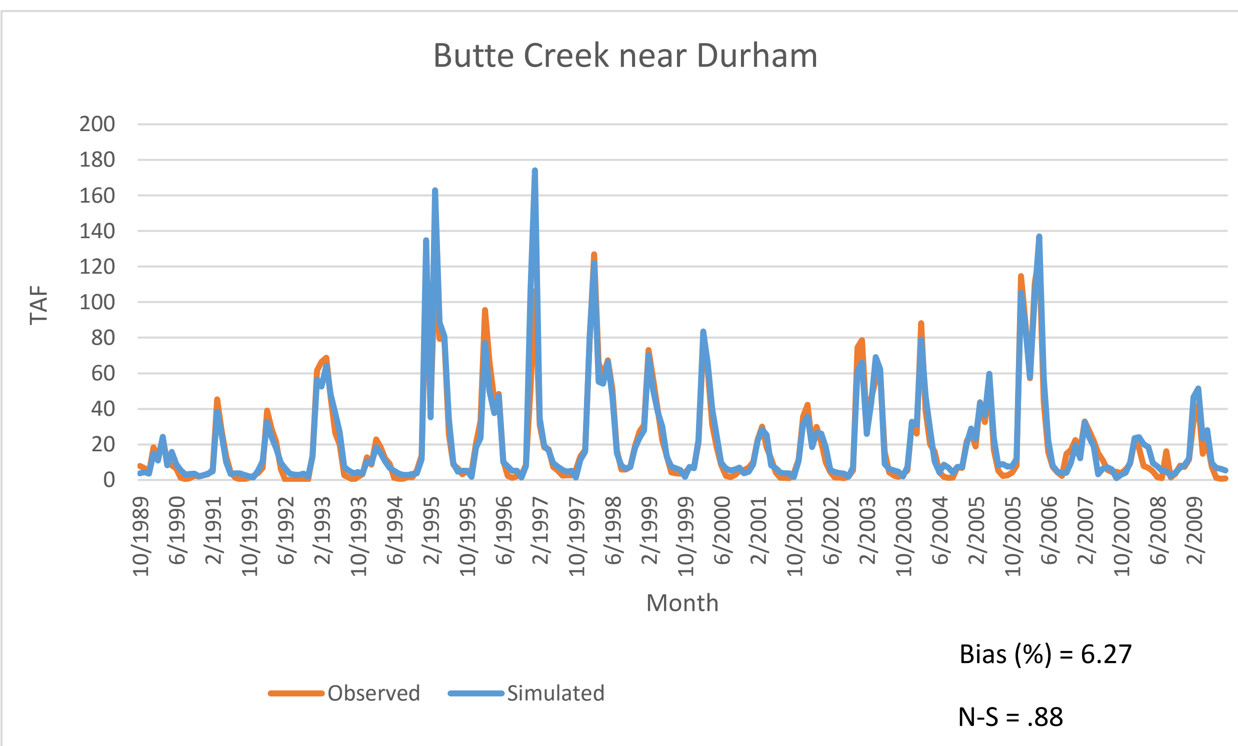

Figure B.7.3a Butte Creek near Durham, Monthly 1990 to 2009

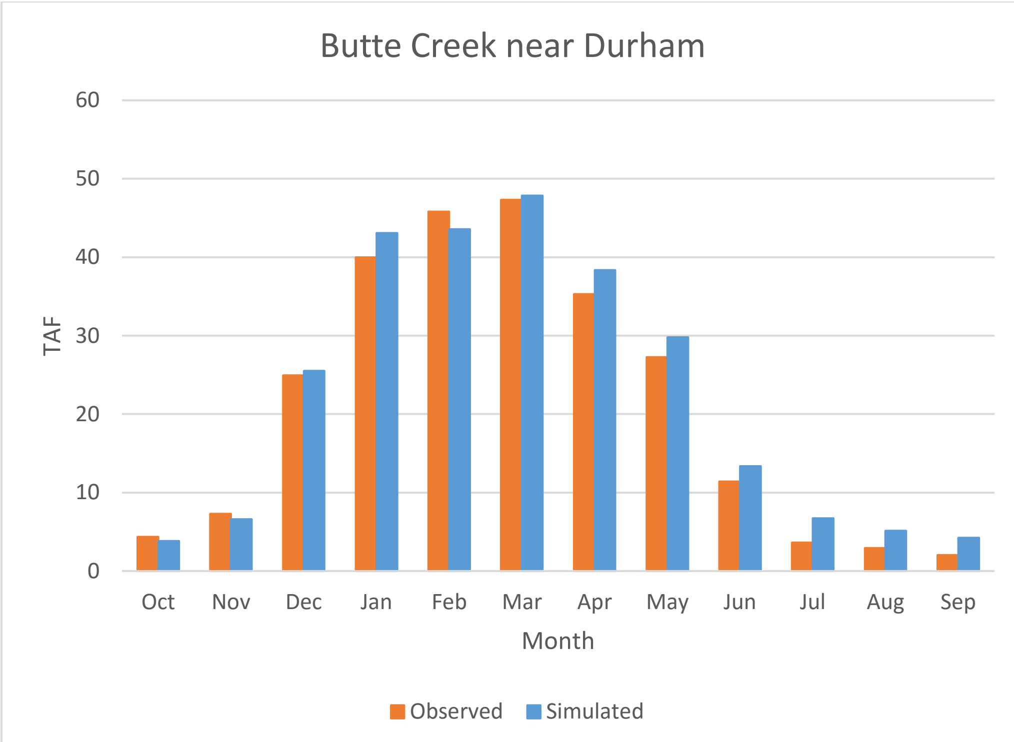

Figure B.7.3b Butte Creek near Durham, Average Monthly

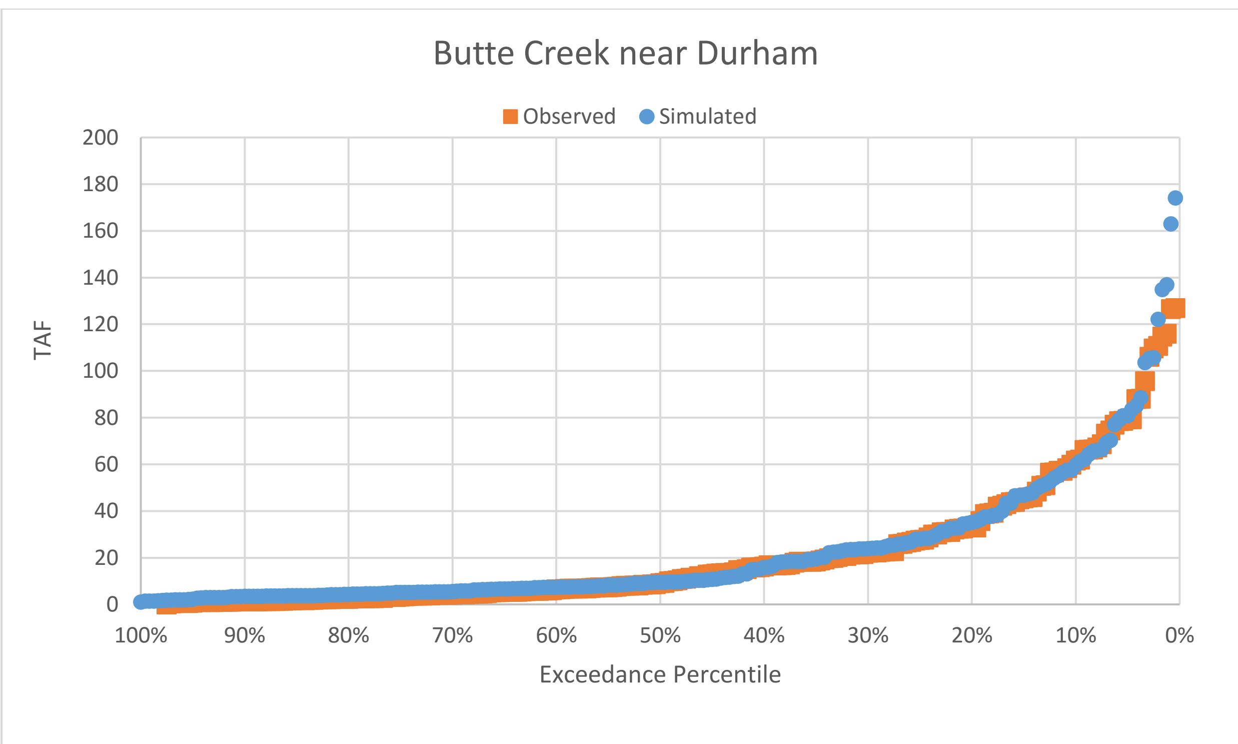

Figure B.7.3c Butte Creek near Durham, Exceedance

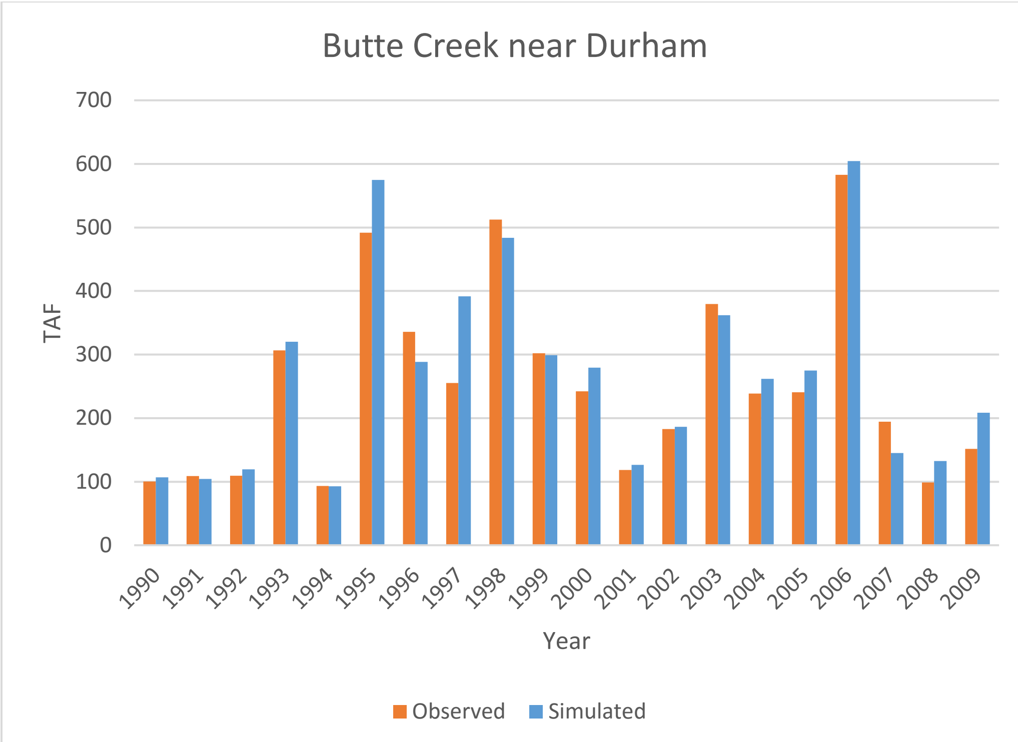

Figure B.7.3d Butte Creek near Durham, Annual 1990 to 2009

B.7.4 Cache Creek at Rumsey

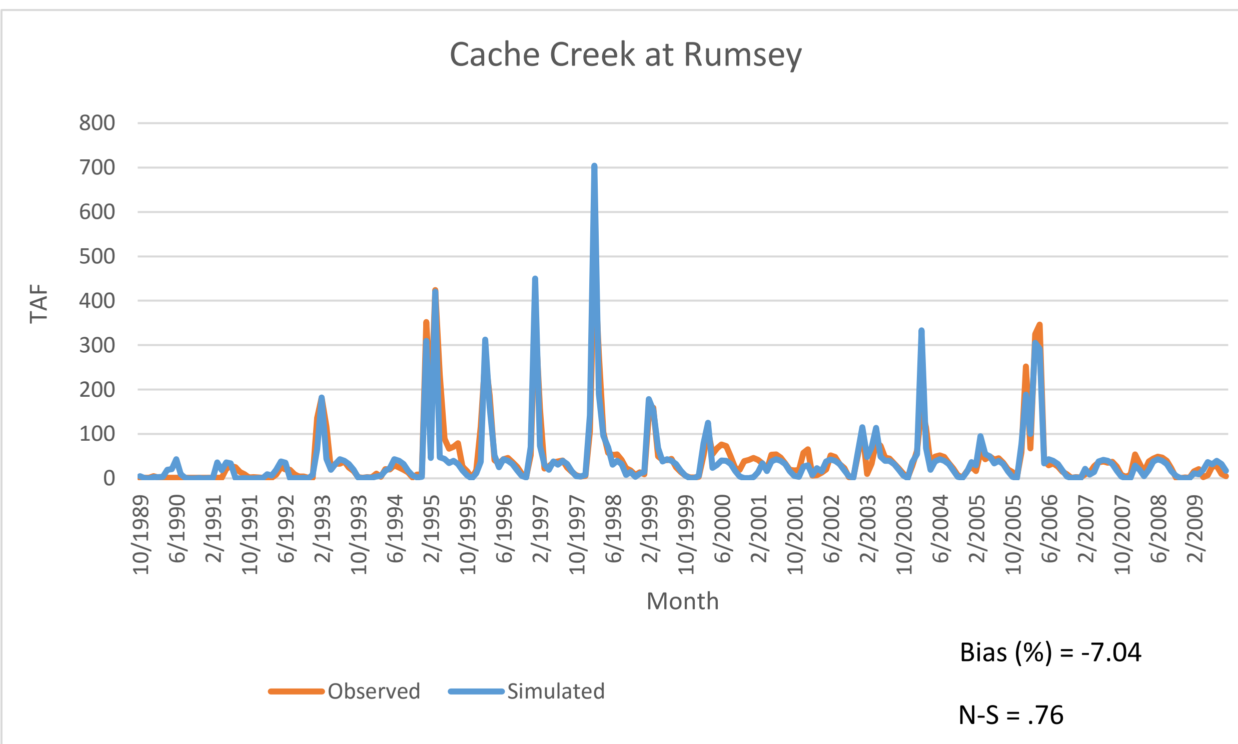

Figure B.7.4a Cache Creek at Rumsey, Monthly 1990 to 2009

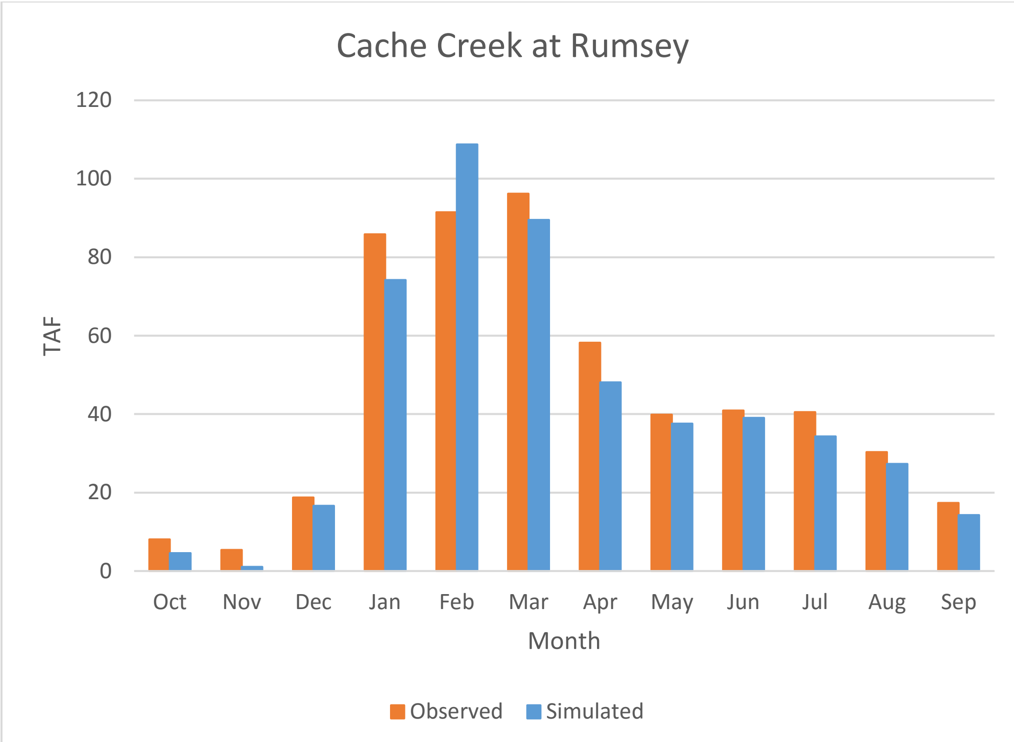

Figure B.7.4b Cache Creek at Rumsey, Average Monthly

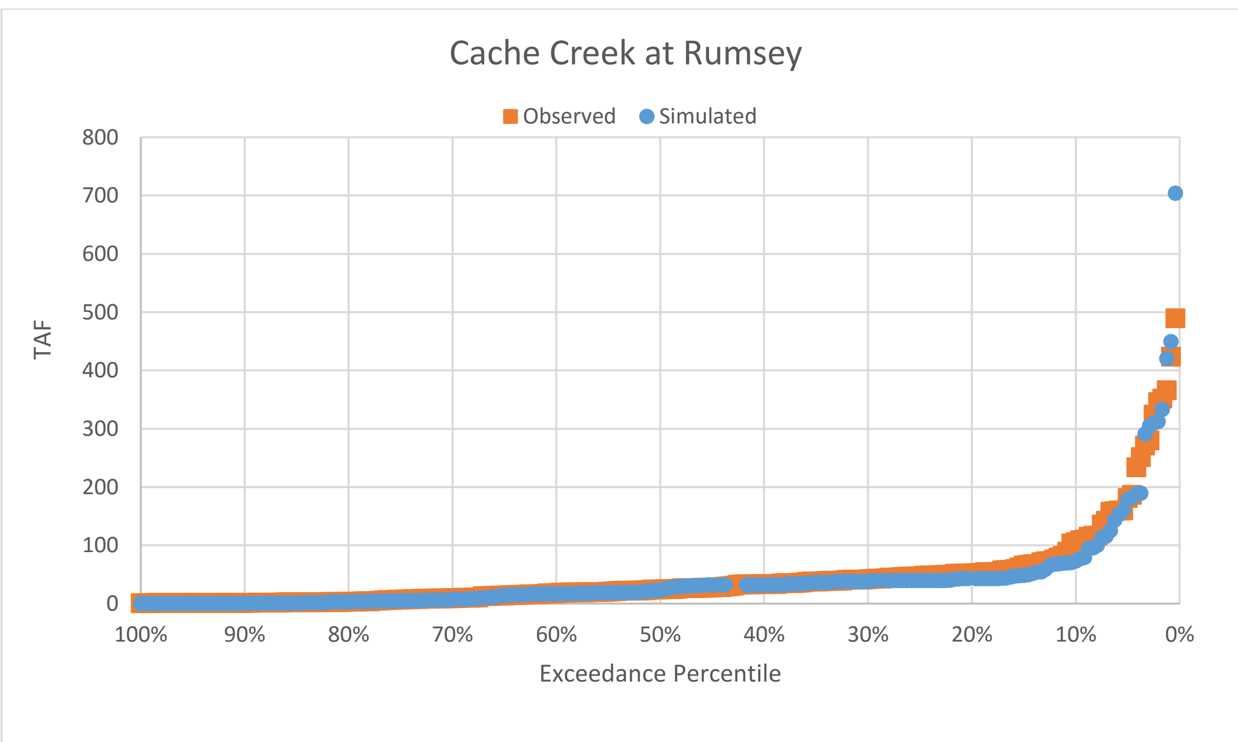

Figure B.7.4c Cache Creek at Rumsey, Exceedance

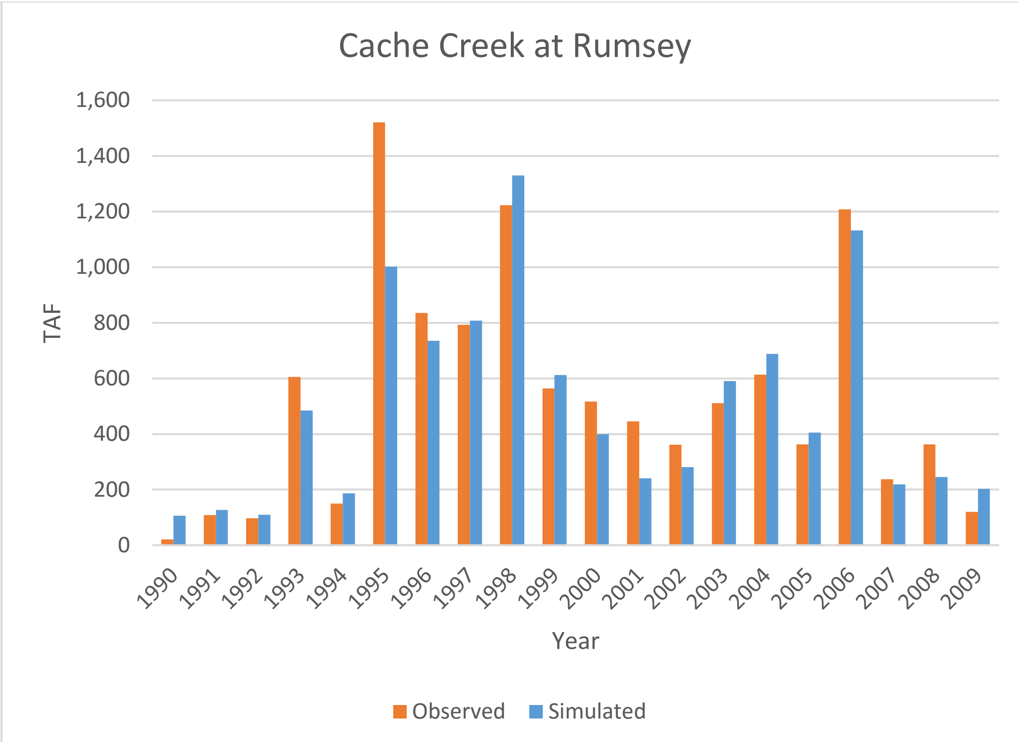

Figure B.7.4d Cache Creek at Rumsey, Annual 1990 to 2009

B.7.5 Putah Creek below Solano Diversion Dam

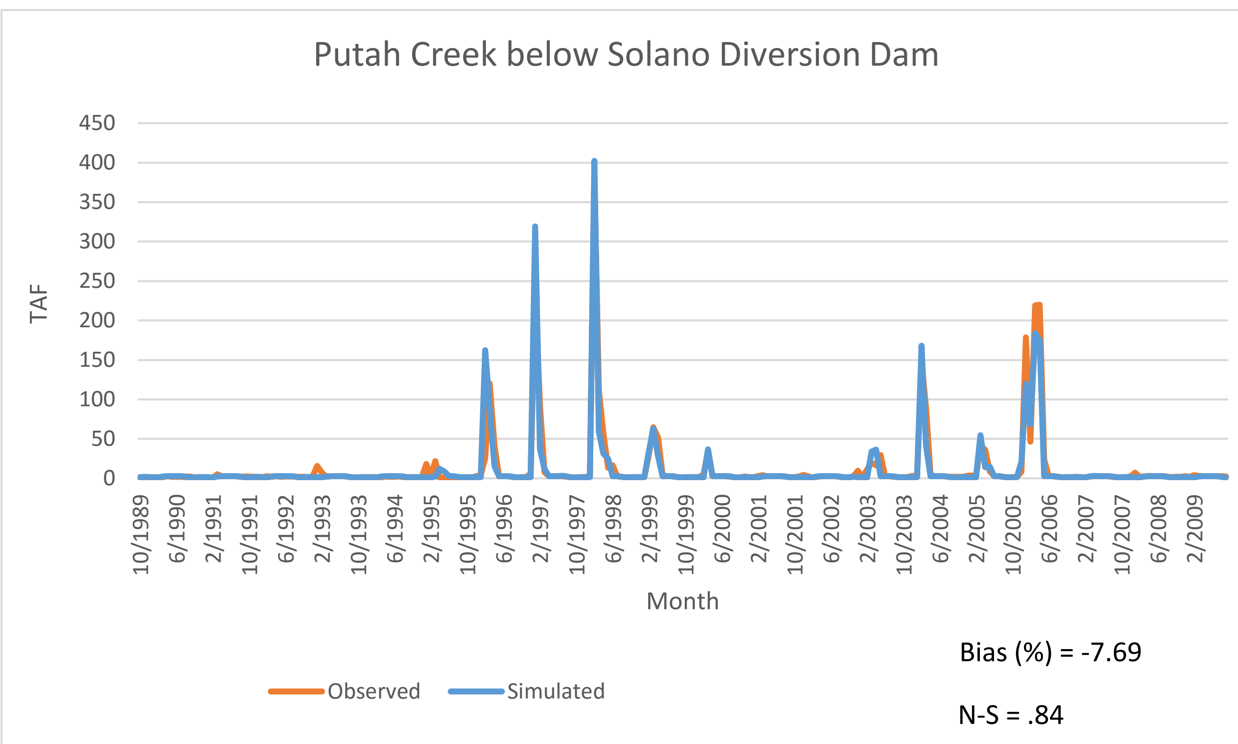

Figure B.7.5a Putah Creek below Solano Diversion Dam, Monthly 1990 to 2009

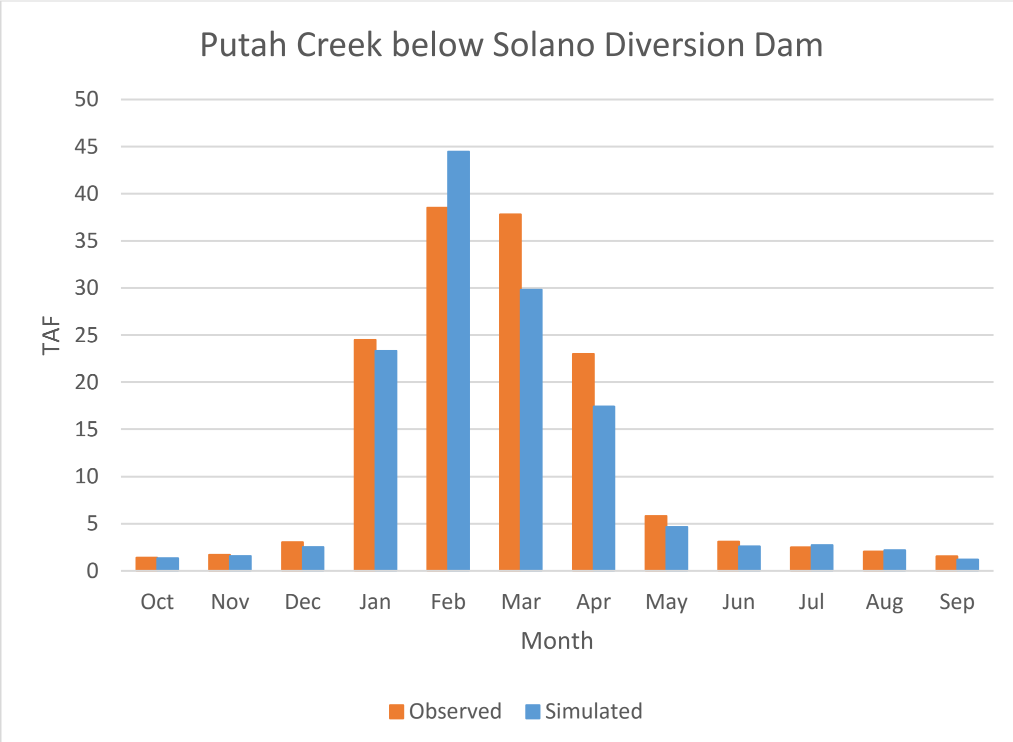

Figure B.7.5b Putah Creek below Solano Diversion Dam, Average Monthly

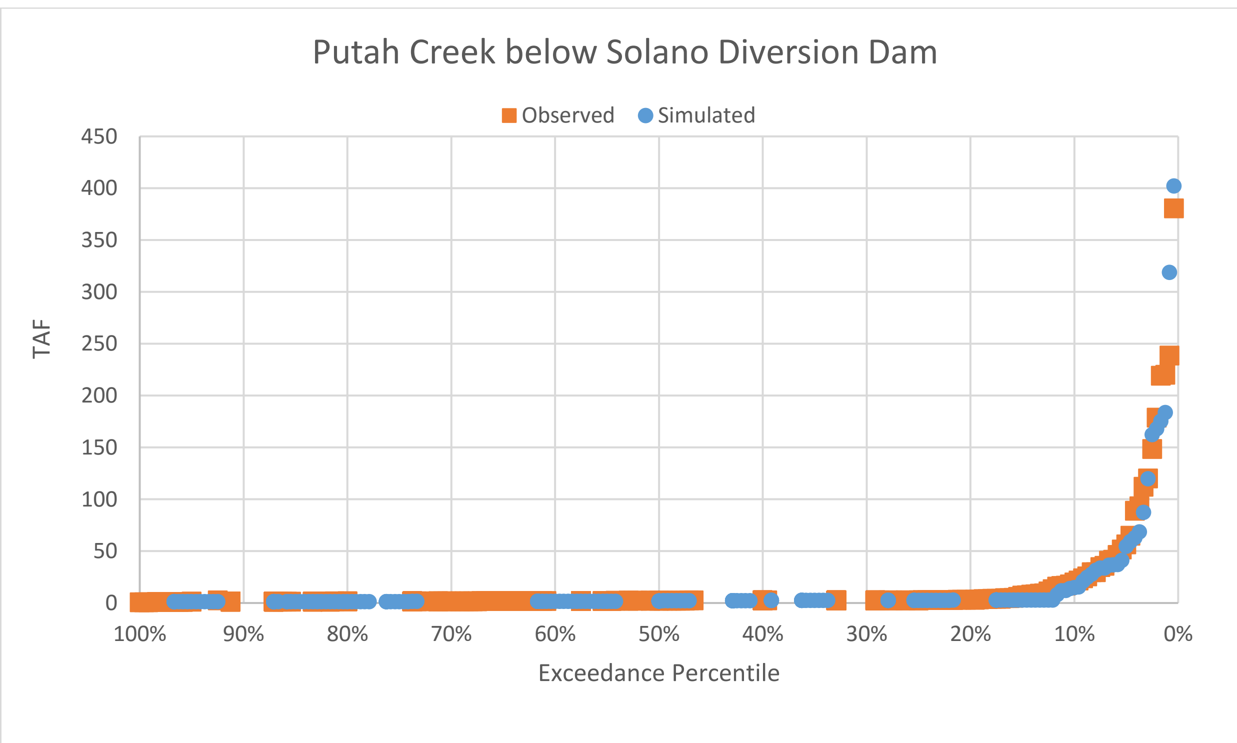

Figure B.7.5c Putah Creek below Solano Diversion Dam, Exceedance

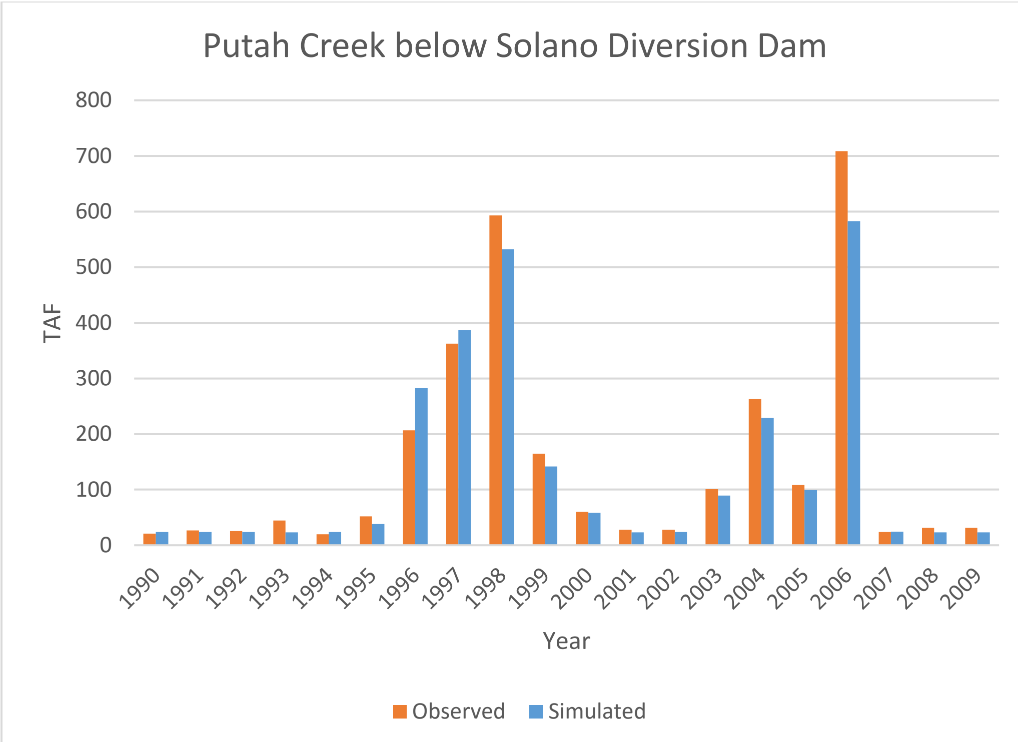

Figure B.7.5d Putah Creek below Solano Diversion Dam, Annual 1990 to 2009

B.7.6 Mokelumne River at Woodbridge

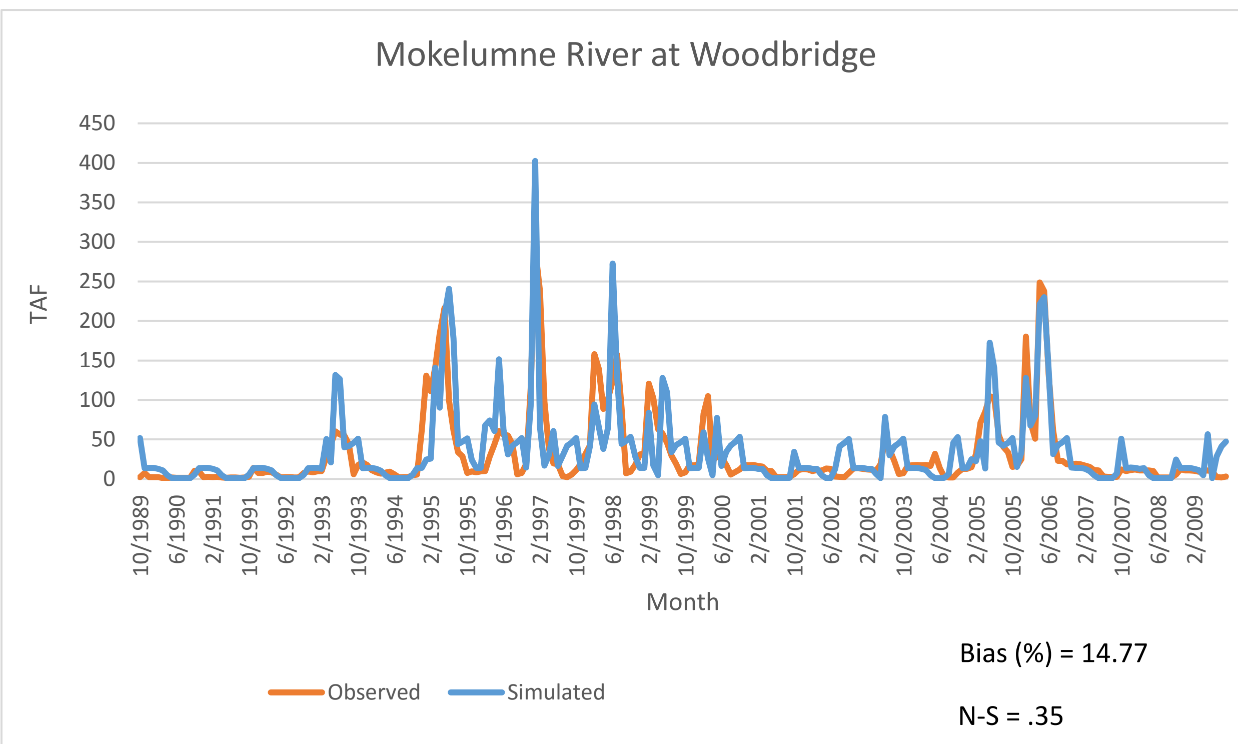

Figure B.7.6a Mokelumne River at Woodbridge, Monthly 1990 to 2009

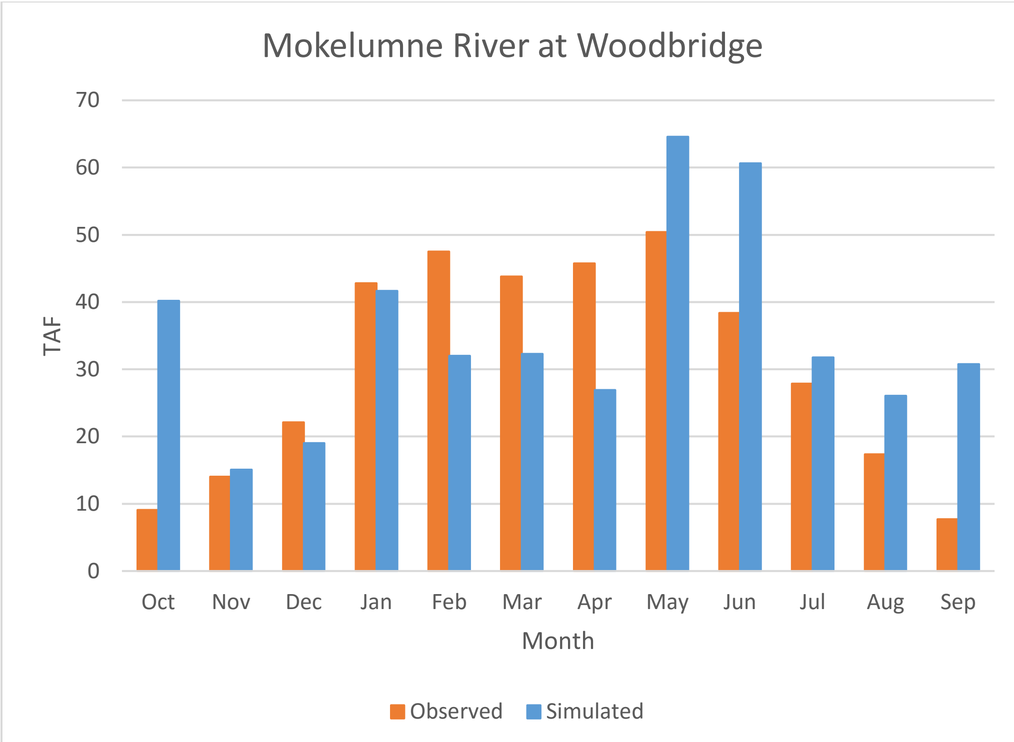

Figure B.7.6b Mokelumne River at Woodbridge, Average Monthly

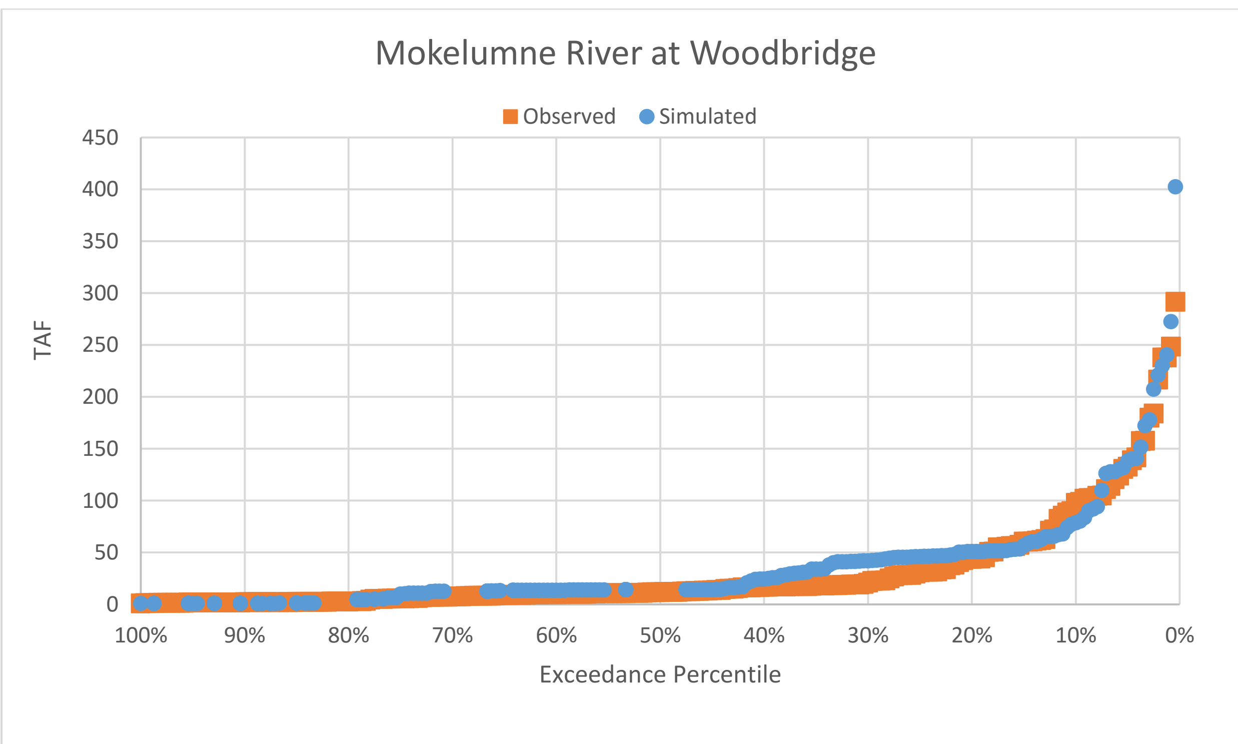

Figure B.7.6c Mokelumne River at Woodbridge, Exceedance

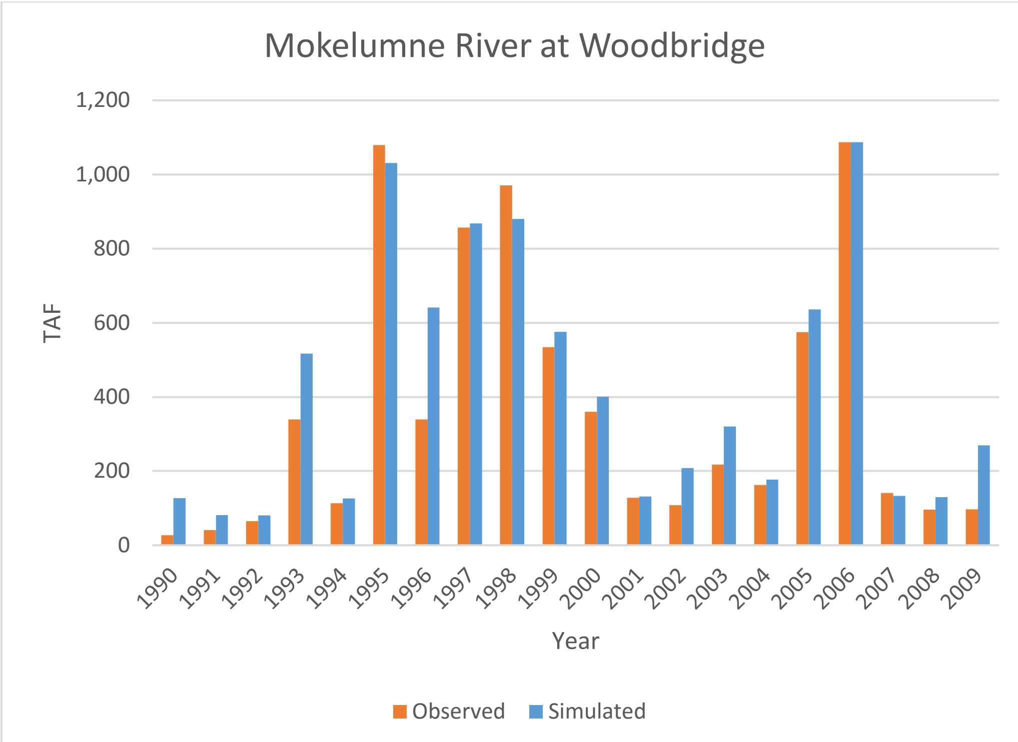

Figure B.7.6d Mokelumne River at Woodbridge, Annual 1990 to 2009

B.7.7 Calaveras River below New Hogan Dam

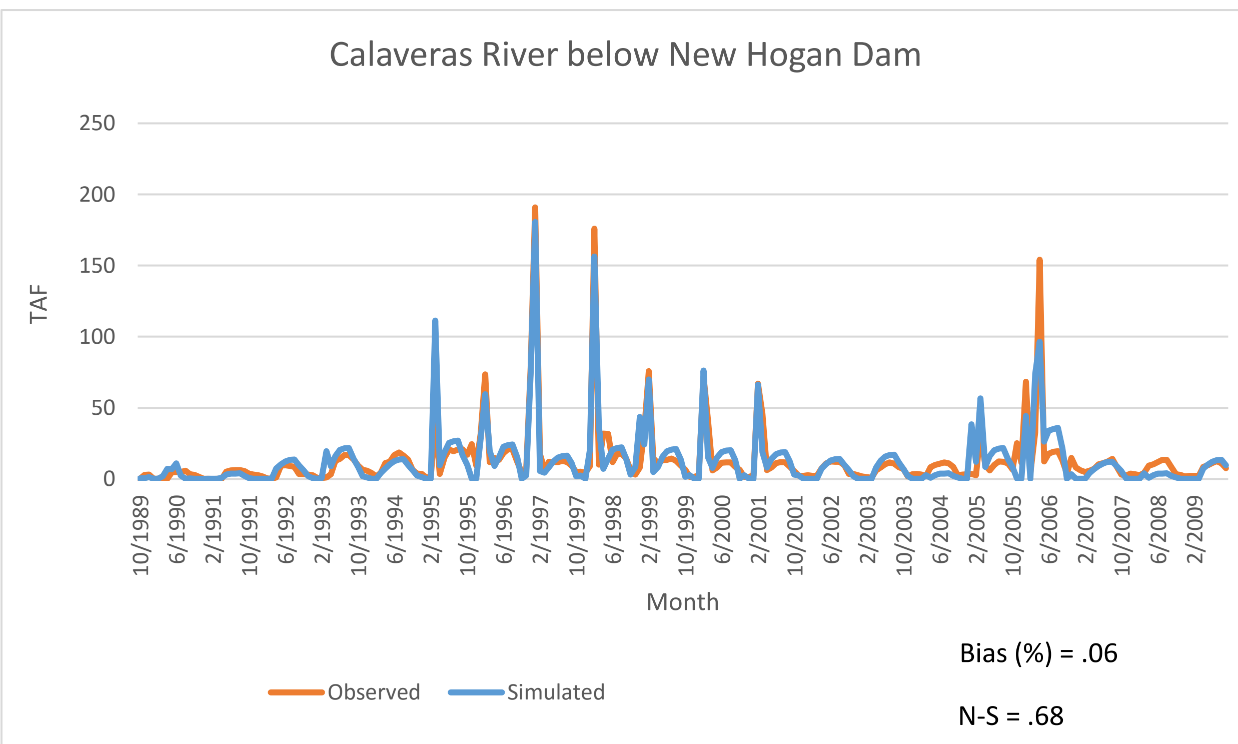

Figure B.7.7a Calaveras River below New Hogan Dam, Monthly 1990 to 2009

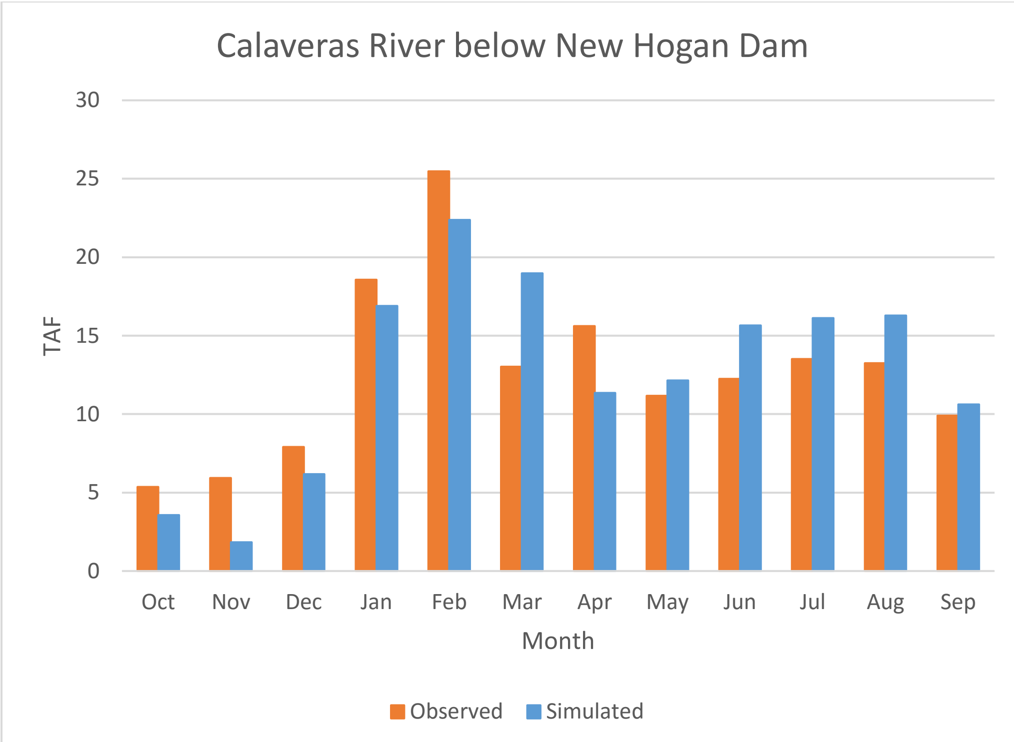

Figure B.7.7b Calaveras River below New Hogan Dam, Average Monthly

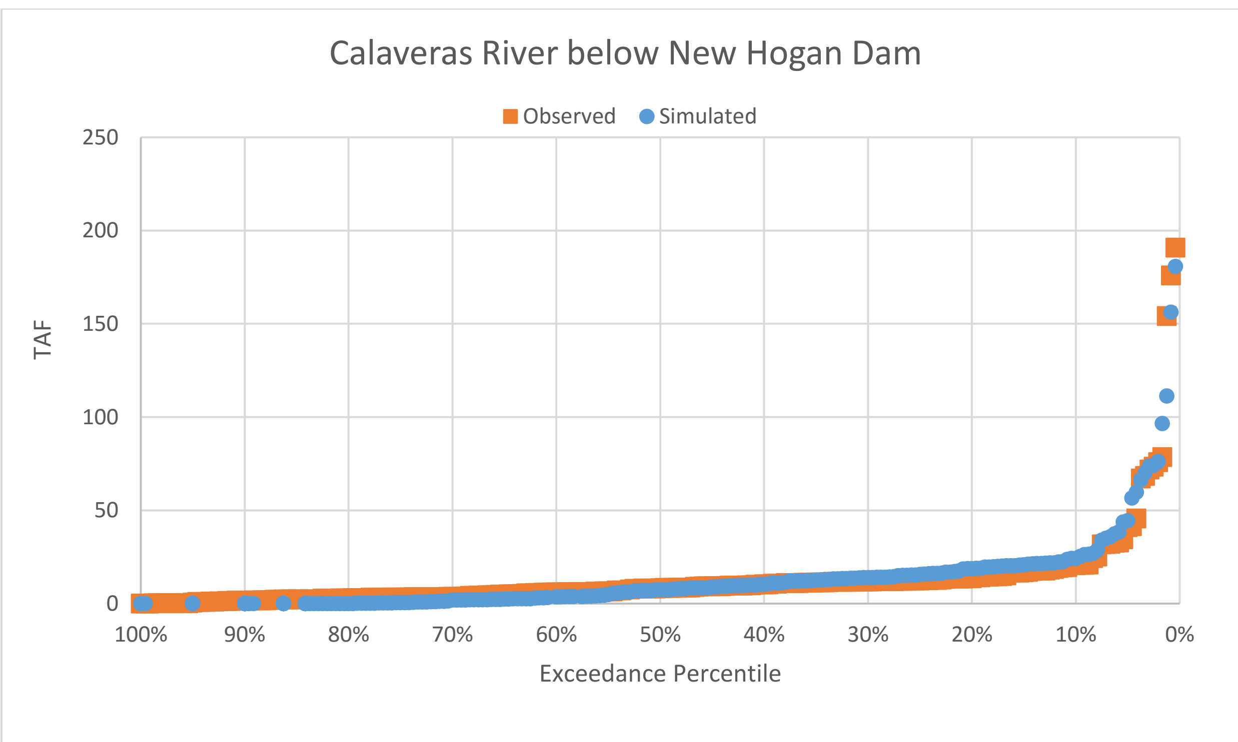

Figure B.7.7c Calaveras River below New Hogan Dam, Exceedance

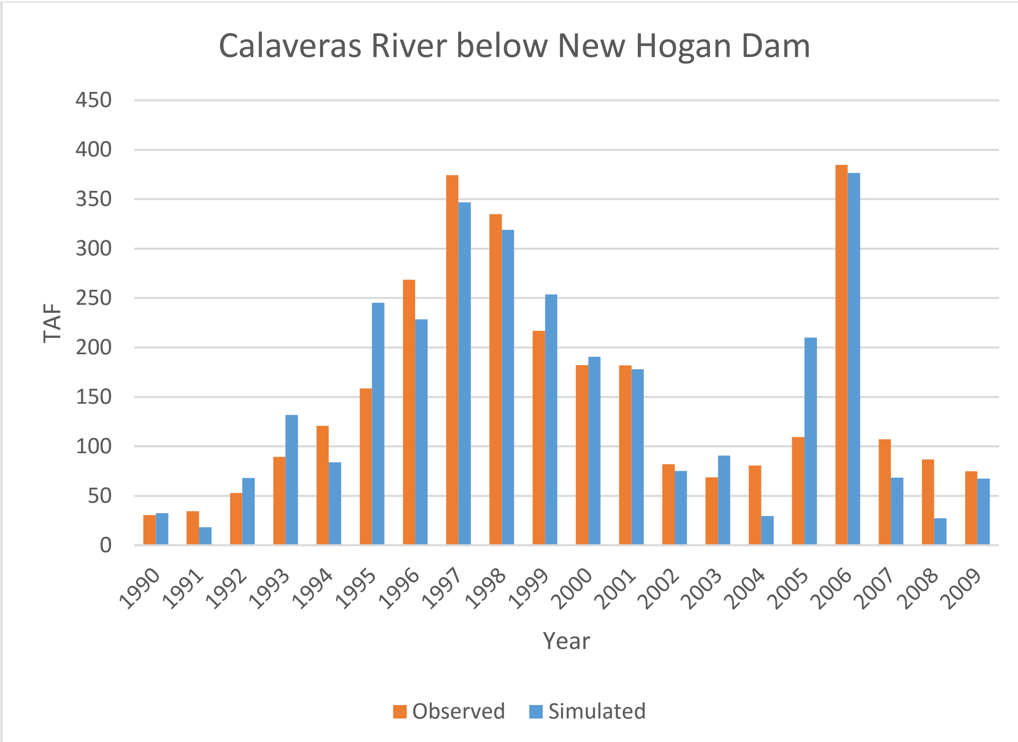

Figure B.7.7d Calaveras River below New Hogan Dam, Annual 1990 to 2009

B.8 Non-Project Reservoir Storage Validation

B.8.1 New Bullards Bar Storage

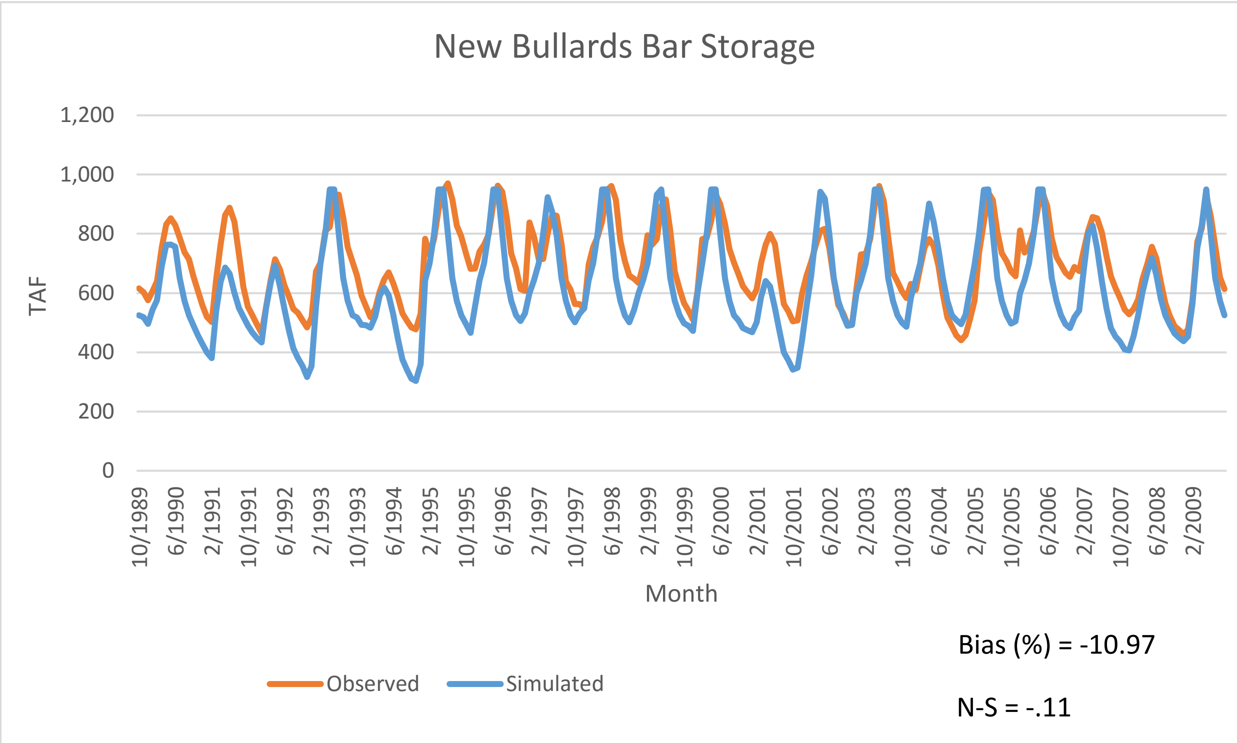

Figure B.8.1a New Bullards Bar Storage, Monthly 1990 to 2009

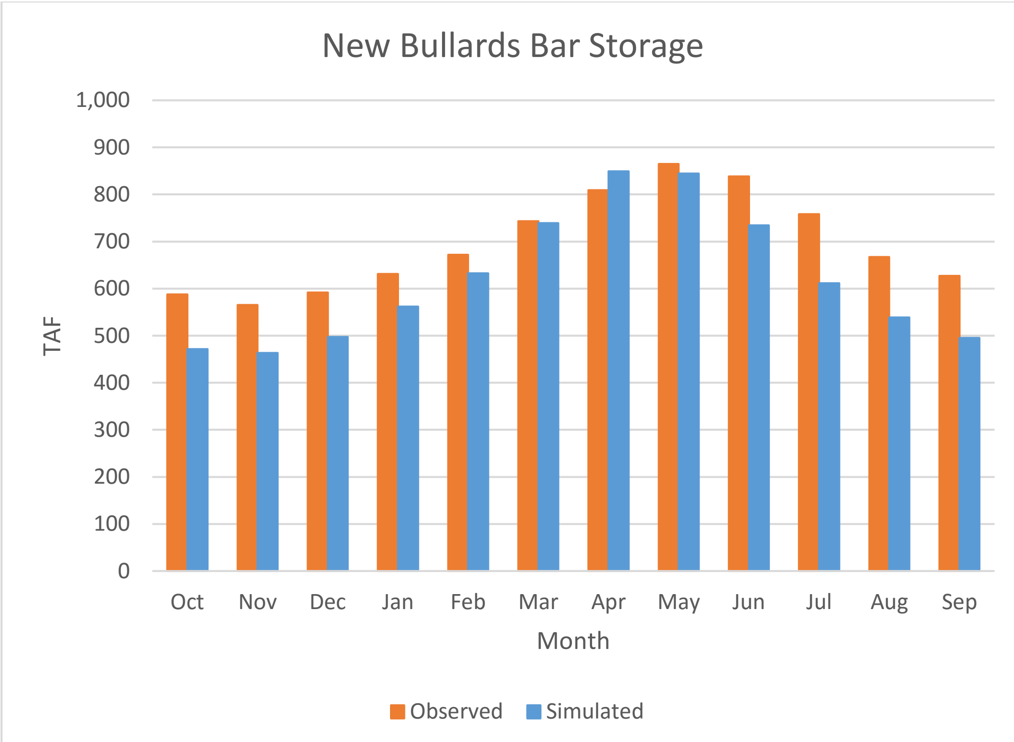

Figure B.8.1b New Bullards Bar Storage, Average Monthly

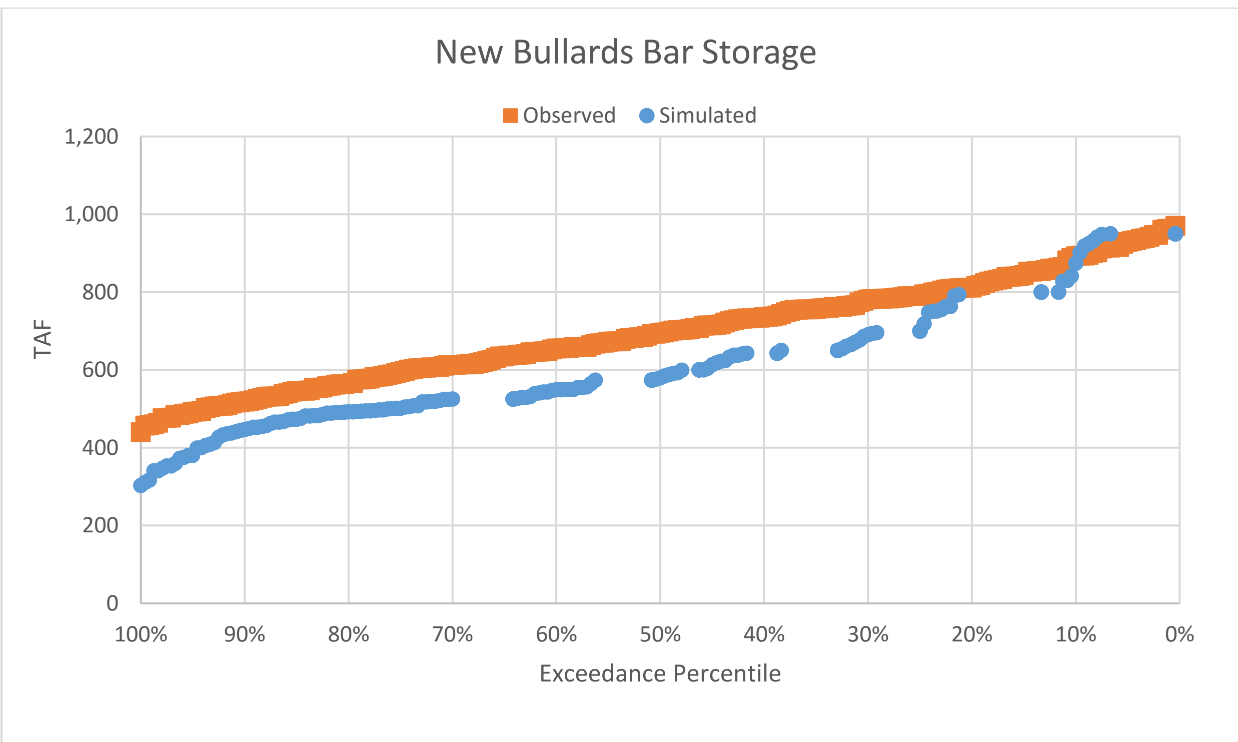

Figure B.8.1c New Bullards Bar Storage, Exceedance

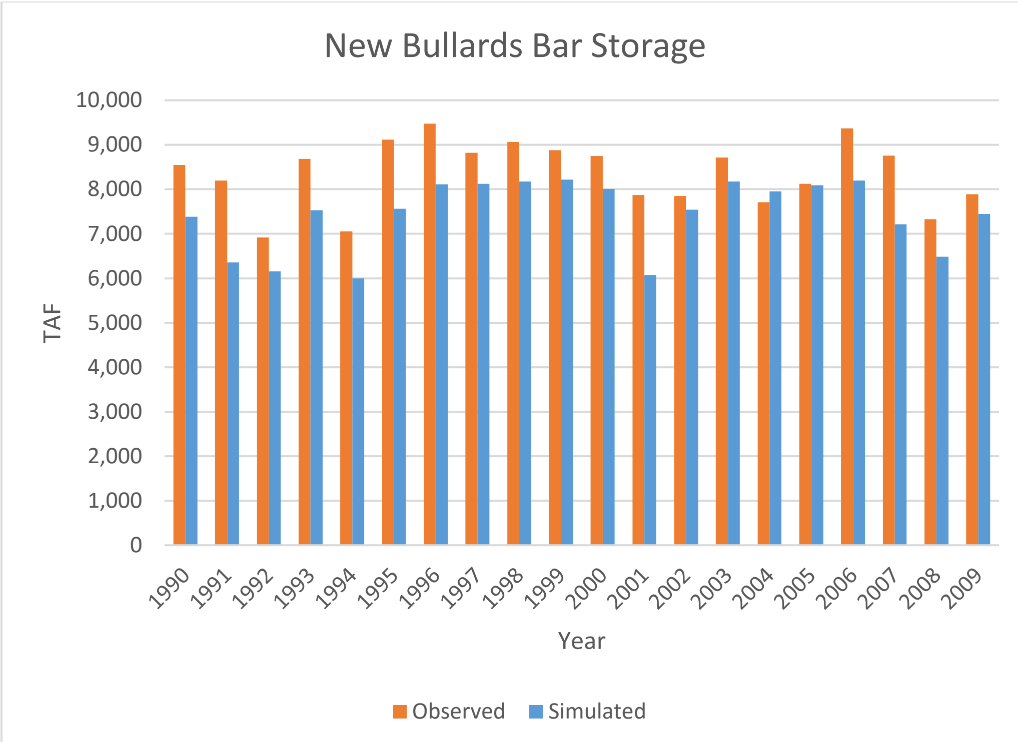

Figure B.8.1d New Bullards Bar Storage, Annual 1990 to 2009

B.8.2 Camp Far West Storage

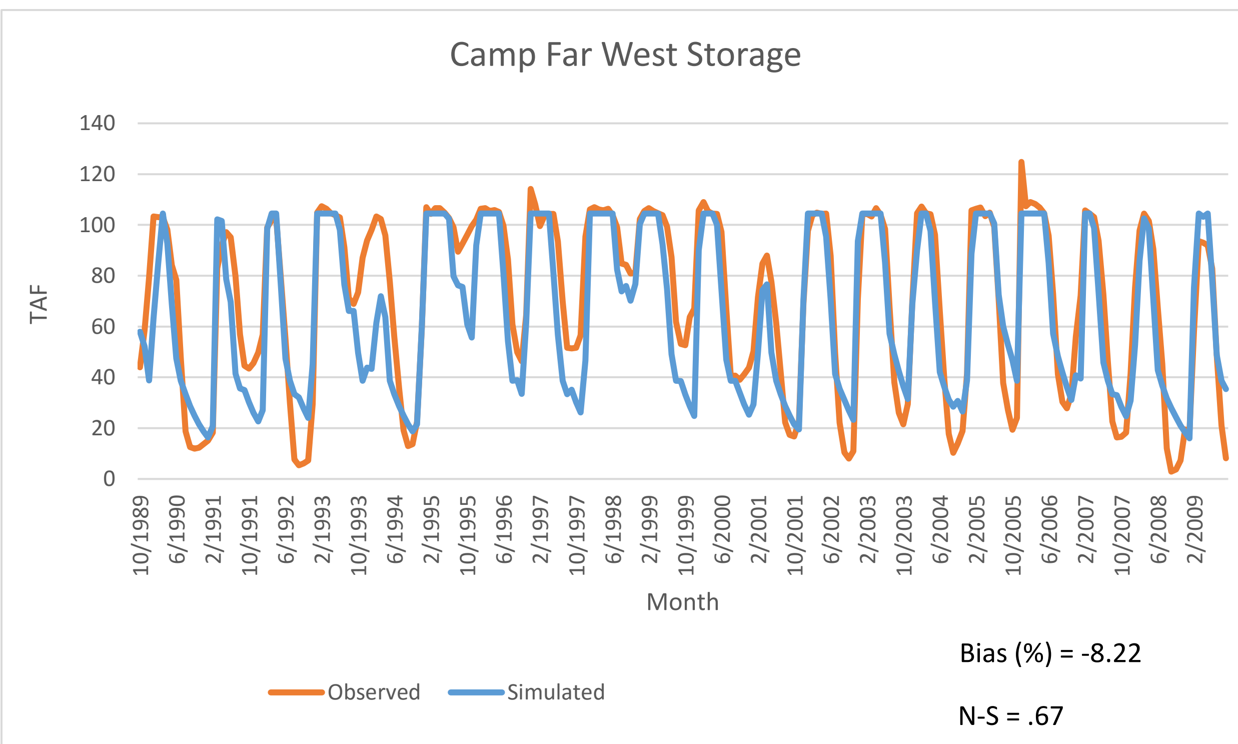

Figure B.8.2a Camp Far West Storage, Monthly 1990 to 2009

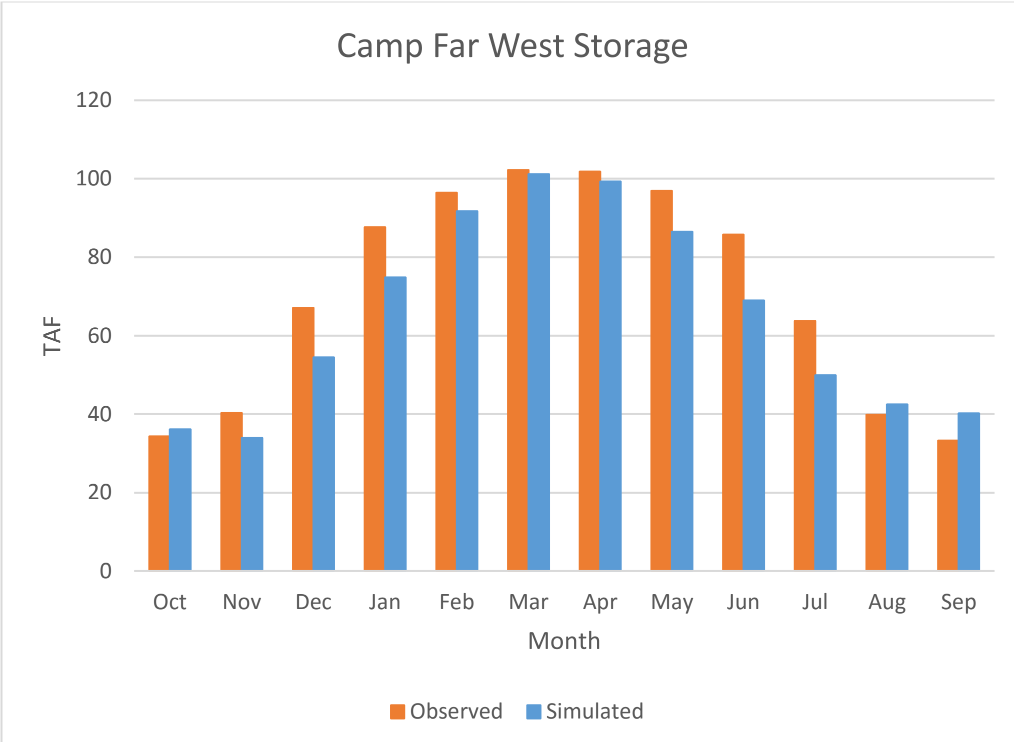

Figure B.8.2b Camp Far West Storage, Average Monthly

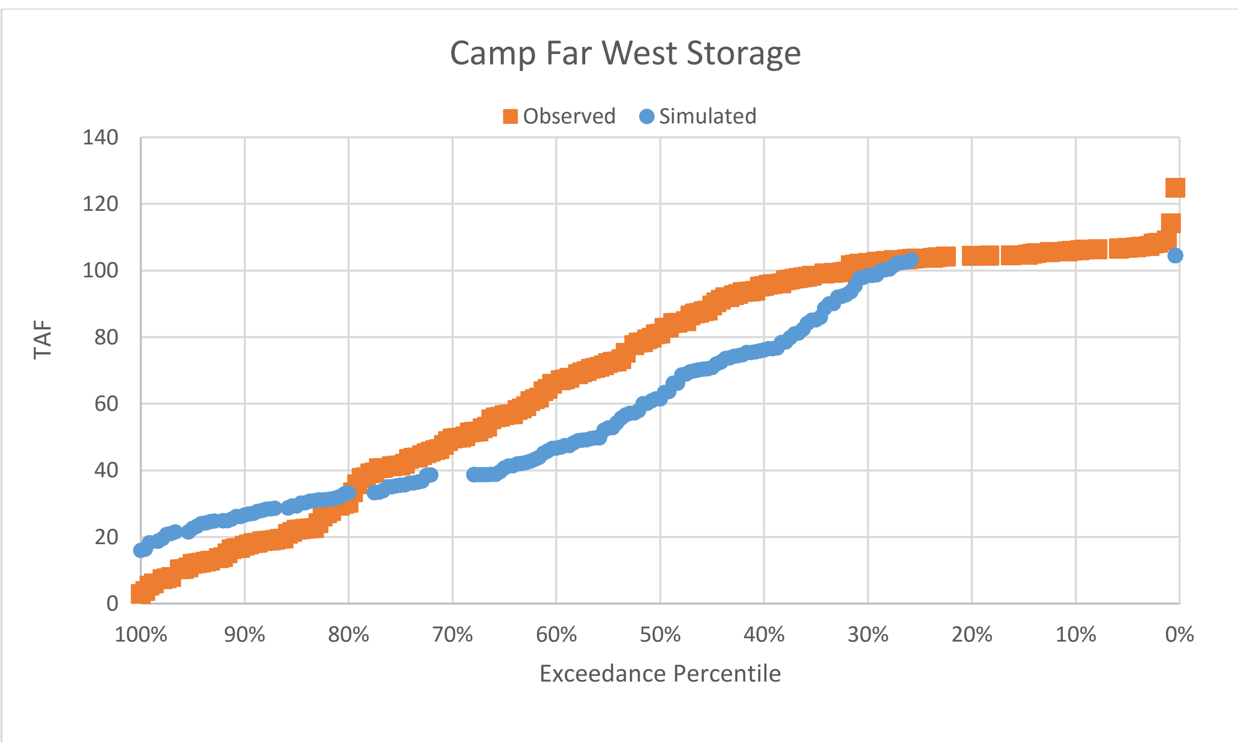

Figure B.8.2c Camp Far West Storage, Exceedance

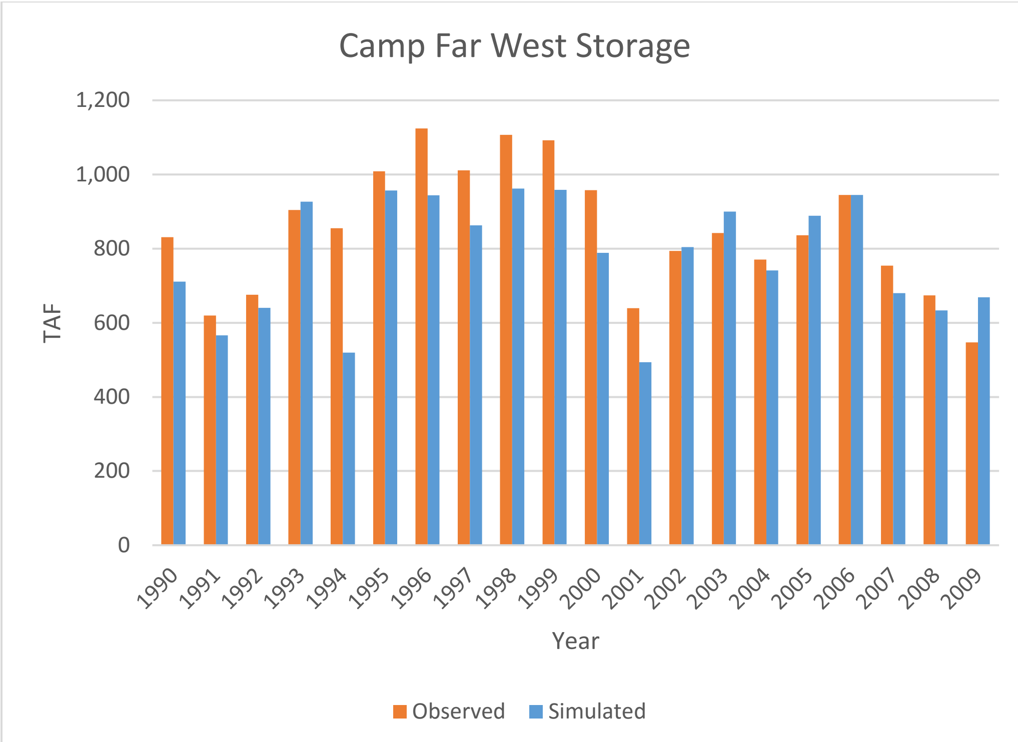

Figure B.8.2d Camp Far West Storage, Annual 1990 to 2009

B.8.3 Black Butte Storage

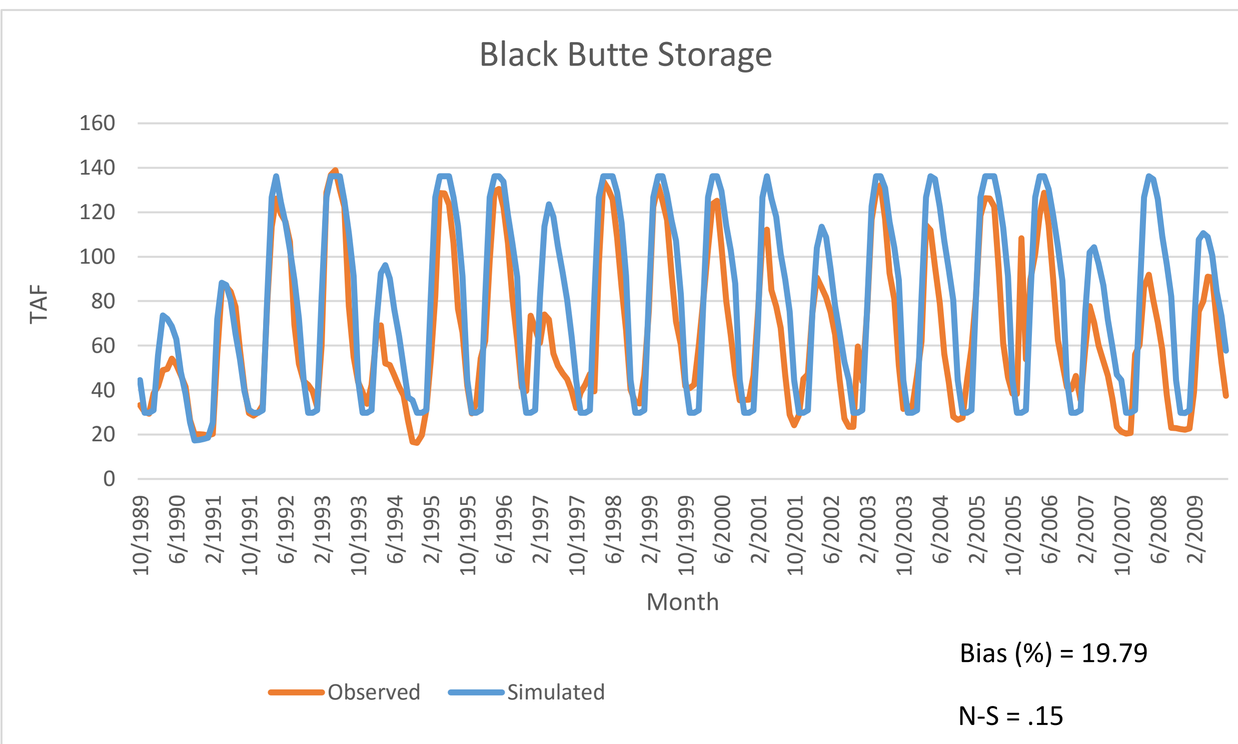

Figure B.8.3a Black Butte Storage, Monthly 1990 to 2009

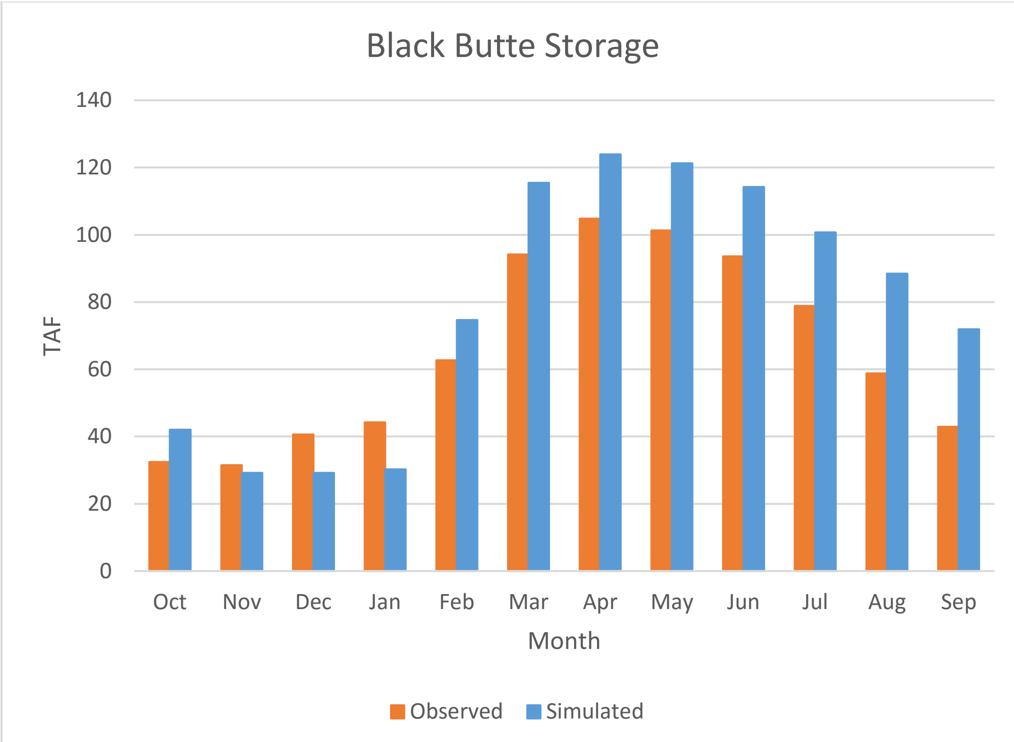

Figure B.8.3b Black Butte Storage, Average Monthly

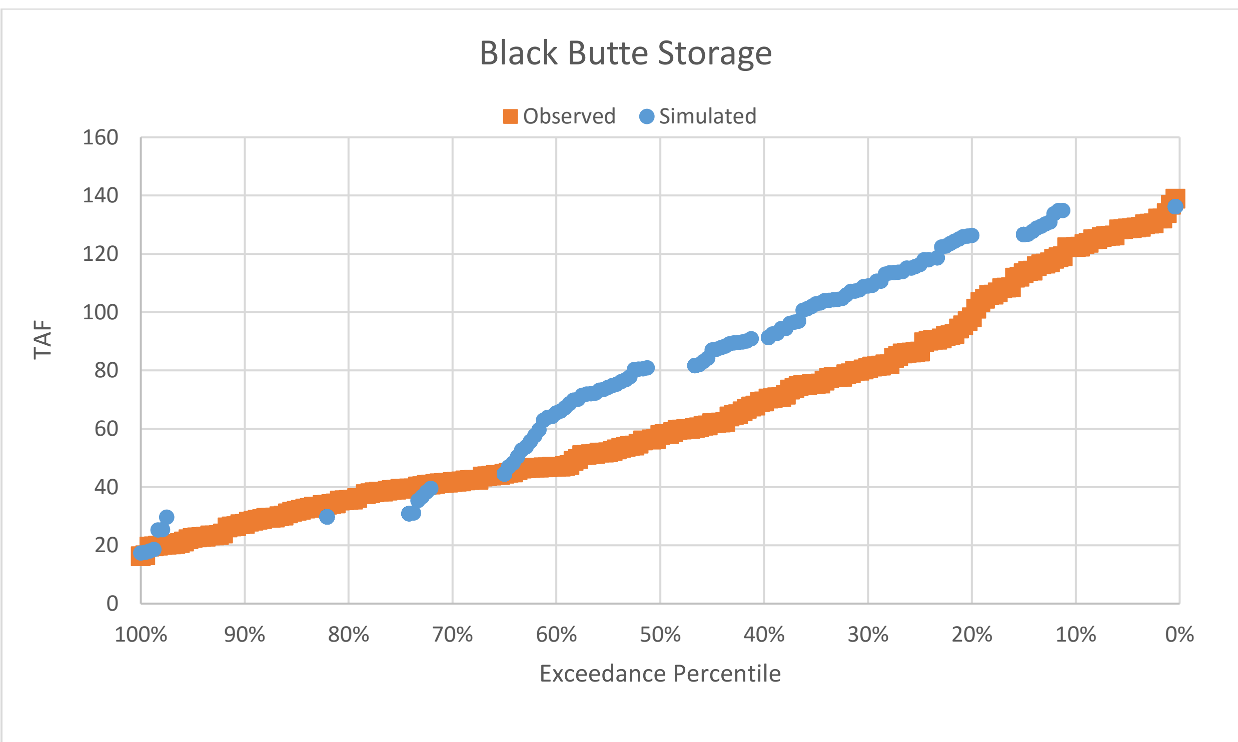

Figure B.8.3c Black Butte Storage, Exceedance

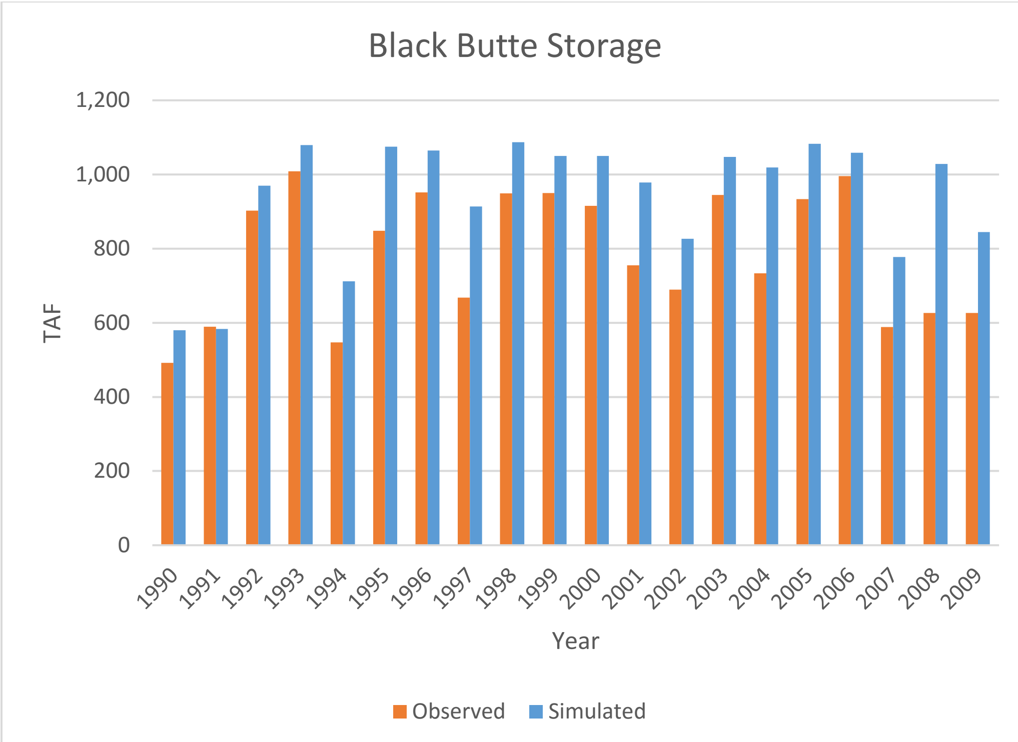

Figure B.8.3d Black Butte Storage, Annual 1990 to 2009

B.8.4 Clear Lake Storage

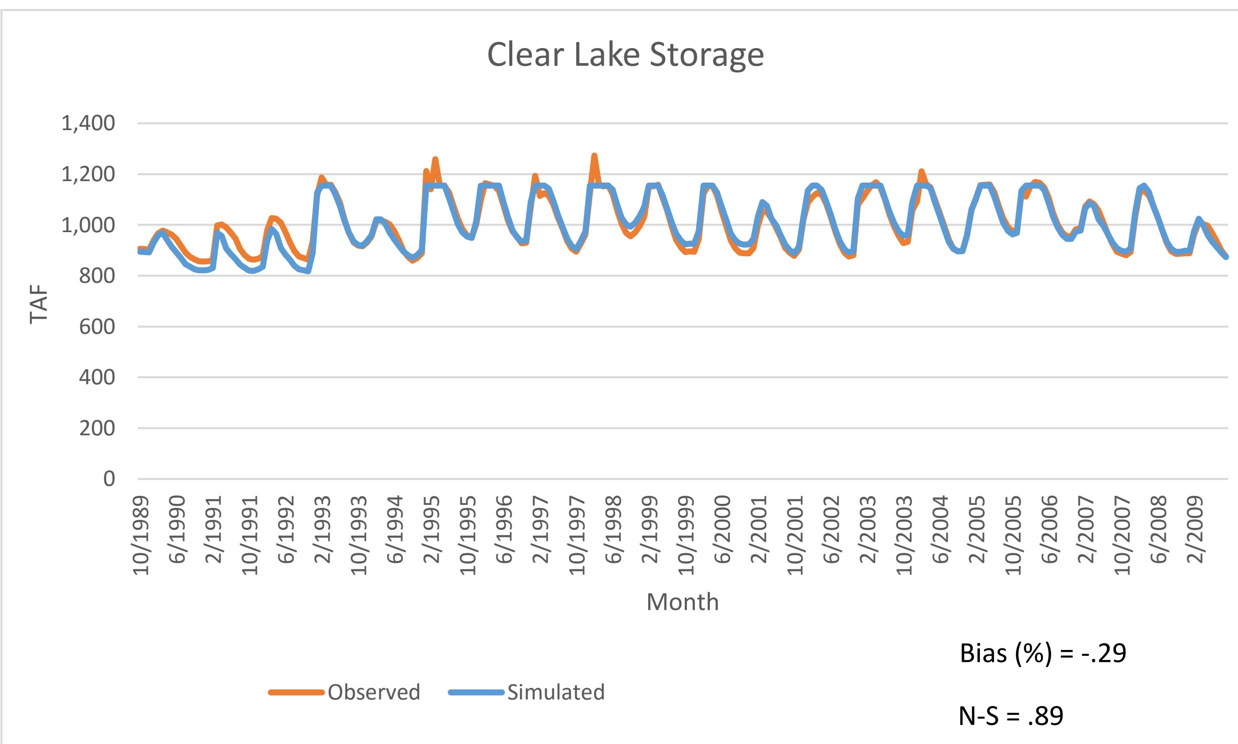

Figure B.8.4a Clear Lake Storage, Monthly 1990 to 2009

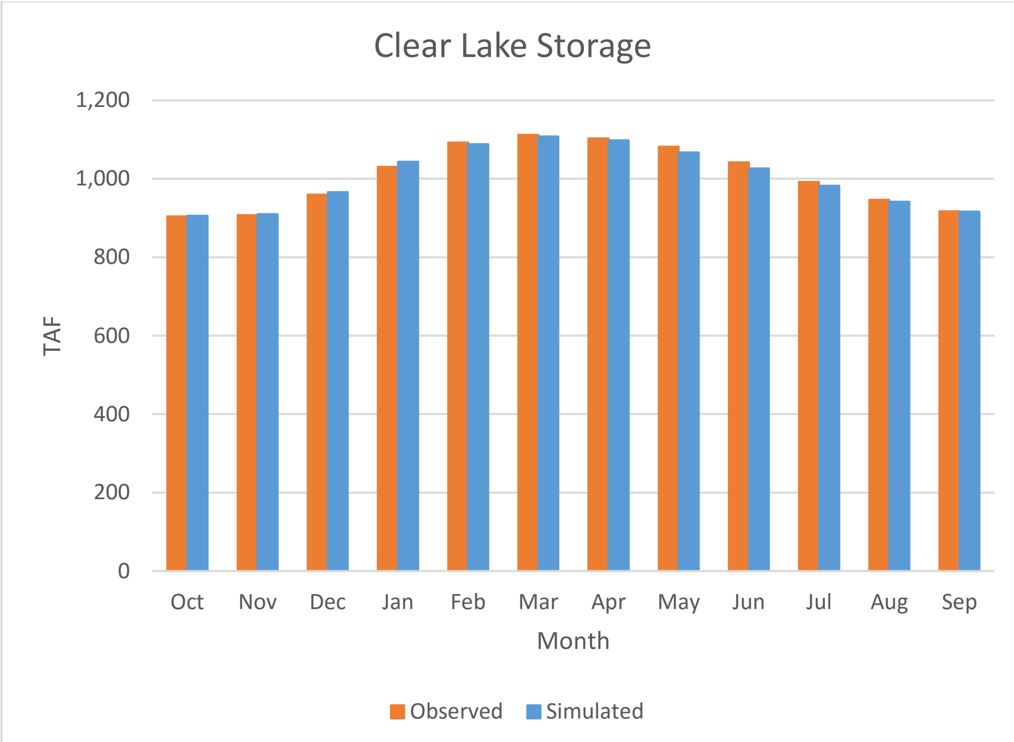

Figure B.8.4b Clear Lake Storage, Average Monthly

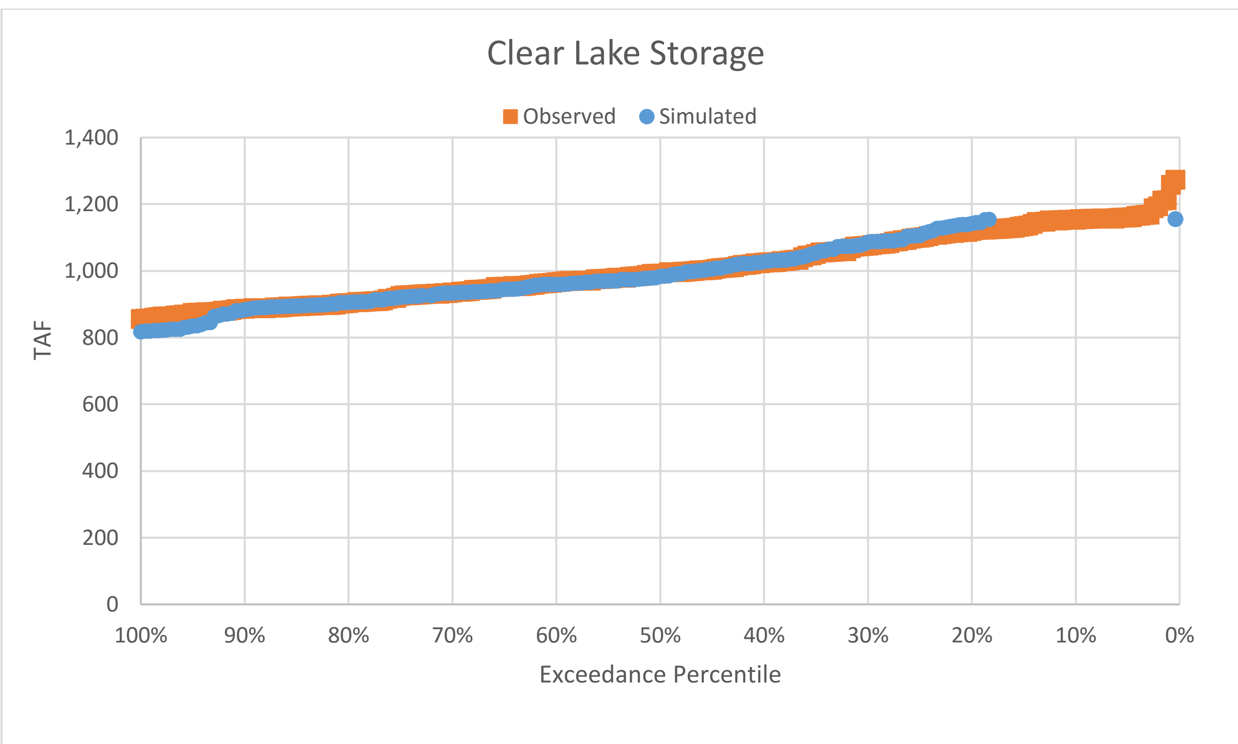

Figure B.8.4c Clear Lake Storage, Exceedance

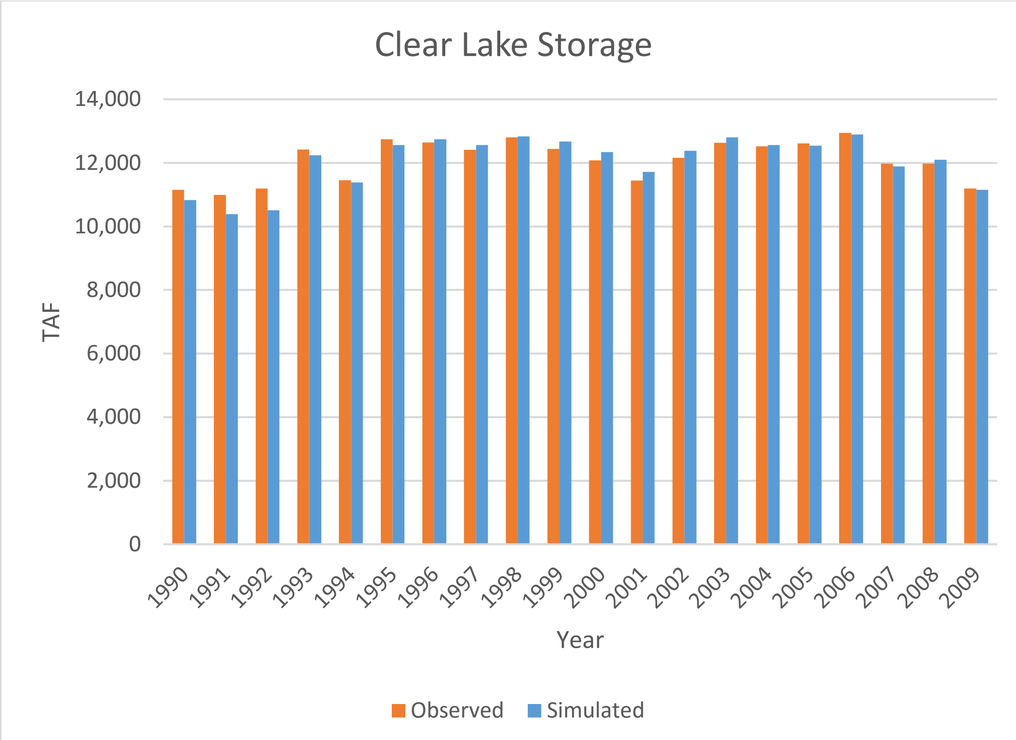

Figure B.8.4d Clear Lake Storage, Annual 1990 to 2009

B.8.5 Indian Valley Storage

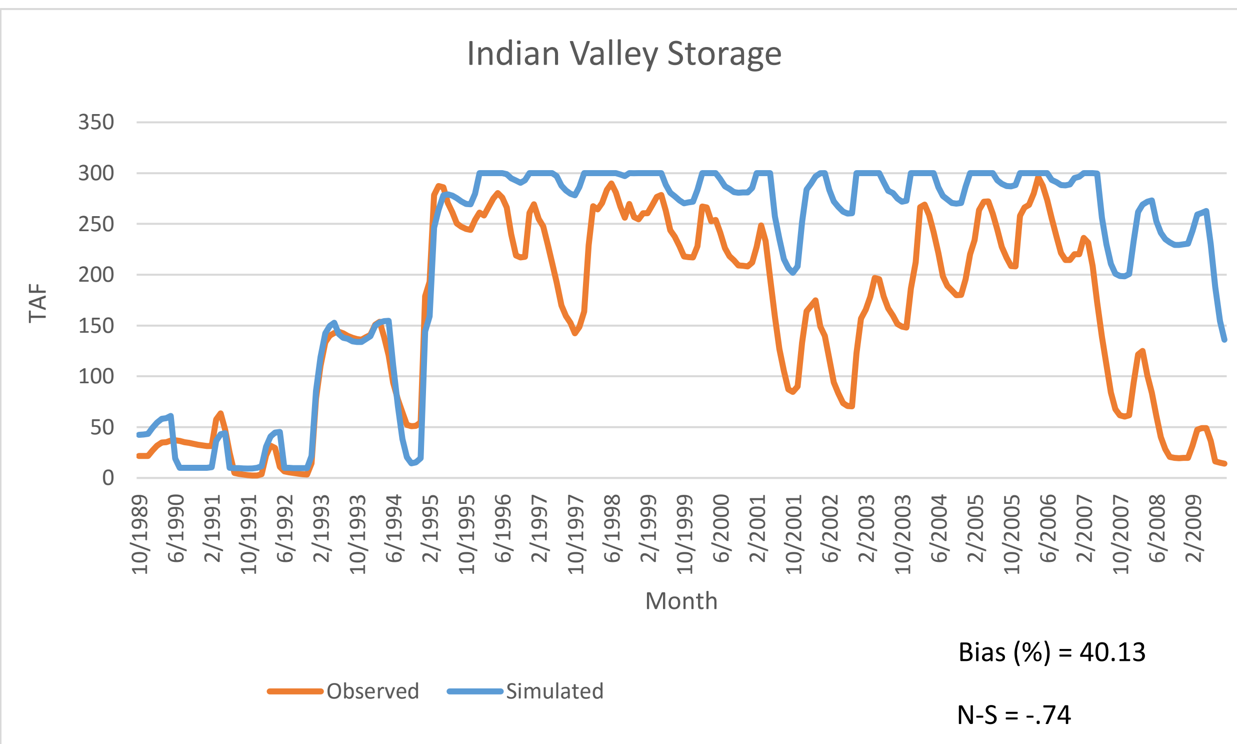

Figure B.8.5a Indian Valley Storage, Monthly 1990 to 2009

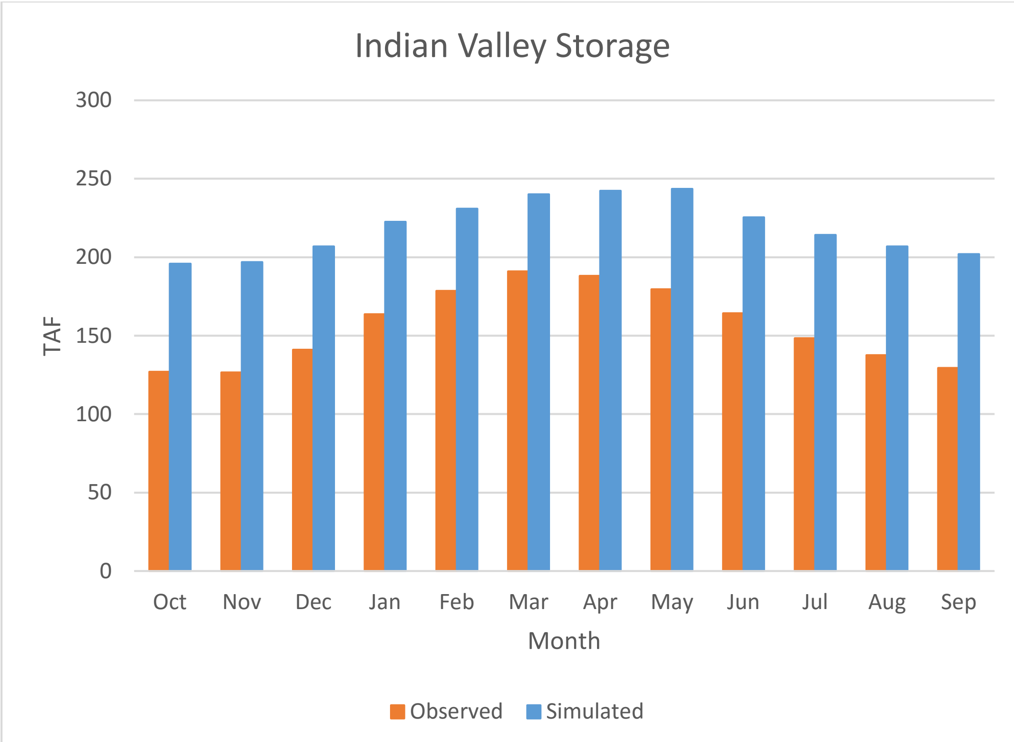

Figure B.8.5b Indian Valley Storage, Average Monthly

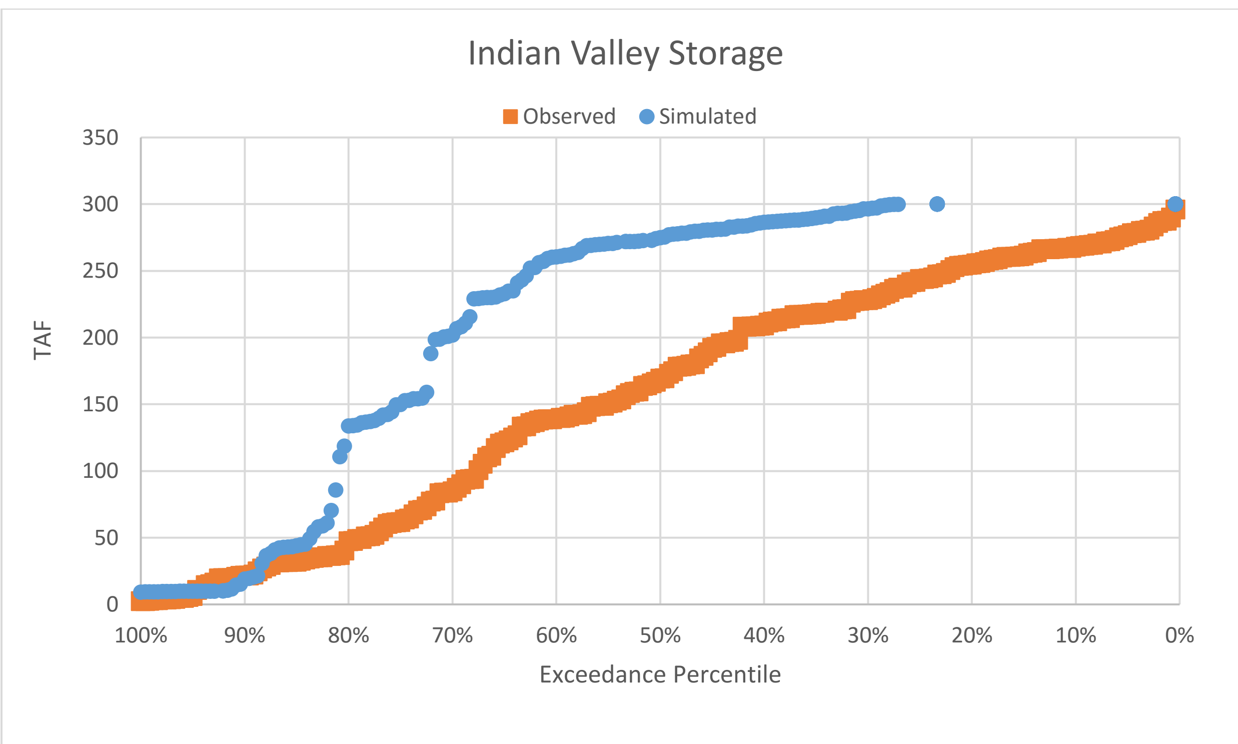

Figure B.8.5c Indian Valley Storage, Exceedance

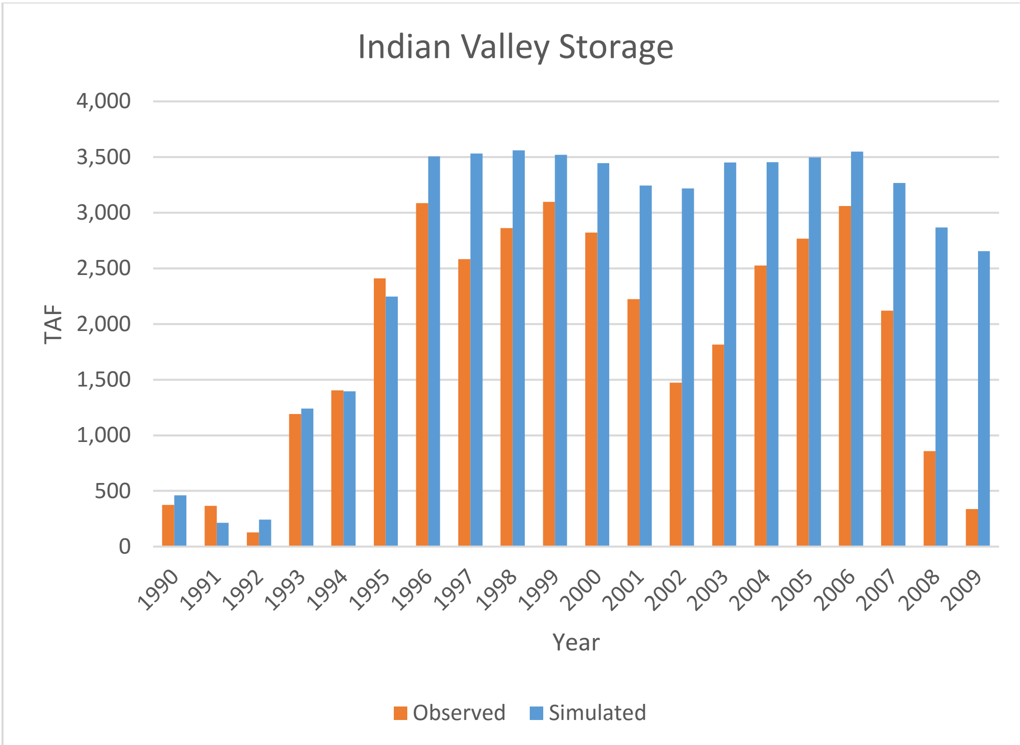

Figure B.8.5d Indian Valley Storage, Annual 1990 to 2009

B.8.6 Lake Berryessa Storage

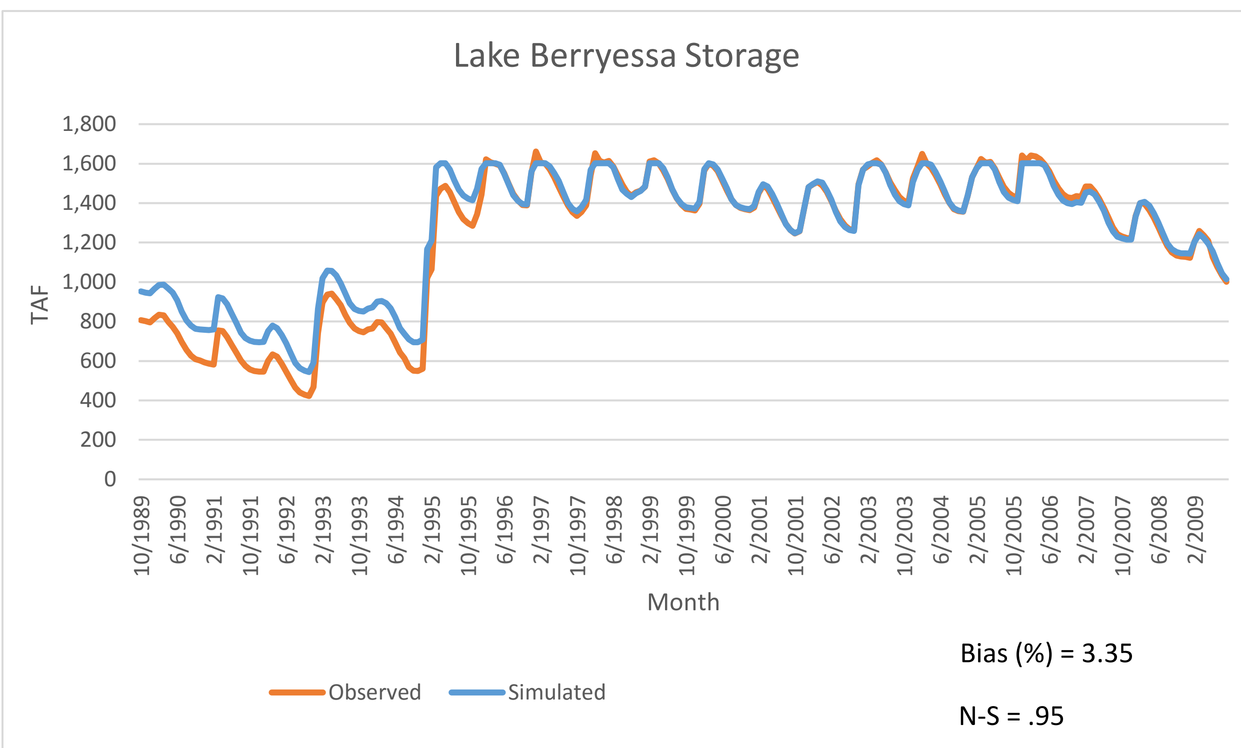

Figure B.8.6a Lake Berryessa Storage, Monthly 1990 to 2009

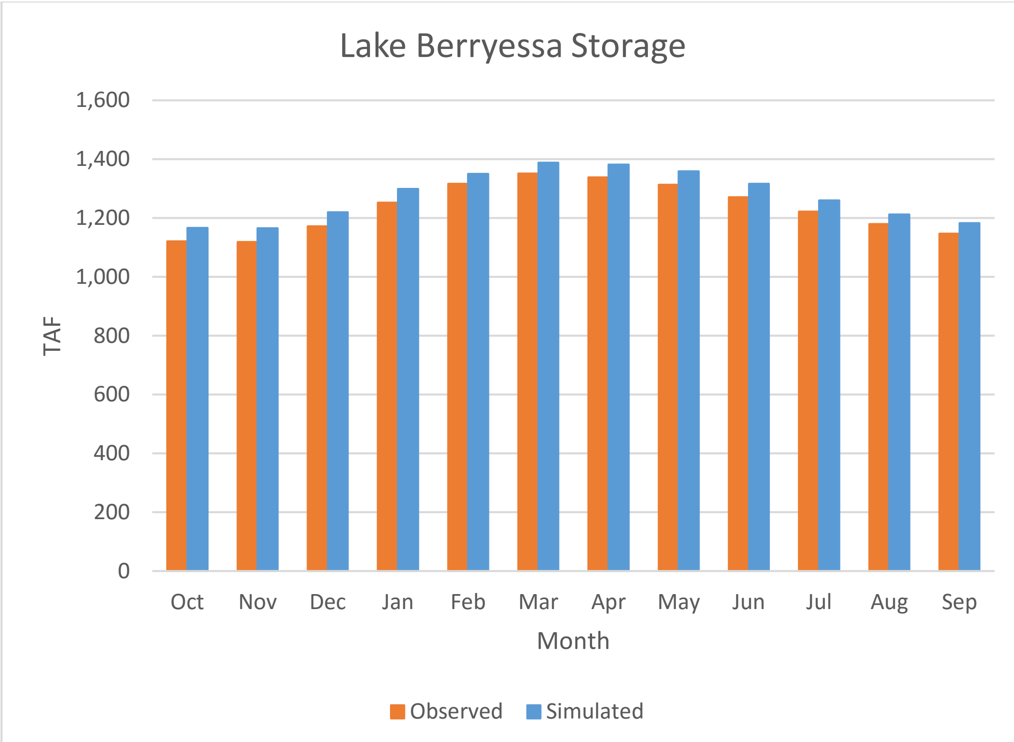

Figure B.8.6b Lake Berryessa Storage, Average Monthly

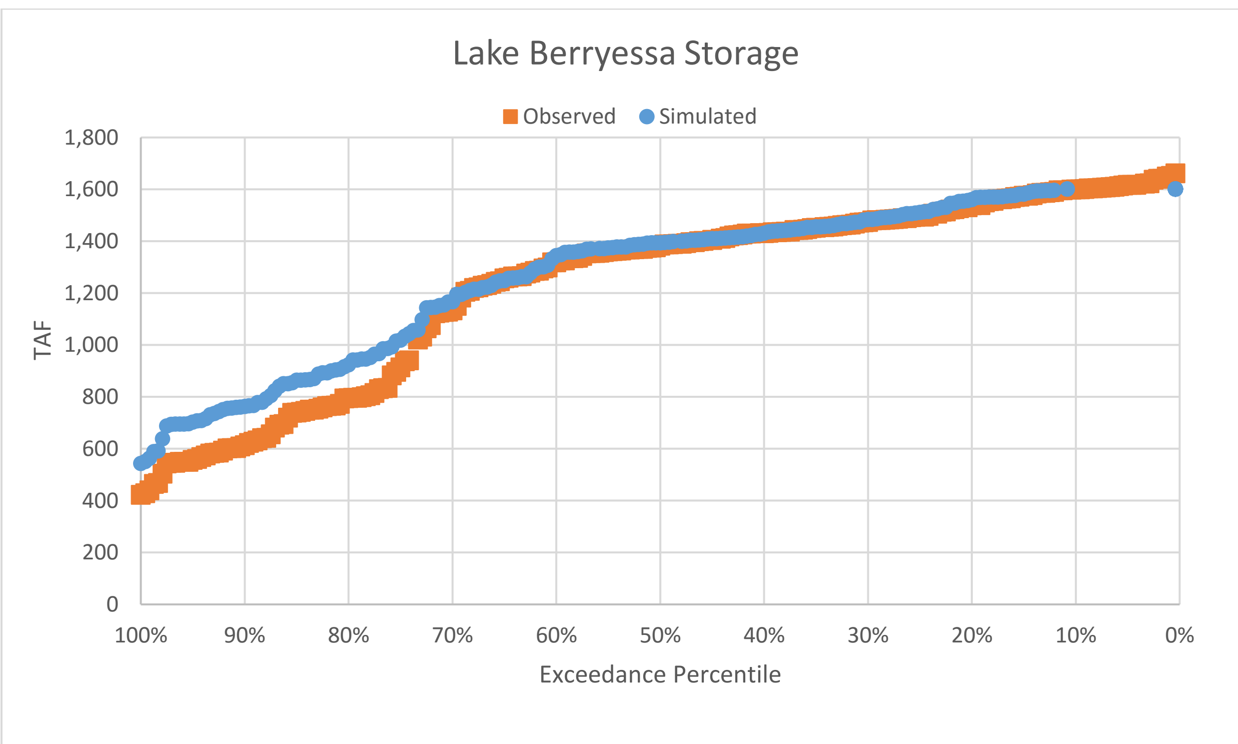

Figure B.8.6c Lake Berryessa Storage, Exceedance

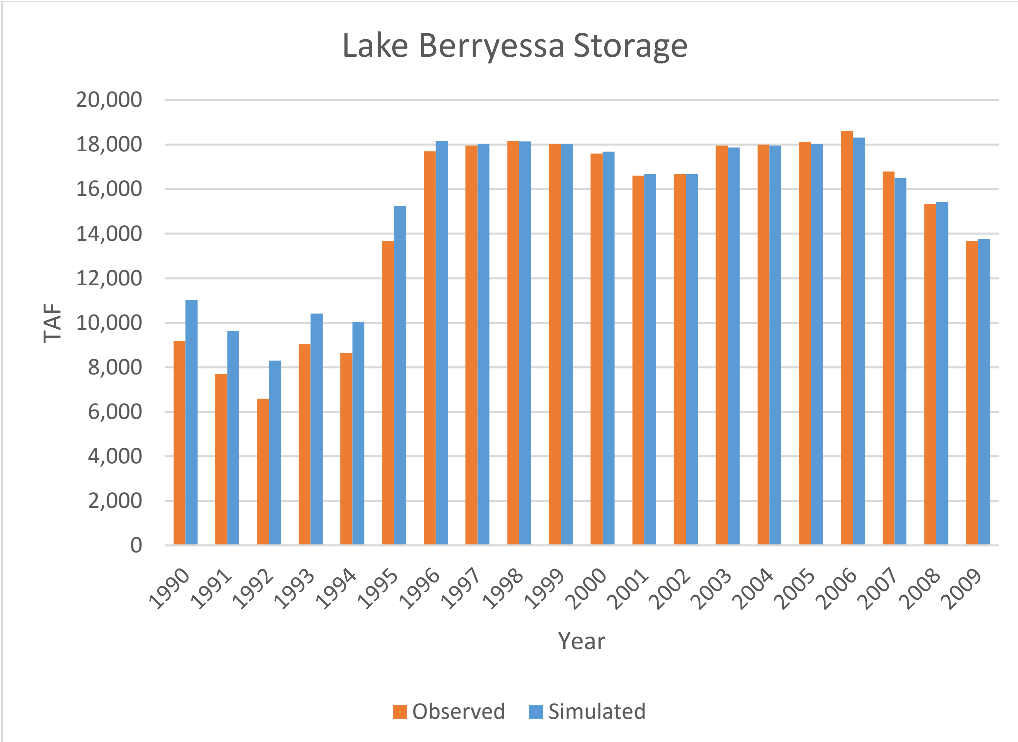

Figure B.8.6d Lake Berryessa Storage, Annual 1990 to 2009

B.8.7 Camanche Reservoir Storage

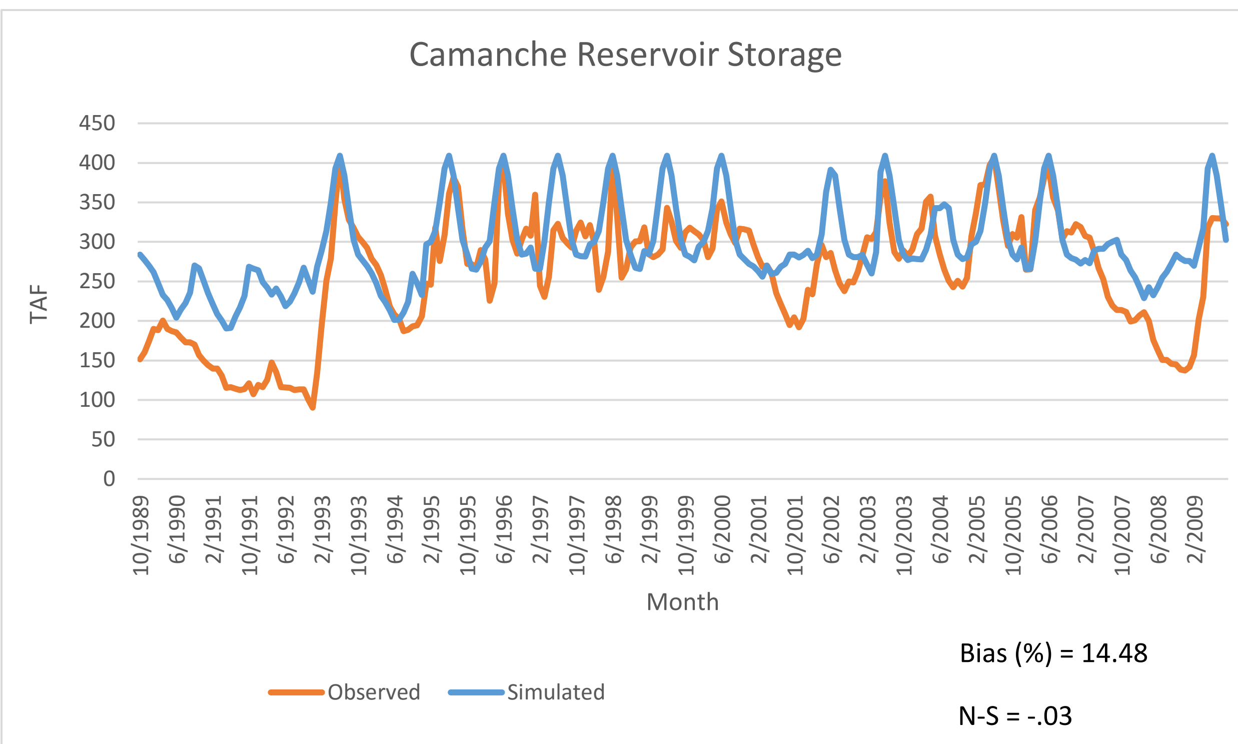

Figure B.8.7a Camanche Reservoir Storage, Monthly 1990 to 2009

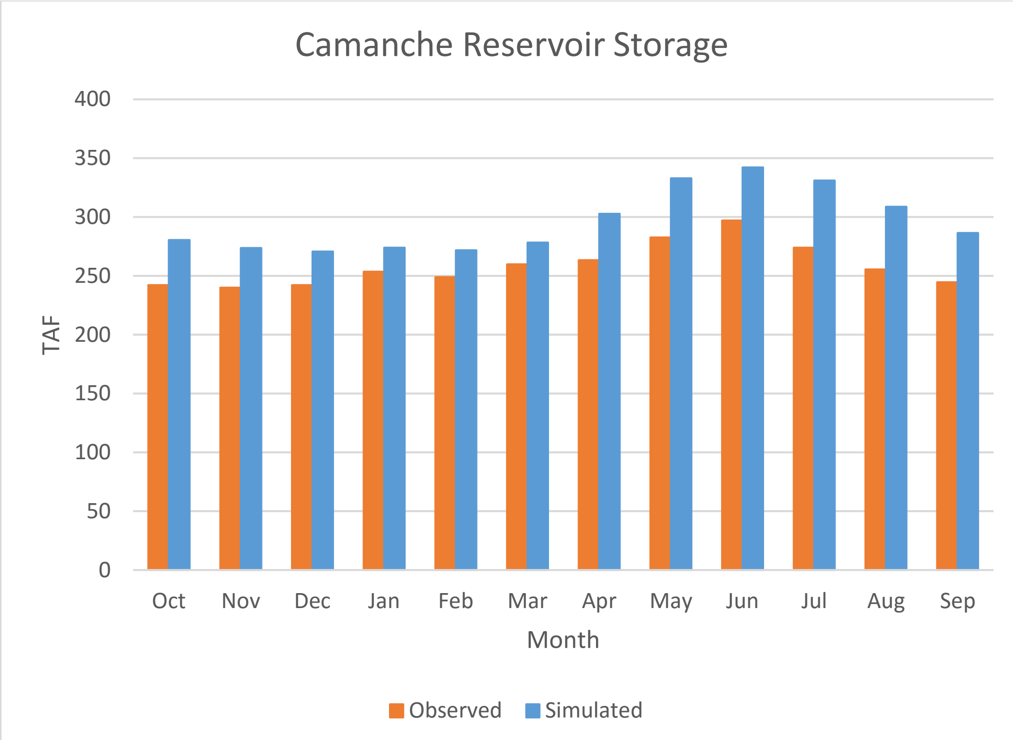

Figure B.8.7b Camanche Reservoir Storage, Average Monthly

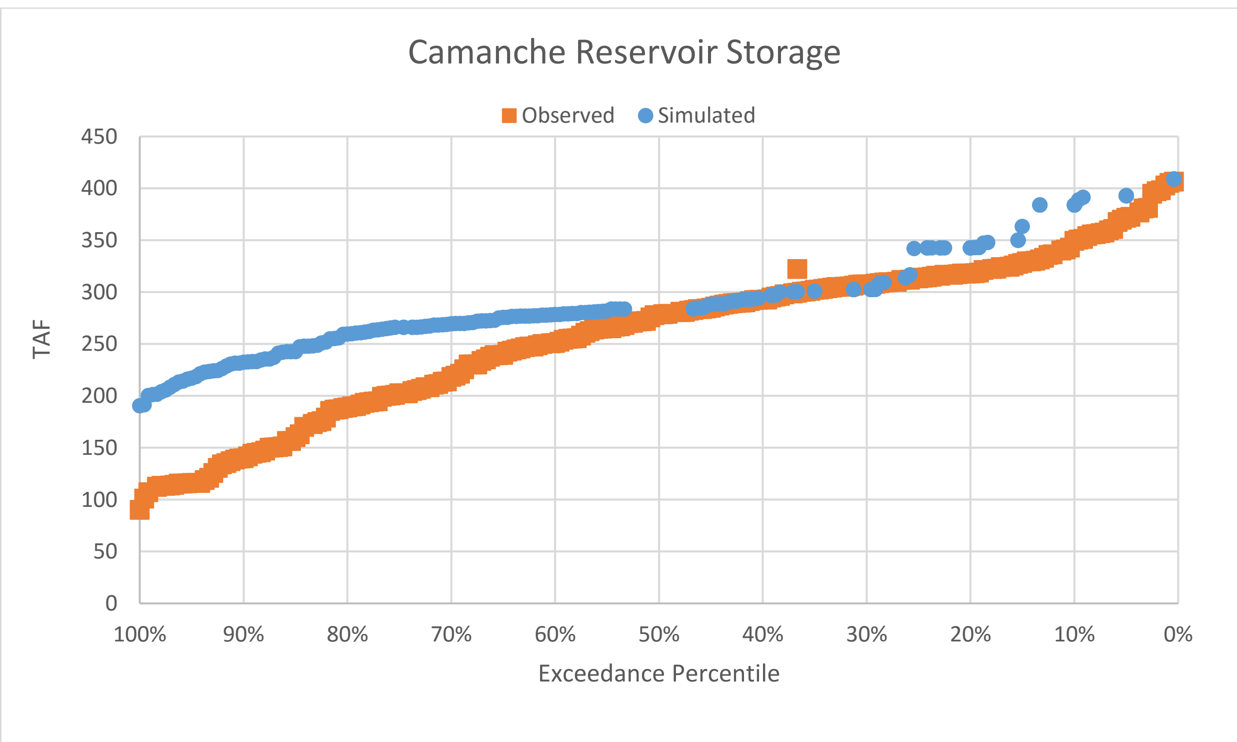

Figure B.8.7c Camanche Reservoir Storage, Exceedance

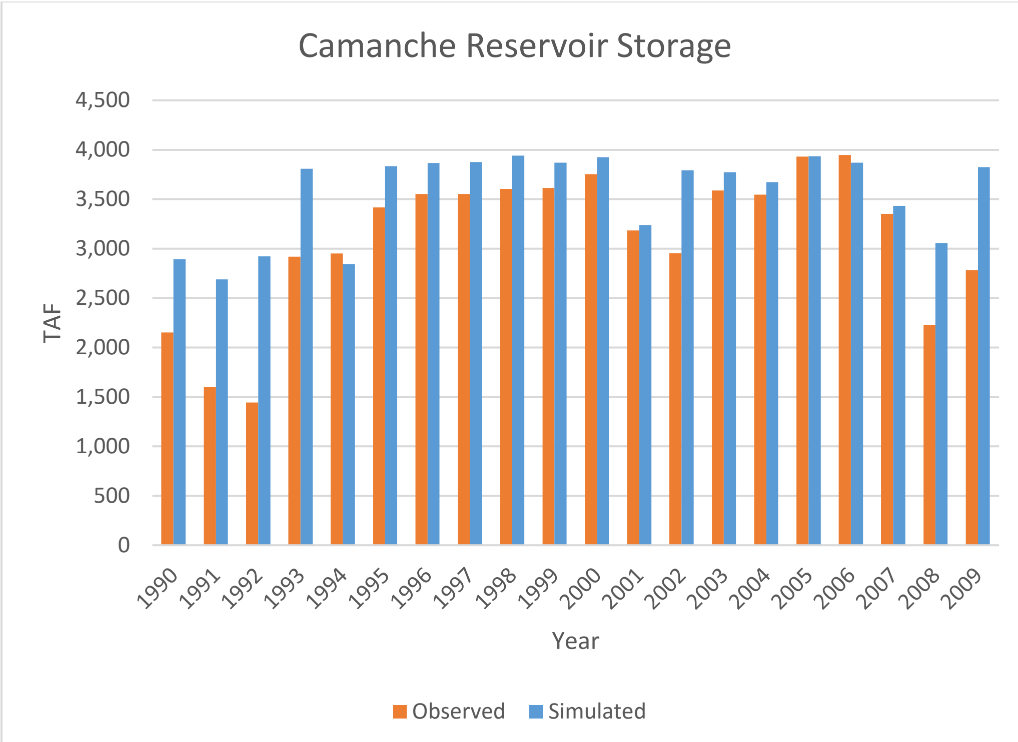

Figure B.8.7d Camanche Reservoir Storage, Annual 1990 to 2009

B.8.8 New Hogan Lake Storage

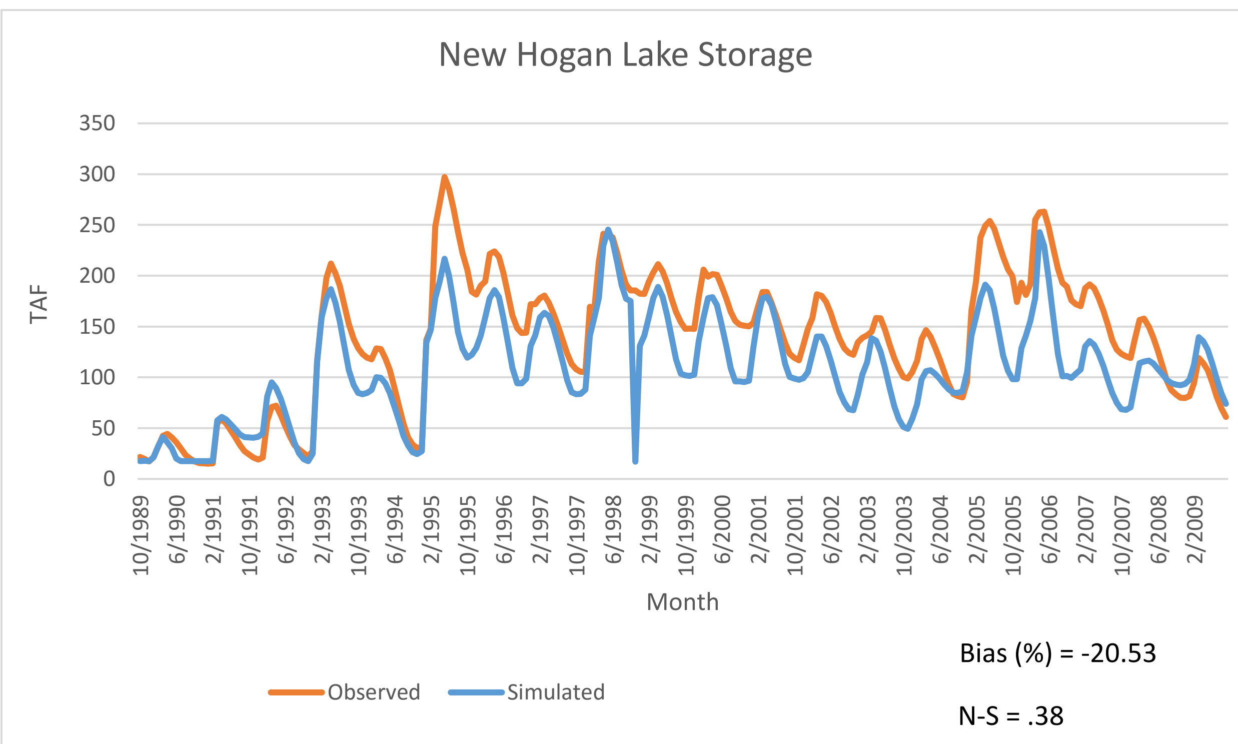

Figure B.8.8a New Hogan Lake Storage, Monthly 1990 to 2009

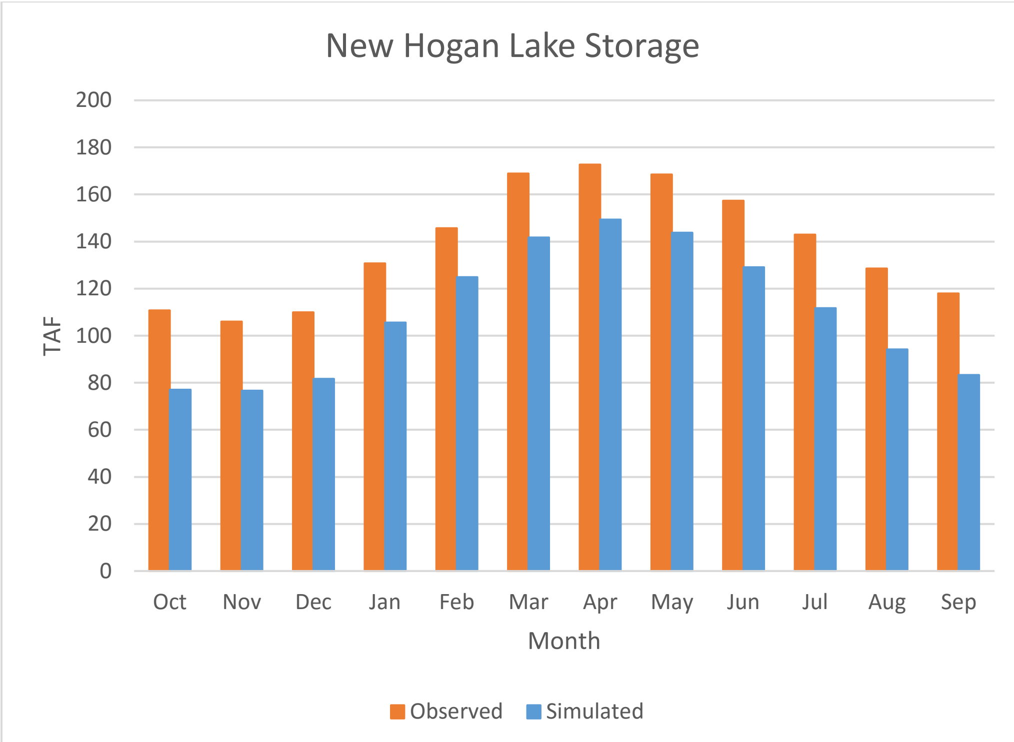

Figure B.8.8b New Hogan Lake Storage, Average Monthly

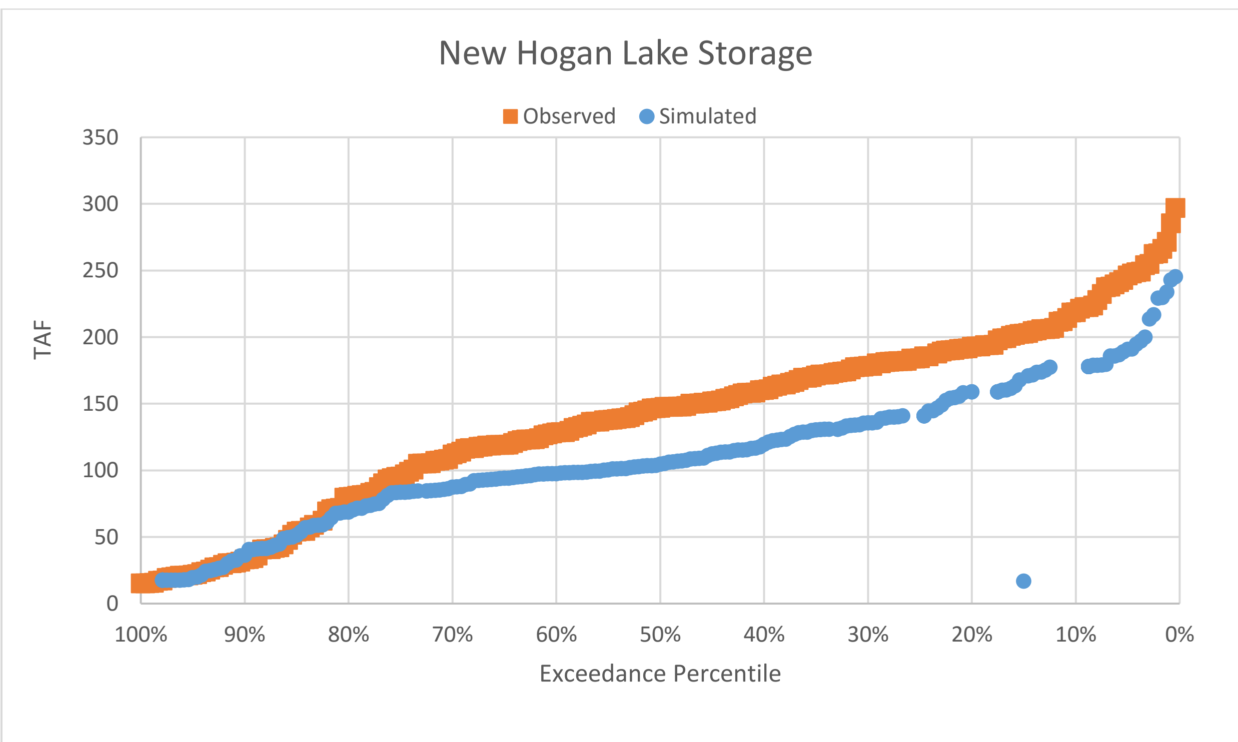

Figure B.8.8c New Hogan Lake Storage, Exceedance

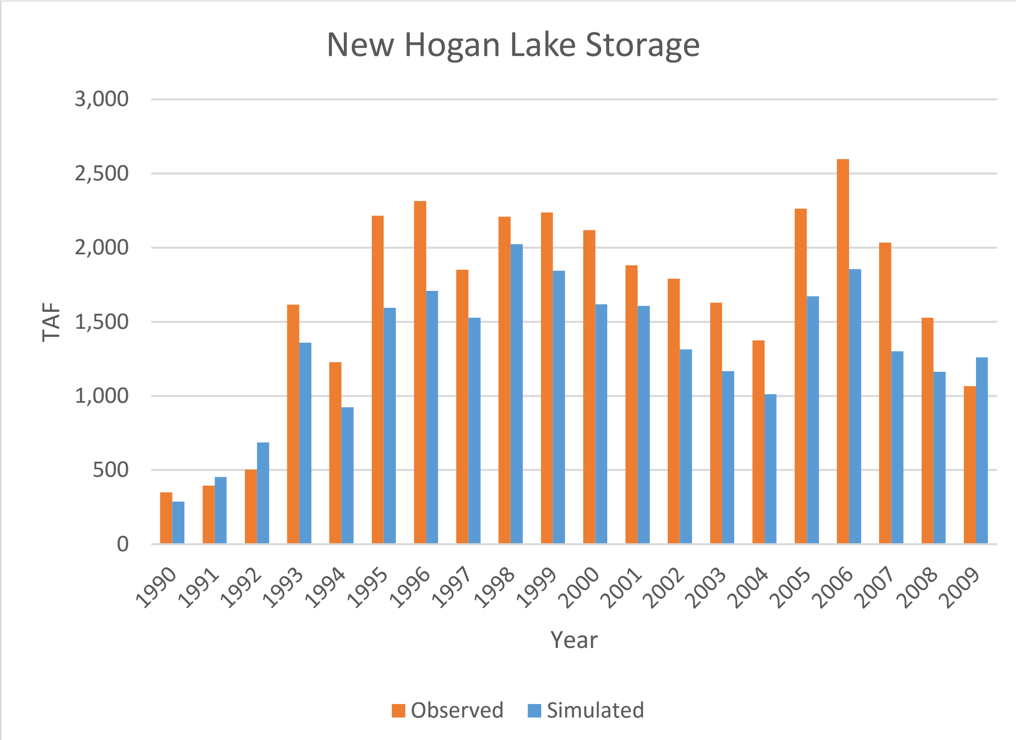

Figure B.8.8d New Hogan Lake Storage, Annual 1990 to 2009

B.9 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

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