# San Luis Low Point Improvement Project Planning Study Report

## Appendix B Hydrologic Modeling Technical Report

*Prepared for Reclamation by MBK Engineers and CDM Smith under Contract No. R10PC20537*

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# Chapter 1
# Background and Project Description

The purpose of the San Luis Low Point Improvement Project (SLLPIP) is to address the delivery schedule uncertainty and water supply reliability problems with San Luis Reservoir when reservoir storage drops below a certain threshold and low point issues may develop. Low point issues occur when conditions in San Luis Reservoir promote the growth of reservoir-wide algae. Algae blooms generally reach diversion facilities when reservoir storage is at or below 300,000 acre-feet (AF), corresponding to a lake elevation of approximately 370 feet. The first diversion facilities to be affected by algae blooms are intakes for the Pacheco Pumping Plant serving the San Felipe Division of the Central Valley Project (CVP). Water quality within algae blooms is not suitable for municipal and industrial water users and existing water treatment facilities in Santa Clara County, and may not be suitable for agricultural water users with drip irrigation systems in San Benito County. The SLLPIP investigated alternatives to remedy these potential issues and avoid supply interruptions to San Felipe Division contractors due to algae blooms in San Luis Reservoir.

This technical appendix to the Planning Study Report and environmental documentation describes modeling tools and assumptions used in analysis of SLLPIP alternatives. The Planning Study evaluated several alternatives for the ability to satisfy SLLPIP objectives. Each alternative was simulated in a model of the CVP and State Water Project (SWP) to determine effects on water supply for the San Felipe Division, Santa Clara Valley Water District (SCVWD), and effects in other areas of the CVP/SWP[1]. CalSim II model results for each alternative were compared to results of a No Action Alternative to quantify changes in water deliveries, reservoir storage levels, river flows, and CVP/SWP operations in the Sacramento-San Joaquin River Delta (Delta). Simulated water deliveries were used in the economic analysis of each alternative, conducted as part of the Planning Study. Simulated reservoir storage, river flow, Delta outflow and Delta exports were used to evaluate environmental effects during preparation of the Environmental Impact Statement/Environmental Impact Report (EIS/EIR). Key model results are summarized and presented in this report for each alternative. Model results for each alternative were subsequently input to the water supply model used by SCVWD to simulate the local effects of each alternative on the operation and performance of the SCVWD system. Water Evaluation and Planning (WEAP) model results for each alternative were compared to a No Action Alternative to quantify the effects of each alternative

[1] The Treatment Alternative would provide SCVWD uninterrupted access to storage in San Luis Reservoir similar to the access that would be provided by implementation of the Lower San Felipe Intake. As a result, the modeling results presented in this appendix for the Lower San Felipe Intake are utilized in the EIS/EIR and Planning Study Report to evaluate anticipated water supply impacts and benefits for both alternatives.

to local water treatment plant (WTP) deliveries, and local surface and groundwater storage that contribute to SCVWD emergency water supply.

# Chapter 2
# Water Operations Modeling

Water operations modeling is a key step in the analysis of SLLPIP alternatives. Water operations model results frequently serve as the basis of subsequent economic and environmental analyses. This section provides brief descriptions of the models used to analyze alternatives. Descriptions include model assumptions and modifications made to baseline model files provided by Department of Interior, Bureau of Reclamation (Reclamation). Model limitations for analysis of SLLPIP alternatives are also described.

## 2.1 Operations Models

Two models were used to analyze effects of SLLPIP alternatives. CalSim II was used to simulate CVP/SWP operations, including San Luis Reservoir and San Felipe Division deliveries. Subsequent analysis includes input of Calsim II CVP and SWP allocation and delivery results for each alternative to a WEAP model of the SCVWD system to simulate the local effects on the operation and performance of the SCVWD system.

### 2.1.1 CalSim II

Water operations modeling of the CVP/SWP system was performed using CalSim II. CalSim II is a planning model designed to simulate operations of CVP and SWP reservoirs and water delivery systems. CalSim II simulates flood control operating criteria, water delivery policies, in-stream flow, and Delta outflow requirements. CalSim II is the best available tool for modeling CVP and SWP operations and is the primary system-wide hydrologic model used by California Department of Water Resources (DWR) and Reclamation to conduct planning and impact analyses of potential projects.

CalSim II is a simulation by optimization model. The model simulates operations by solving a mixed-integer linear program to maximize an objective function for each month of the simulation. CalSim II was developed by Reclamation and DWR to simulate operation of the CVP and SWP for defined physical conditions and a set of regulatory requirements. The model simulates these conditions using 82 years of historical hydrology from water year 1922 through 2003.

CalSim II modeling conducted for the SLLPIP was developed from a baseline model provided by Reclamation to the project team. A baseline CalSim II simulation at a future level of development (LOD) was developed by Reclamation in January 2015. Baseline studies include actions in the reasonable and prudent alternatives from National Marine Fishery Service's (NMFS') 2009 Biological Opinion (BO) for Chinook salmon and United States Fish and Wildlife Service's (USFWS') 2008 BO for delta smelt. Additional key assumptions governing CVP/SWP operations in CalSim II are described in Attachment A to this Appendix.

### 2.1.2 CalSim II Representation of San Felipe Division

Water service contractors supplied through the Pacheco Pumping Plant make up the San Felipe Division of the CVP and include SCVWD, San Benito County Water District (SBCWD), and Pajaro Valley Water Management Agency. Table 2-1 summarizes agricultural and municipal and industrial (M&I) water service contracts, in thousands of AFAF per year, represented in CalSim II for each agency in the San Felipe Division.

**Table 2-1. CVP San Felipe Division Annual Contract Quantities (1,000 AFAF)**

| Agency | Ag Contract | M&I Contract | Agency Total |
|---|---|---|---|
| Santa Clara Valley Water District | 33.1 | 119.4 | 152.5 |
| San Benito County Water District | 35.6 | 8.3 | 43.9 |
| Pajaro Valley Water Management Agency | 6.3 | 0.0 | 6.3 |
| Total by Contract Type | 75 | 127.7 | 202.7 |

Calsim II simulates delivery of this contract water through the Pacheco Pumping Plant. CalSim II simulates Reclamation's annual allocation process for agricultural and M&I water service contracts in various divisions of the CVP. CalSim II uses a monthly demand pattern that varies from one month to the next but is the same each year to simulate delivery of CVP contract supplies. Monthly deliveries are subject to model allocations, annual contract amounts, and availability of water to meet contract demands.

### 2.1.3 Modifications to Reclamation CalSim II Baselines

Baseline models provided by Reclamation required modifications for use in evaluating operations under SLLPIP alternatives, including the Future No Action (FNA). The following sections describe key changes.

#### *2.1.3.1 Refined Export Estimates and San Luis Reservoir Operations*

The most significant modification to the baseline model provided by Reclamation was the improvement of Delta export estimates, simulated CVP and SWP allocations, and the operations of San Luis Reservoir. These modifications to CalSim II were made by MBK Engineers in 2015 under a separate contract with Reclamation intended to improve simulated operations of San Luis Reservoir. Additional detail on the specific model changes and the associated effects to CalSim II simulated operations are provided in a technical memorandum from July 2015 (Attachment C).

Model improvements addressed three long-standing issues in CalSim II simulated operations and resulted in a significantly improved operation of San Luis Reservoir. The first improvement involved replacing static input tables of estimated Delta export capacity used in allocation logic. These tables were replaced with an iterative process that uses prior simulations to develop more reliable, and more realistic, Delta export estimate forecasts.

The second improvement was to address instances where simulated CVP allocations to south-of-Delta water service contractors (SOD allocations) were low, yet a significant volume of water remained in the CVP portion of San Luis Reservoir. Under these conditions, Reclamation is likely to increase SOD allocations to deliver the water that is already in storage. This model improvement tends to increase allocations and further draw down storage in the CVP portion of San Luis Reservoir in dry periods, particularly during the 1932 through 1934 period.

The third improvement with implications to the operation of San Luis Reservoir and the SLLPIP were modifications to the San Luis target storage levels, or “rulecurve”, in CalSim II. The purpose of rulecurve is to prioritize balance between storage in north-of-Delta (NOD) reservoirs and San Luis Reservoir for both the CVP and SWP. Rulecurve controls release from NOD reservoirs for export when there is a choice between storing water in NOD reservoirs and releasing water for export and storing it in San Luis Reservoir. Rulecurve was improved to better simulate the scheduling of releases and Delta exports to balance storage in CVP and SWP reservoirs.

Each of these three model improvements affect the simulated operation of San Luis Reservoir in CalSim II and improved a previous deficiency in model operations for the SLLPIP.

#### *2.1.3.2 San Felipe Division M&I Delivery Interruptions*

CalSim II was modified to simulate San Felipe Division M&I water service delivery interruptions that may occur due to low point issues. Simulated deliveries to M&I water service contractors were interrupted when previous end-of-month combined CVP and SWP storage in San Luis Reservoir was less than 300,000 AFAF. Interrupted San Felipe Division M&I water service contract deliveries were not rescheduled or delivered in later months. This water was simulated as remaining in San Luis Reservoir and available for allocation in future years. San Felipe Division agricultural water service deliveries were simulated to occur as long as storage in CVP San Luis Reservoir was above dead pool.

### 2.1.4 Level of Development

CalSim II simulations at a projected LOD are used to depict how the modeled water system might operate with an assumed physical and institutional configuration imposed on a long-term hydrologic sequence. A future LOD study is needed to explore how the system may perform under an assumed future set of physical and institutional conditions. This future setting is developed by assuming year 2030 land use, facilities, and operational objectives and is used for the FNA Condition for the National Environmental Policy Act (NEPA) analysis.

A FNA CalSim II simulation depicts how the Delta, its major tributaries, and the CVP/SWP may operate in the future without the Project. Areas tributary to the Delta have experienced numerous physical and institutional changes over the years, and are continuing to experience change. Projecting the availability of facilities, institutional, and regulatory requirements, and the practices that will affect the management of future water supplies and demands is a daunting task. Nevertheless, reasonable assumptions must be made regarding these items to estimate future conditions. These assumptions include actions in the reasonable and prudent alternatives from NMFS' 2009 BO for Chinook salmon and USFWS' 2008 BO for delta smelt.

### 2.1.5 CalSim II Limitations

There are limitations to the use of CalSim II for most projects. A key limitation for the SLLPIP analysis is the ability to adequately simulate San Luis Reservoir operations. CalSim II is the only available model that adequately simulates the integrated operations of the CVP and SWP both north and south of the Delta; therefore, it must be relied upon as the foundation of most studies that affect CVP/SWP operations. However, CalSim II was developed primarily to simulate reservoir operations upstream of the Delta, Delta conditions and exports. CalSim II does not consider several variables that affect San Luis Reservoir storage. An understanding of the limitations of CalSim II for the analysis of SLLPIP alternatives is necessary to properly characterize results.

One method for evaluating model adequacy is to compare model results with observed data. Unfortunately, this method is no longer appropriate for CalSim II and San Luis Reservoir storage. CalSim II assumptions for the Future No Action Alternative include actions in the reasonable and prudent alternatives from USFWS' 2008 BO for delta smelt and NMFS' 2009 BO for Chinook salmon. These two operational constraints were added to the system in 2008 and 2009, respectively. Requirements contained in the BOs result in significant operational changes including changes in upstream reservoir release, the ability to move water through the Delta, and the operation of both the CVP and SWP portions of San Luis Reservoir. CVP/SWP operators have operated to these requirements since 2009 providing only a few years of observed data under the BOs. The CalSim II simulation period does not include the historical hydrology for this period. Therefore, there is no common period between the model and observed data under a similar regulatory condition. A comparison of historical San Luis Reservoir storage and simulated storage under the BOs illustrates the change in regulatory requirements, but is not useful for understanding model limitations.

## 2.1.6 Santa Clara Valley Water District's WEAP Model

SCVWD uses the WEAP system model developed by the Stockholm Environment Institute's U.S. Center. WEAP is a software tool for water resources planning. WEAP uses a database to maintain water demand and supply information and drive the mass balance on a link-node architecture. In addition, the model evaluates a full range of water development and management options, and takes account of multiple and competing uses. The following model description was adapted from a document provided by SCVWD staff.

### *2.1.6.1 General Model Description*

The SCVWD WEAP model is designed primarily to simulate SCVWD's local water system of facilities that recharge Santa Clara County's groundwater basins, operation of its reservoirs and creeks, existing and proposed treatment and distribution facilities, and raw water conveyance system of imported water. WEAP also accounts for non-District sources and distribution of water in Santa Clara County , including: imported water from the Hetch-Hetchy System, recycled water, and local water developed by other agencies. WEAP was formulated to simulate the total management of current and future water resources within Santa Clara County.

WEAP operates on a monthly time-step, and can simulate any defined set of hydrologic years with either fixed demands or any sequence of yearly demands. For this analysis, WEAP used an 82-year hydrologic record consistent with CalSim II.

WEAP is primarily a surface water supply simulation model. However, WEAP does track groundwater basin storage as a mass balance of inputs and outputs. The central focus of WEAP results is typically operation of the County's groundwater basins; the artificial recharge of sufficient water such that total natural and artificial recharge balances demands on the basins within the bounds of operational basin storage capacity. WEAP can also pass pumping demand data and recharge data to SCVWD's groundwater models to ensure basin storage results are in-line with groundwater model determinations.

### *2.1.6.2 Major Components of WEAP*

WEAP has a data structure composed of five major systems: water demands, groundwater, local surface water, treated water, and raw water conveyance. Each major system is described in further detail below.

#### 2.1.6.2.a Water Demands System

The water demands system is designed around a long-standing division of the County into water service areas that are closely associated with water retailer areas. Areas that are not served by a retail water agency are delineated using geographic and/or hydrologic boundaries. Water demand data have been developed using another model that uses census data and growth projections to generate annual service area water demands. These water demands are then reconciled with each retailer's Urban Water Management Plan for growth projections.

Water is delivered to meet demands according to availability, and priority. Commonly, the lowest priority source of supply (or last to be used to meet service area demands) is groundwater. Therefore, service area groundwater pumping is calculated as the supply necessary to meet service area water needs after taking into account conservation, treated water, and other available alternate supplies for a specific service area.

**2.1.6.2.b Groundwater System**

The groundwater system comprises the County's three groundwater subbasins and is currently depicted in WEAP with each basin having specific recharge, pumping, and subsurface inflows and outflows. Recharge occurs through streams and existing or planned recharge ponds that are located over the groundwater basins. Groundwater pumping is simulated to occur in water service areas associated with each basin.

The most northern basin is called the Santa Clara Valley basin. The central basin is called the Coyote basin. The southern basin is called the Llagas basin. One of the primary objectives of WEAP's Groundwater System is to determine if the basins all stay within their respective operational storage capacities and subsidence does not occur.

**2.1.6.2.c Local Surface Water System**

The local surface water system contains the major watersheds and their respective streams. The major streams, as used in WEAP, are those that are either: (1) controlled by a storage reservoir; (2) receive imported water; or (3) directly affect flow of a stream that is controlled by a reservoir or receives imported water. Each major stream that is processed by WEAP is defined as either regulated (controlled by reservoir releases) or unregulated (not controlled by a reservoir).

Regulated stream flow data are defined in WEAP as monthly unimpaired flows at the various reservoirs sites and downstream accretions between the reservoir and the basin boundary. Unregulated stream flows are defined in WEAP as monthly stream flows of the unregulated streams at the upstream basin boundary.

Recharge ponds are another part of the local surface water system. Recharge ponds can be connected to streams and/or raw water pipeline turnouts and can provide a source of recharge for associated groundwater basins.

Each major stream and recharge pond are defined within this system with a monthly recharge rate based on observed historical rates. Each stream has a variety of methods for connecting to other streams, reservoirs, ponds and raw water piping node recharge turnouts.

### 2.1.6.2.d Treated Water System

The treated water system, as depicted in WEAP, is comprised of a number of subsystems which simulate operation of SCVWD's distribution systems and three treatment plants: Rinconada, Penitencia, and Santa Teresa.

### 2.1.6.2.e Raw Water Conveyance System

The raw water conveyance system comprises the pipelines, canals, conduits, pumping plants, and other related facilities used to convey both imported and local raw water to recharge facilities, treatment plants, reservoirs, and other miscellaneous raw water turnouts.

Two imported water supplies are simulated in WEAP. One is from the South Bay Aqueduct (SBA) of the SWP and the other is from the San Felipe Division of the CVP. Raw water supplies available from the SWP/CVP are provided through contracts with the State and Federal governments. SCVWD's SWP maximum contract is for 100,000 AF annually of Table A water. SCVWD's CVP maximum contract is for 152,500 AF annually. WEAP relies on CalSim II's representation of CVP/SWP operations and deliveries through the SBA and Pacheco Pumping Plant, by using CalSim II output for CVP and SWP allocations and deliveries as input.

SCVWD participates in a water banking and exchange program with the Semitropic Water Storage District in Kern County. In wetter years, SCVWD is able to store excess Delta-conveyed water in the Semitropic groundwater bank for later use, particularly in dry years. This operation is defined in WEAP.

A banking arrangement with agencies from outside of Santa Clara County is also defined in WEAP to store excess imported supplies in wet years and draw upon these banked supplies in drought years.

### 2.1.6.2.f System Water Needs

WEAP's first major step in the analysis process is establishment of system water needs. Annual projected total water needs, expected water conservation savings, and expected sources of supply for each water service area are defined by the user. Sources of annual supplies are:

(1) Treated water from Rinconada, Penitencia, and Santa Teresa

(2) Other sources not managed by SCVWD (e.g. Hetch-Hetchy System)

(3) Raw surface water deliveries from SCVWD's raw water pipelines

(4) Recycled water from existing or proposed facilities

(5) Groundwater

(6) Water conservation

All or any combination of the above sources of water may be available to a service area. Groundwater pumping is computed by WEAP as the difference between a service area's total annual demands and its other annual sources of supplies.

#### 2.1.6.2.g Operation of Local Facilities

WEAP then simulates reservoir operations using the defined storage rule curve for each reservoir. Rule curves define how much water can be released from the reservoir to meet remaining recharge capacity in ponds and streams connected to the regulated outlet stream. Reservoirs can also be connected to raw water pipelines and release water to meet these demands. When the reservoir is simulated to spill water, some of this excess can be moved to a pipeline if conveyance and demand allow. In times of excess imported CVP/SWP supply, reservoirs connected to a pipeline can store excess imported supply if conveyance and storage capacity allow. Monthly reservoir inflow is defined for each reservoir, and reservoir evaporation is calculated based on observed historical rates.

#### 2.1.6.2.h Operation of Raw Water System

The raw water system serves as the nucleus of WEAP, determining how much and where imported water will be delivered through pipelines to WTPs and recharge turnouts. For the distribution of imported water, WEAP can draw its first priority supplies from either the SBA or the San Felipe Division. When needed, releases from any defined water banks and reservoirs connected to pipelines will be initiated.

Priorities are also defined by the user to determine the order of where the imported water is distributed. When there is not enough water to meet all facility needs, or conveyance of all water is not possible, reductions are made by WEAP according to the following priorities:

(1) Excess raw water to reservoirs connected to pipelines, and banking facilities outside of the County

(2) Raw water delivered to recharge facilities

(3) Raw water surface deliveries

(4) Raw water delivered to meet the needs of SCVWD's various treatment plants

WEAP was used to simulate SCVWD's water operations for each alternative, including the no action alternative, at a future LOD. CalSim II output for CVP and SWP allocations and deliveries were provided to SCVWD staff for each alternative to run WEAP and summarize results. WEAP results include local reservoir operations, flows at key locations, groundwater banking operations, and SCVWD's ability to meet service area demands. WEAP output for treated water deliveries was a key input to the economic evaluation.

## 2.2 Supplemental Support for Modeling Results

As discussed in the previous sections, CalSim II is the only tool available that includes the majority of the system components and inputs that affect storage conditions in San Luis Reservoir. An accurate simulation of San Luis Reservoir is extremely difficult to achieve because myriad factors and human decisions affect it. CalSim II's simulation of a future condition represents only one of many possible future conditions. Additional understanding of the potential range of future conditions may be gained from review of historical hydrology and system conditions.

An understanding of the historical hydrology and CVP SOD operations were combined to provide supplemental information to accompany CalSim II modeling results. A review of the hydrology identified conditions and factors that contribute to, or help prevent the occurrence of low point issues. The frequency of occurrence for those contributing and preventing factors can help identify years when low point issues are more and less likely. The frequency of occurrence of factors or combinations of factors can define a minimum and maximum number of years when low point issues are more likely to occur. This information provides a model-independent estimate of the range of potential low point occurrences and helps support CalSim II model results.

CVP operators currently target drawing down the CVP portion of San Luis Reservoir to minimum pool each year when making allocations. Reasons why CVP storage stays above or dips below minimum pool can be characterized as either supply or demand factors. Supply factors include reservoir inflows north and south of the Delta, the availability of local supplies or surplus flows south of the Delta, and unforeseen increases or reductions in Delta exports. Demand factors include meteorological conditions such as temperature, wind, and precipitation that drive evapotranspiration from crops and changes in cropping patterns that influence the timing of demand for water from San Luis Reservoir.

Reclamation currently uses conservative forecasts for both supply (90% exceedance for reservoir inflows) and demand. The use of conservative forecasts reduces the number of times actual inflow is less than forecasted inflow or actual demands exceed forecasts. Low point issues are more likely to occur when actual demands are at or above forecasted demands and/or supplies are at or below forecasted supplies. A review of the historical hydrology and data was made to estimate how frequently the actual factors that influence supply and demand are more likely to be significantly different from forecasted values. Supply factors include reservoir inflows, water year types, water supply forecasts, and spills into Mendota Pool. Demand factors include temperature, precipitation, and evapotranspiration data. Data for most of these factors was previously collected and analyzed to determine the feasibility of predicting potential low point issues. The same data were analyzed to determine the frequency of occurrence for factors that contribute to or help prevent low point issues. The frequency of occurrence for these factors can define a minimum and maximum number of years wherein low point issues are more likely to occur. This analysis attempts to determine the likely range or number of years when low point issues are more likely to occur. A worst case scenario would result in a low point condition occurring every year, whereas low point conditions would never occur in a best case scenario.

Sacramento and San Joaquin Valley Water Year indices can be used as one metric for evaluating factors that may tend to increase or decrease San Luis Reservoir storage conditions.

The Sacramento River is the largest river flowing into the Delta and carries water released from upstream CVP and SWP reservoirs. Water stored in San Luis Reservoir is exported from the Delta. The Sacramento Valley Index is one metric to define overall water supply conditions in the Sacramento Valley and is one supply factor for determining conditions that may increase or decrease the likelihood of low point conditions.

The San Joaquin Valley Water Year Index (SJR Index) is an indicator of hydrologic conditions in much of the area supplied by San Luis Reservoir. Conditions on the San Joaquin River can be an indicator of conditions on other rivers and creeks that serve as local supplies to areas also served from San Luis Reservoir. For example, the SJR Index can be an indicator of flow from the Kings River through James Bypass to Mendota Pool and spills from Friant Dam down the San Joaquin River to Mendota Pool. Spills into Mendota Pool during the April through September irrigation season reduce deliveries from San Luis Reservoir and decrease the likelihood of low point issues. Figure 2-1shows the frequency of such spills and the SJR Index in years when spills occur.

Figure 2-1 shows that historically there have been large volumes of water spilled into Mendota Pool from both the San Joaquin and Kings rivers when the SJR Index is wet. San Joaquin River spills are expected to decrease with implementation of San Joaquin River Restoration, but Kings River spills are likely to continue. While there can be differences between conditions in the northern and southern San Joaquin Valley, or the east and west sides of the San Joaquin River, the SJR Index generally indicates the availability of local water supplies. When the SJR Index is wet or above normal, there is typically more local supply available and less demand for water from San Luis Reservoir and vice versa. In this way, the SJR Index can be an indicator of demand for water from San Luis Reservoir.

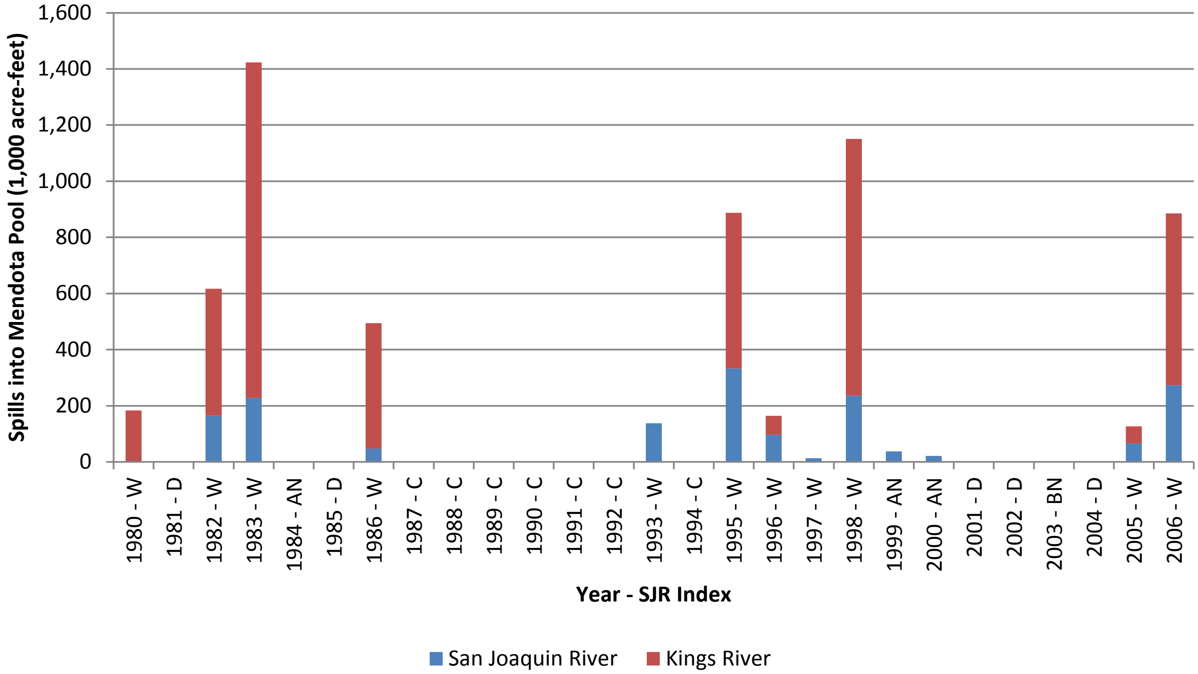


**Figure 2-1. Total April through September Spills into Mendota Pool**

Another indicator of demand may be obtained through analysis of historical temperature data. While numerous factors contribute to crop evapotranspiration and thereby water requirements, temperature is one of the main components and long-term data records of temperature are readily available. Daily temperature records for five locations throughout the San Joaquin Valley were reviewed and analyzed to determine years that were consistently above or below long-term average temperatures from April through September. The period of analysis was the 82-year period of historical hydrology simulated in CalSim II. Stations included in the analysis include Coalinga, Bakersfield, Hanford, Los Banos, and Visalia. Long-term average monthly temperatures were calculated for each station based on the available record. The difference between recorded daily temperature and average monthly temperature were summed for the April 1 through September 30 period each year. These degree-day differences for each station were analyzed to determine years when the stations were consistently above or below the average monthly temperature for the entire season. Data were not available for all years at all stations, but results reflect data for at least three stations for any year identified as consistently above or consistently below average. These results are summarized by SJR Index in the following figure.

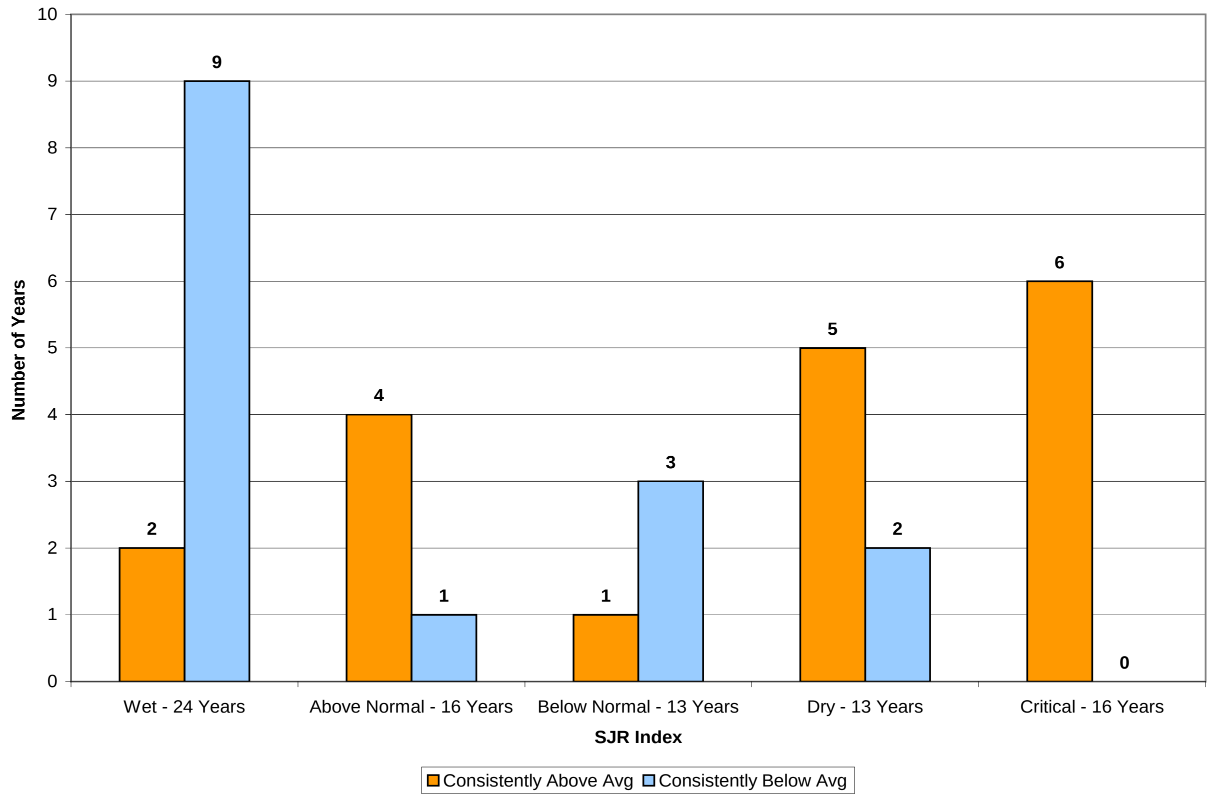


**Figure 2-2. Years with Temperatures Consistently Different from Long-Term Averages throughout the CVP SOD Service Area**

Figure 2-2 illustrates that out of the 82 years analyzed, in 18 years the majority of the stations analyzed show consistently above average temperatures with 11 of those years being classified as dry or critical (5 dry years and 6 critical years) according to the SJR Index on a calendar year basis. Conversely, 15 years show consistently below average temperatures with 10 of those years being classified as wet or above normal (9 wet years and 1 above normal year) according to the SJR Index. The combination of dry conditions and higher temperatures increase demand for water from San Luis Reservoir, and are more likely to result in low point conditions.

Storage levels at low point are also highly dependent on human decision-making including allocations made by CVP operators and water user's response to storage conditions in San Luis Reservoir. Low point conditions will tend to occur when water supplies are less than runoff forecasts, and/or demands exceed forecasted demands used for seasonal operations plans and allocations. Low point conditions may occur outside of dry or critical years, and may not occur in every dry or critical year. However, the combination of dry and critical years with consistently higher temperatures, and therefore demands, are more likely to lead to low point conditions than wet years when demands are lower than forecasted.

Based on Figure 2-1 and Figure 2-2, it is possible to estimate the number of years when low point conditions are more and less likely. Table 2-2 is a summary of this analysis.

**Table 2-2. Number of Calendar Years in Period of Analysis when Low Point Issues are More and Less Likely**

| Water Year Index | Sacramento Valley Index Years | SJR Index Years | Above Average Temperature | Below Average Temperature | Low Point More Likely[1] | Low Point Less Likely[2] |
|---|---|---|---|---|---|---|
| Wet | 26 | 24 | 2 | 9 | - | 9 |
| Above Normal | 12 | 16 | 4 | 1 | 4 | 1 |
| Below Normal | 14 | 13 | 1 | 3 | 1 | - |
| Dry | 18 | 13 | 5 | 2 | 5 | - |
| Critical | 12 | 16 | 6 | 0 | 6 | - |
| Total | 82 | 82 | 18 | 15 | 16 | 10 |

[1] Assuming spills into Mendota Pool decrease the likelihood of low point issues in all wet years and above average temperatures in any other year increase the likelihood of low point issues.

[2] Assuming spills into Mendota Pool combined with below average temperatures in wet and above normal years decrease the likelihood of low point issues.

Table 2-2 shows that in the 82 (calendar) years analyzed, there are 16 years when low point conditions are more likely and 10 years when low point years are less likely to occur. These values, combined with the 82-year period of analysis, can be viewed as potential bookend values for how often low point issues may occur. The maximum number of years when low point issues may occur is 72, 82 minus 10 years when low point is less likely. The minimum number of years when low point may occur is 16, assuming low point issues occur in every year defined as more likely in Table 2-2. The FNA Alternative used for the economic analysis provides one scenario when low point issues occur in 17 years (on a calendar year basis). The distribution of low point years by Sacramento Valley and San Joaquin Valley Index are provided in Table 2-3.

**Table 2-3. Number of Low Point Years by Sacramento Valley and San Joaquin Valley Index for FNA**

| Index Year Type for the Future No Action Alternative | Low Point Years: Sacramento Valley Index | Low Point Years: San Joaquin Valley Index |
|---|---|---|
| Wet | 0 | 0 |
| Above Normal | 3 | 0 |
| Below Normal | 3 | 4 |
| Dry | 4 | 5 |
| Critical | 7 | 8 |
| All Years | 17 | 17 |

Based on the analysis of historical hydrology and temperature, these CalSim II results are within the range of a model independent analysis of potential low point occurrence.

# Chapter 3 Future No Action Alternative

The following section describes the SLLPIP Future No Action Alternative and summarizes key model results for the alternative.

## 3.1 Future No Action Conditions: CalSim II

Results from the FNA Alternative simulation are used to depict operation of the CVP and SWP without SLLPIP alternatives at a future LOD. FNA results are used in a comparative sense with results from SLLPIP alternatives to quantify changes in CVP/SWP operations. Operation of San Luis Reservoir and any San Felipe Division M&I water service contract delivery interruptions are key results for the FNA simulation. These results are summarized in the following figures and tables.

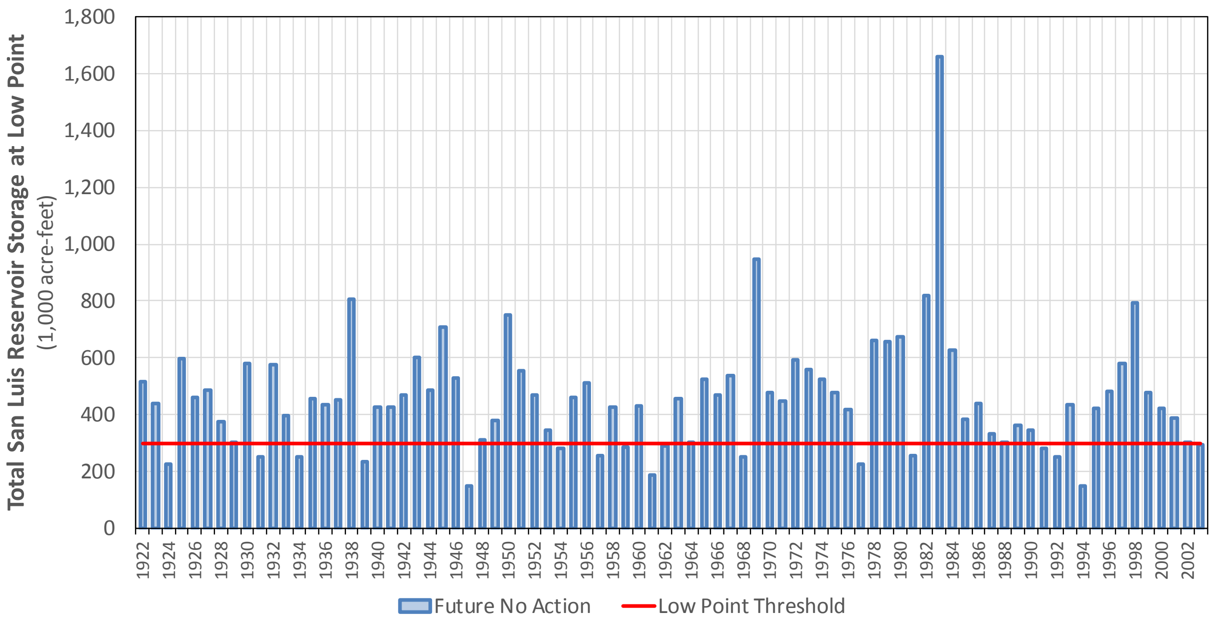


**Figure 3-1. Annual Total San Luis Reservoir Storage at Low-Point**

Figure 3-1 illustrates annual San Luis Reservoir storage at low-point for each year of the FNA simulation. A low point threshold of 300,000 AFAF is shown on the figure to illustrate years when low-point issues may develop. A low point of less than 300,000 AFAF occurs in 17 of the 82 years simulated.

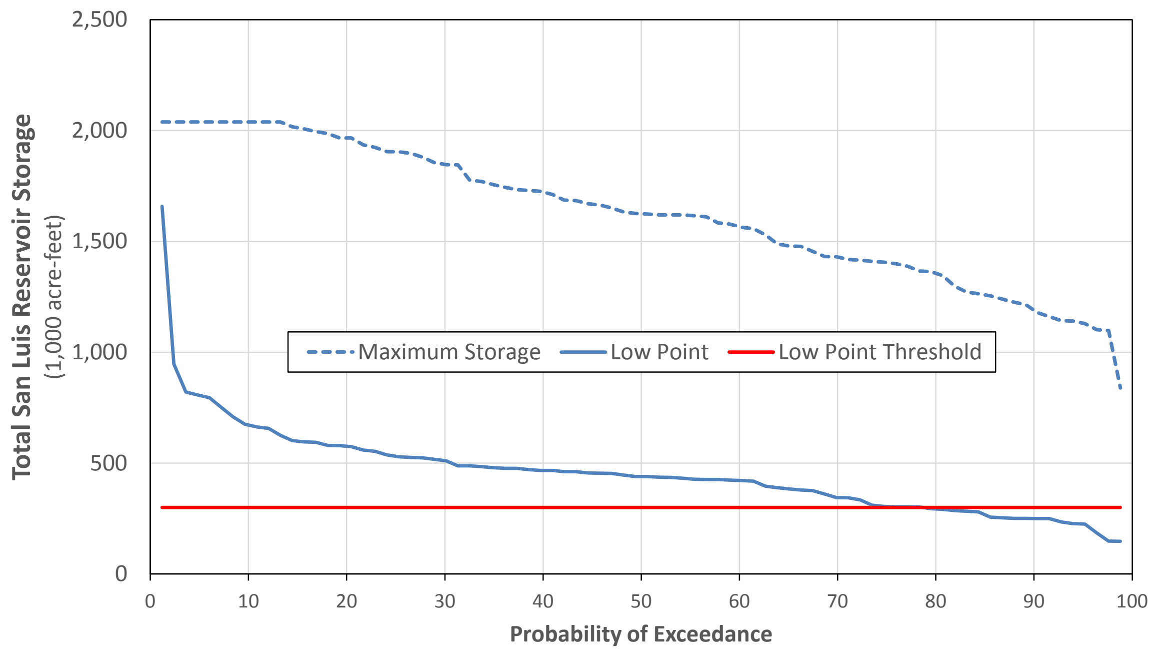


**Figure 3-2. Probability of Total San Luis Reservoir Maximum and Low Point Storage**

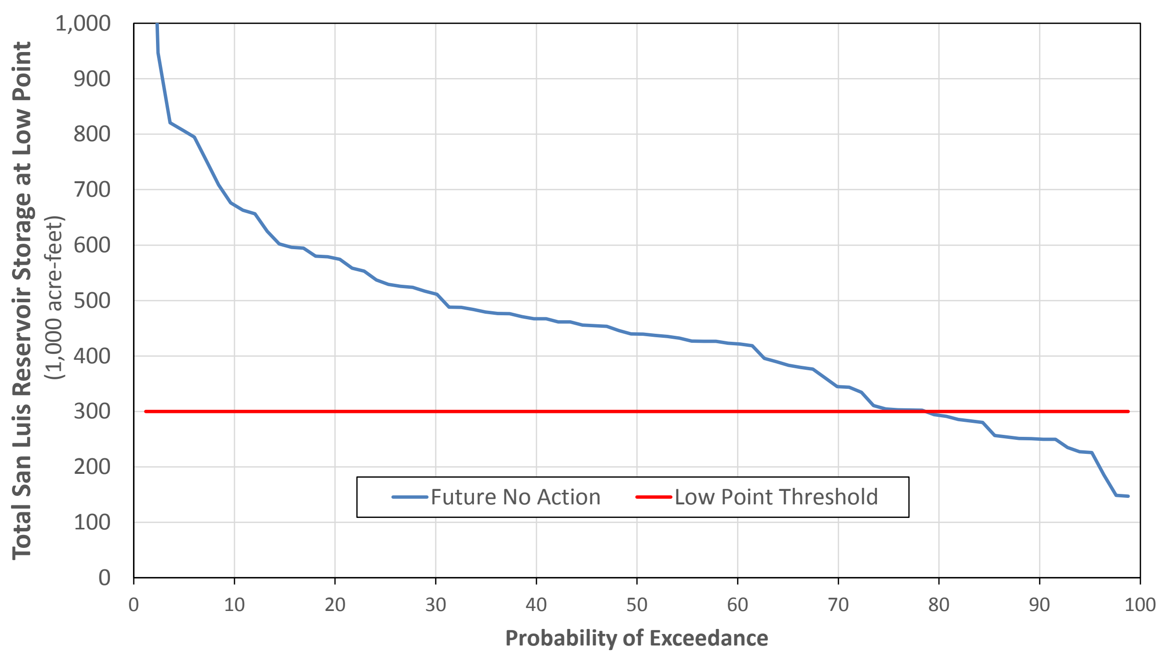


**Figure 3-3. Probability of Total San Luis Reservoir Low Point Storage**

Figure 3-3 illustrates annual San Luis Reservoir storage at low-point as a probability of exceedance. Results presented in Figure 3-3 indicate that storage may be below 300,000 AF in approximately 20 percent (17 out of 82) of all years at a future LOD.

Low point issues are assumed to occur when total San Luis Reservoir storage is less than 300,000 AF. When low point issues occur, San Felipe Division M&I contractors do not take delivery due to water quality concerns and deliveries are interrupted.

Table 3-1 is a summary of average annual interrupted San Felipe Division M&I deliveries for the FNA condition. Interrupted supplies reflect the volume of water that would not be delivered relative to the San Felipe M&I allocation for each water year type.

**Table 3-1. Average Annual Interrupted San Felipe Division M&I Deliveries**

| Sacramento Valley Index | Future No Action (1,000 AFAF) |
|---|---|
| Wet | 0.7 |
| Above Normal | 5.2 |
| Below Normal | 6.7 |
| Dry | 2.6 |
| Critical | 3.5 |
| All Years | 3.2 |

## 3.2 Future No Action Conditions: WEAP

SCVWD's WEAP model was run to understand how interrupted San Felipe Division M&I deliveries affect SCVWD surface and groundwater storage conditions, as well as SCVWD's ability to meet treated water demands. WEAP outputs have been summarized in the following figures and tables.

Imported water supplies entering the SCVWD system are either sent directly to one of the WTPs, or routed into storage, either in one of the local surface water reservoirs or recharged into one of the local groundwater basins. While local reservoir and groundwater basin storage levels are dependent on local hydrologic conditions, changes in storage between an alternative and the future no action model run will indicate changes to the volume of imported supply and/or operational changes triggered by the change in imported supplies. Accordingly, Table 3-2 includes relevant WEAP model output, including: annual average WTP delivery , annual average storage levels for total local surface water storage, total local groundwater storage, Semitropic storage, and the total SCVWD Emergency Supply. The total SCVWD Available Storage is a sum of the total local surface storage, total local groundwater storage, and Semitropic storage. Total SCVWD Emergency Supply is the average volume of water available to the system under a water supply emergency, such as a Delta outage. This value only includes the total local surface storage and the North County groundwater storage that would be accessible in an emergency.

**Table 3-2. Annual Average WTP Delivery and Storage Conditions for the Future No Action model run**

| Annual Average Values (1,000 acre-feet) | Future No Action |
|---|---|
| **Total WTP Delivery/M&I Water Supply** | 129 |
| Unmet WTP Demand | 2 |
| Total Local Surface Storage | 90 |
| North County Groundwater Storage | 316 |
| Total Local Groundwater Storage | 464 |
| Total Semitropic Storage | 150 |
| **Total SCVWD Available Storage** | 704 |
| **Total SCVWD Emergency Supply** | 406 |

The following figure illustrates annual WTP deliveries from the Future No Action WEAP results. Years when total San Luis Reservoir storage falls below 300,000 AF (low point years) are noted. Many of the years with reduced total WTP deliveries correspond to low point years. However, reduced water plant deliveries can also be caused by dry hydrologic conditions in Santa Clara County and in years with low imported water deliveries from the CVP and SWP.

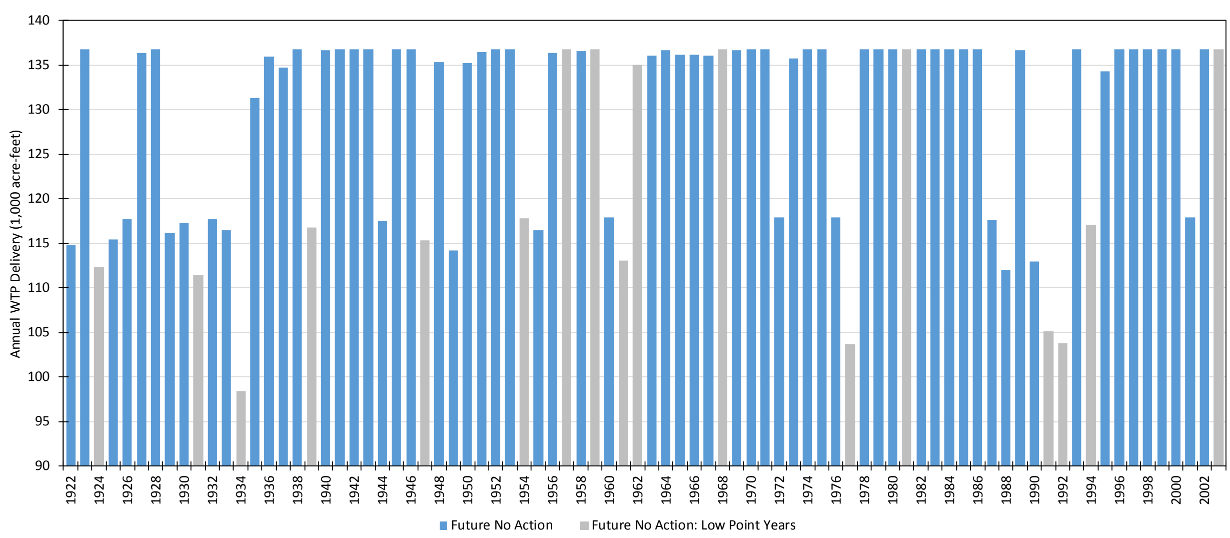


**Figure 3-4. Simulated Annual WTP Deliveries, Future No Action**

# Chapter 4
# Lower San Felipe Intake Alternative

This alternative includes construction of a new, lower San Felipe Intake to allow reservoir drawdown to its minimum operating level without algae reaching the San Felipe Intake. Moving the San Felipe Intake to an elevation equal to the Gianelli Intake would allow for continued San Felipe Division deliveries even when the total storage volume in San Luis Reservoir is below the 300,000 AF level.

A new intake would be constructed and connected to the existing San Felipe Division Intake via approximately 20,000 feet of new pipeline or tunnel. The San Felipe Intake is currently at elevation 334 feet, and algae-laden water can reach the intake when reservoir levels reach approximately 369 feet (approximately 300,000 AF in storage). Because the Gianelli Intake is at elevation of 296 feet (approximately 30 feet lower than the minimum operating pool), algae-laden water does not typically reach the Gianelli Intake. The new intake in this alternative would be at elevation 296 feet, the same elevation as the Gianelli Intake. The lower intake facility would allow the San Felipe Division to receive water from the lower reservoir levels that do not contain high concentrations of algae. A hypolimnetic aeration facility would also be constructed.

## 4.1 Modeling Approach and Assumptions

The Lower San Felipe Intake Alternative allows delivery to San Felipe Division M&I contractors if San Luis Reservoir storage is maintained above dead pool. This operation was simulated in CalSim II by removing the constraint requiring San Luis Reservoir storage to be greater than 300,000 AF for delivery to San Felipe Division M&I contractors.

## 4.2 Water Operations Modeling Results: CalSim II

The Lower San Felipe Intake Alternative was analyzed over an 82-year period to estimate the potential change in CVP deliveries due to the physical change to the intake. The following sections summarize the effects of the alternative on CVP SOD M&I and agricultural water service contract deliveries and the CVP/SWP system.

### 4.2.1 CVP Deliveries

The Lower San Felipe Intake Alternative allows for increases to San Felipe Division M&I water service contract deliveries by eliminating delivery interruptions due to low-point issues. San Felipe Division M&I deliveries increase because contractors can take delivery of water when San Luis Reservoir is below 300,000 AF.

Increased deliveries to San Felipe Division M&I contractors reduce CVP deliveries to SOD agricultural water service contractors. Agricultural deliveries decrease, as compared to the FNA Alternative, because interrupted M&I deliveries under the FNA Alternative remain in San Luis Reservoir and are included as supply available for allocation to CVP/SWP contractors in subsequent years. Under the Lower San Felipe Intake Alternative, that water is delivered and allocations in future years may be slightly less than under the no action alternative.

The following tables summarize changes in deliveries to San Felipe Division M&I contractors and CVP SOD agricultural water service contractors with the Lower San Felipe Intake Alternative.

**Table 4-1. San Felipe Division M&I Deliveries under the Lower San Felipe Intake Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | Lower San Felipe Intake (1,000 AF) | Change from FNA (1,000 AF) |
|---|---|---|---|
| Wet | 114 | 115 | 1 |
| Above Normal | 98 | 103 | 5 |
| Below Normal | 95 | 102 | 7 |
| Dry | 90 | 92 | 2 |
| Critical | 73 | 76 | 3 |
| All Years | 97 | 100 | 3 |

Table 4-1 shows an average annual increase in San Felipe Division M&I deliveries of 3,000 AF under the Lower San Felipe Intake Alternative. Delivery increases occur only within the San Felipe Division. There is no meaningful change to CVP SOD M&I contractors outside the San Felipe Division because there is no meaningful change to M&I allocations. Increased deliveries match interrupted San Felipe Division M&I deliveries presented previously in Table 3-1.

**Table 4-2. CVP SOD Agricultural Deliveries under the Lower San Felipe Intake Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF ) | Lower San Felipe Intake (1,000 AF ) | Change from FNA (1,000 AF ) |
|---|---|---|---|
| Wet | 1,341 | 1,341 | 0 |
| Above Normal | 1,009 | 1,004 | -5 |
| Below Normal | 878 | 876 | -2 |
| Dry | 591 | 589 | -2 |
| Critical | 176 | 176 | 0 |
| All Years | 878 | 876 | -2 |

Table 4-2 shows an average annual decrease in CVP SOD agricultural service contract deliveries of 2,000 AF. Simulated deliveries decrease because under the FNA Alternative interrupted San Felipe Division M&I deliveries remain in San Luis Reservoir and are available to be allocated to agricultural water service contractors in subsequent years. Slightly lower SOD agricultural deliveries in the Lower San Felipe Intake Alternative result when this interrupted supply is instead delivered to San Felipe Division M&I contractors.

### 4.2.2 CVP/SWP Effects

The Lower San Felipe Intake Alternative has the potential to affect CVP/SWP operations beyond San Luis Reservoir and the contractors who take delivery of water from the reservoir. As described in the previous section, interrupted M&I deliveries under the FNA Alternative tend to increase allocations and deliveries to other CVP contractors relative to the Lower San Felipe Alternative. Changes in SOD allocations can affect other areas of the CVP and, in some instances, the SWP due to requirements in the Coordinated Operation Agreement. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following table provides a high-level summary of changes throughout the CVP/SWP system. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B to this Appendix.

**Table 4-3. Summary of CVP/SWP System Effects under the Lower San Felipe Intake Alternative**

| Future No Action | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Delta Outflow (cfs) | 5,905 | 11,432 | 20,703 | 42,028 | 52,793 | 42,230 | 30,980 | 22,070 | 12,345 | 7,785 | 4,433 | 9,728 |
| Jones Pumping Plant (cfs) | 3,491 | 3,546 | 3,918 | 3,234 | 3,314 | 3,114 | 1,210 | 1,081 | 2,575 | 3,387 | 3,718 | 3,972 |
| Banks Pumping Plant (cfs) | 3,211 | 3,798 | 4,732 | 3,606 | 4,040 | 4,024 | 1,193 | 985 | 2,426 | 5,832 | 5,403 | 5,045 |
| Sac. River into Delta (cfs) | 10,870 | 15,725 | 21,534 | 29,935 | 36,387 | 30,746 | 22,316 | 19,041 | 15,950 | 18,013 | 14,204 | 17,822 |
| Sac. River at Keswick (cfs) | 6,211 | 6,913 | 6,488 | 8,357 | 10,648 | 8,336 | 7,035 | 8,114 | 10,768 | 12,754 | 10,088 | 8,125 |
| Sac River at NCP (cfs) | 6,012 | 9,018 | 11,278 | 13,679 | 15,379 | 14,107 | 8,840 | 7,088 | 5,647 | 6,248 | 5,280 | 7,841 |
| Feather River blw. Thermalito (cfs) | 2,538 | 1,999 | 2,457 | 4,043 | 4,291 | 5,284 | 3,033 | 3,629 | 3,660 | 7,061 | 4,838 | 5,376 |
| Lower Feather River (cfs) | 3,030 | 2,896 | 4,794 | 10,756 | 11,750 | 12,395 | 8,768 | 7,659 | 6,210 | 7,677 | 5,790 | 7,100 |
| American River at Nimbus (cfs) | 1,618 | 2,608 | 3,357 | 4,542 | 5,221 | 4,048 | 3,369 | 3,383 | 3,195 | 3,273 | 2,245 | 2,448 |
| American River at H. St. (cfs) | 1,442 | 2,444 | 3,219 | 4,385 | 5,033 | 3,855 | 3,088 | 3,044 | 2,805 | 2,722 | 1,852 | 2,135 |
| SJ River at Vernalis (cfs) | 2,710 | 2,605 | 3,248 | 4,821 | 6,203 | 7,165 | 7,473 | 5,747 | 4,609 | 3,188 | 2,032 | 2,312 |
| Shasta Storage (TAF) | 2,612 | 2,570 | 2,752 | 3,023 | 3,277 | 3,646 | 3,938 | 3,955 | 3,656 | 3,196 | 2,884 | 2,693 |
| Folsom Storage (TAF) | 457 | 431 | 456 | 473 | 493 | 592 | 719 | 838 | 803 | 671 | 591 | 505 |
| Oroville Storage (TAF) | 1,591 | 1,565 | 1,701 | 1,915 | 2,192 | 2,439 | 2,716 | 2,854 | 2,746 | 2,302 | 2,011 | 1,710 |
| CVP San Luis Storage (TAF) | 231 | 351 | 523 | 644 | 738 | 809 | 729 | 573 | 408 | 245 | 146 | 179 |
| SWP San Luis Storage (TAF) | 339 | 331 | 431 | 574 | 706 | 814 | 730 | 562 | 404 | 410 | 377 | 381 |
| **Lower San Felipe Intake Alt.** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 5,908 | 11,434 | 20,704 | 42,021 | 52,783 | 42,227 | 30,976 | 22,070 | 12,345 | 7,784 | 4,433 | 9,729 |
| Jones Pumping Plant (cfs) | 3,495 | 3,548 | 3,921 | 3,236 | 3,317 | 3,114 | 1,210 | 1,081 | 2,576 | 3,386 | 3,716 | 3,984 |
| Banks Pumping Plant (cfs) | 3,211 | 3,794 | 4,733 | 3,606 | 4,043 | 4,026 | 1,193 | 985 | 2,427 | 5,832 | 5,403 | 5,045 |
| Sac. River into Delta (cfs) | 10,876 | 15,727 | 21,538 | 29,933 | 36,386 | 30,744 | 22,313 | 19,041 | 15,951 | 18,011 | 14,202 | 17,836 |
| Sac. River at Keswick (cfs) | 6,219 | 6,913 | 6,490 | 8,352 | 10,642 | 8,335 | 7,031 | 8,114 | 10,768 | 12,752 | 10,086 | 8,137 |
| Sac River at NCP (cfs) | 6,020 | 9,019 | 11,279 | 13,678 | 15,381 | 14,106 | 8,836 | 7,088 | 5,647 | 6,247 | 5,278 | 7,854 |
| Feather River blw. Thermalito (cfs) | 2,538 | 1,999 | 2,457 | 4,044 | 4,291 | 5,283 | 3,033 | 3,628 | 3,659 | 7,059 | 4,835 | 5,374 |
| Lower Feather River (cfs) | 3,031 | 2,896 | 4,794 | 10,756 | 11,750 | 12,395 | 8,768 | 7,658 | 6,211 | 7,676 | 5,790 | 7,100 |
| American River at Nimbus (cfs) | 1,616 | 2,609 | 3,358 | 4,542 | 5,221 | 4,049 | 3,369 | 3,383 | 3,195 | 3,273 | 2,244 | 2,449 |
| American River at H. St. (cfs) | 1,441 | 2,446 | 3,219 | 4,385 | 5,033 | 3,855 | 3,088 | 3,044 | 2,805 | 2,722 | 1,852 | 2,136 |
| SJ River at Vernalis (cfs) | 2,710 | 2,605 | 3,248 | 4,821 | 6,203 | 7,165 | 7,473 | 5,747 | 4,609 | 3,188 | 2,032 | 2,312 |
| Shasta Storage (TAF) | 2,612 | 2,569 | 2,751 | 3,022 | 3,276 | 3,646 | 3,938 | 3,955 | 3,656 | 3,197 | 2,884 | 2,693 |
| Folsom Storage (TAF) | 457 | 431 | 456 | 473 | 493 | 592 | 719 | 838 | 803 | 671 | 591 | 504 |
| Oroville Storage (TAF) | 1,591 | 1,565 | 1,701 | 1,915 | 2,192 | 2,439 | 2,716 | 2,854 | 2,746 | 2,302 | 2,011 | 1,710 |
| CVP San Luis Storage (TAF) | 230 | 349 | 521 | 642 | 737 | 808 | 728 | 572 | 407 | 244 | 145 | 178 |
| SWP San Luis Storage (TAF) | 339 | 331 | 431 | 574 | 706 | 814 | 730 | 562 | 404 | 410 | 377 | 381 |
| **Change from Future No Action** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 3 | 2 | 1 | -7 | -11 | -2 | -4 | 0 | 0 | 0 | 0 | 1 |
| Jones Pumping Plant (cfs) | 4 | 3 | 2 | 2 | 3 | -1 | 0 | 0 | 0 | 0 | -2 | 12 |
| Banks Pumping Plant (cfs) | 0 | -3 | 1 | -1 | 3 | 1 | 0 | 0 | 0 | 0 | -1 | 0 |
| Sac. River into Delta (cfs) | 6 | 2 | 3 | -2 | -1 | -1 | -3 | 0 | 1 | -2 | -2 | 14 |
| Sac. River at Keswick (cfs) | 8 | 0 | 2 | -5 | -5 | -1 | -4 | 0 | 0 | -2 | -2 | 12 |
| Sac River at NCP (cfs) | 7 | 1 | 1 | -1 | 2 | -1 | -4 | 0 | 0 | -1 | -2 | 13 |
| Feather River blw. Thermalito (cfs) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -1 | -3 | -2 | -2 |
| Lower Feather River (cfs) | 1 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 |
| American River at Nimbus (cfs) | -2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| American River at H. St. (cfs) | -1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| SJ River at Vernalis (cfs) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shasta Storage (TAF) | -1 | -1 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Folsom Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oroville Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CVP San Luis Storage (TAF) | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| SWP San Luis Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Results presented in Table 4-3 show only small changes in the CVP/SWP system.

## 4.3 Water Operations Modeling Results: WEAP

The additional San Felipe Division deliveries under the Lower San Felipe Intake Alternative provide additional imported supply for the SCVWD system. The results in Table 4-4 demonstrate how the additional supply helps to increase the total WTP deliveries, while also boosting average local surface, groundwater, and Semitropic storage levels. This allows the average annual emergency supply to increase by approximately 2,500 AF. ‘Change from FNA’ values are calculated and rounded from values with additional precision compared to those presented in the table. As a result, 'Change from FNA' values may reflect a different value than the difference between the Future No Action and Lower/Intake Treatment results shown in the table.

**Table 4-4. Annual Average WTP Delivery and Storage Conditions for the Lower San Felipe Intake Alternative as compared to the FNA.**

| Annual Average Values (1,000 acre-feet) | Future No Action | Lower Intake/ Treatment | Change from FNA |
|---|---|---|---|
| **Total WTP Delivery/M&I Water Supply** | 129 | 129 | 1 |
| Unmet WTP Demand | 2 | 1 | -1 |
| Total Local Surface Storage | 90 | 90 | 0 |
| North County Groundwater Storage | 316 | 318 | 2 |
| Total Local Groundwater Storage | 464 | 467 | 2 |
| Total Semitropic Storage | 150 | 179 | 29 |
| **Total SCVWD Available Storage** | 704 | 736 | 32 |
| **Total SCVWD Emergency Supply** | 406 | 408 | 2 |

Compared to the FNA Alternative, annual WTP deliveries are typically higher in years when demand is not fully met, as shown in Figure 4-1. This is especially true in low point years, when additional CVP supply is able to be delivered to the SCVWD system.

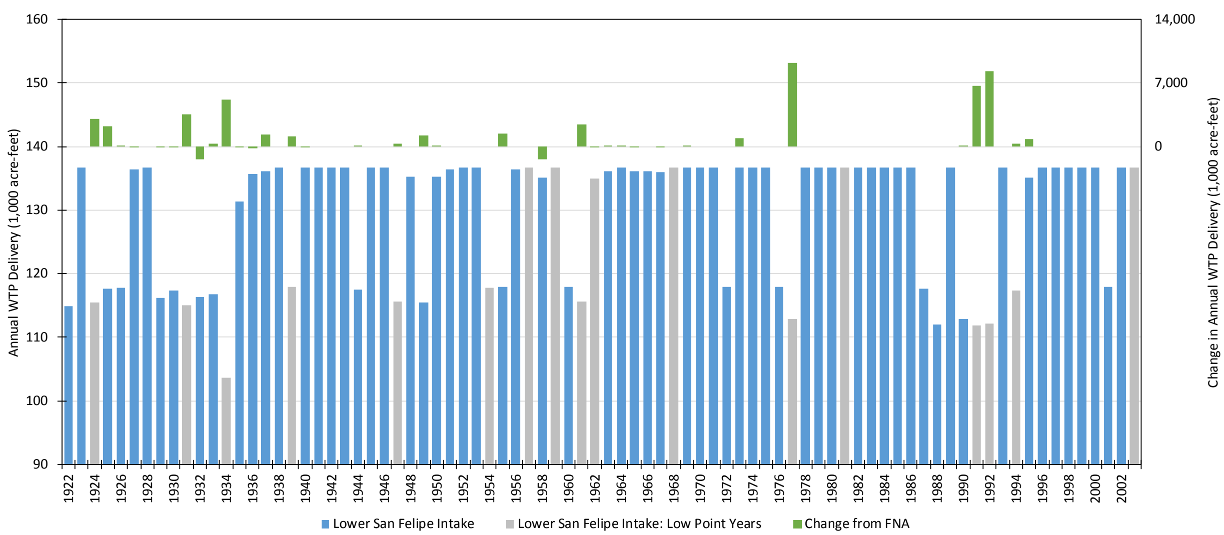


**Figure 4-1. Annual Water Treatment Plant Delivery and Change from the FNA**

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# Chapter 5
# San Luis Reservoir Expansion Alternative

The San Luis Reservoir Expansion Alternative would raise Sisk Dam by approximately ten feet above the dam safety raise currently being considered. The dam raise would allow water levels in the reservoir to also increase by ten feet, which results in a total storage increase of approximately 120,000 AF. This expansion would require additional construction at the dam (beyond what is required for the dam safety effort), including raising the impermeable layer to allow the water level increase.

The San Luis Reservoir Expansion Alternative would allocate the increased capacity to the CVP only. This expanded capacity would be operated in the same way as the current CVP portion of San Luis Reservoir, with the reservoir used for seasonal storage. The new capacity would fill after the existing capacity is filled, which would result in increased CVP yield during wetter years.

## 5.1 Modeling Approach and Assumptions

The San Luis Reservoir Expansion Alternative was simulated in CalSim II by increasing the storage capacity of both the CVP and SWP portion of San Luis Reservoir. The increased capacity of San Luis Reservoir could be filled during times when there is surplus Delta outflow in excess of required Delta outflow and Delta outflow needed to meet Delta water quality standards (Delta surplus). Delta surplus can only be exported when there also is available Delta export capacity. These periods typically overlap with periods when the existing CVP or SWP portion of San Luis Reservoir is full in the FNA.

This alternative may incidentally assist in maintaining storage in San Luis Reservoir above 300,000 AF and thus reducing the magnitude and/or magnitude of delivery interruptions to San Felipe Division M&I contractors.

## 5.2 Water Operations Modeling Results: CalSim II

The San Luis Reservoir Expansion Alternative was analyzed over an 82-year period to estimate the potential change in CVP deliveries due to the physical change in San Luis Reservoir.  The following sections summarize the effects of the alternative on CVP SOD M&I and agricultural water service contract deliveries and the CVP/SWP system.

### 5.2.1 CVP Deliveries

By allowing for additional CVP SOD storage, the San Luis Reservoir Expansion Alternative increases CVP deliveries to SOD water service contractors. The following tables summarize changes in deliveries to San Felipe Division M&I contractors and CVP SOD agricultural water service contractors under the San Luis Reservoir Expansion Alternative.

**Table 5-1. San Felipe Division M&I Deliveries under the San Luis Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | San Luis Reservoir Expansion (1,000 AF) | Change from FNA (1,000 AF) |
|---|---|---|---|
| Wet | 114 | 115 | 1 |
| Above Normal | 98 | 99 | 1 |
| Below Normal | 95 | 95 | 0 |
| Dry | 90 | 91 | 1 |
| Critical | 73 | 73 | 0 |
| All Years | 97 | 98 | 1 |

Table 5-1 shows minimal changes in the average annual San Felipe Division M&I deliveries under the San Luis Reservoir Expansion Alternative.

**Table 5-2. CVP SOD Agricultural Deliveries under the San Luis Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | San Luis Reservoir Expansion (1,000 AF) | Change from FNA (1,000 AF) |
|---|---|---|---|
| Wet | 1,341 | 1,366 | 25 |
| Above Normal | 1,009 | 1,027 | 18 |
| Below Normal | 878 | 899 | 21 |
| Dry | 591 | 593 | 2 |
| Critical | 176 | 176 | 0 |
| All Years | 878 | 893 | 15 |

Table 5-2 shows an average annual increase in CVP SOD agricultural service contract deliveries of 15 TAF. ‘Change from FNA’ values are calculated and rounded from values with additional precision compared to those presented in the table. As a result, ‘Change from FNA’ values may reflect a different value than the difference between the Future No Action and San Luis Reservoir Expansion results shown in the table.

### 5.2.2 SWP Deliveries

The San Luis Reservoir Expansion Alternative has the potential to decrease SWP deliveries by reducing SWP exports from the Delta through Banks Pumping Plant. Banks Pumping Plant exports can be reduced as compared to the FNA because the additional CVP storage capacity under the alternative allows the CVP to export more of the water they are entitled to under the Coordinated Operations Agreement. Under the FNA, the SWP is able to export this water when the CVP portion of San Luis Reservoir fills and CVP SOD demands are being met.

The following tables summarize the average annual simulated SWP Table A and Article 21 deliveries for the FNA, CVP Reservoir Expansion Alternative, and the change from the FNA. Results summarized in these tables show relatively small changes compared to the volume of delivery in the FNA.

**Table 5-3. SWP Table A Deliveries under the San Luis Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | San Luis Reservoir Expansion (1,000 AF) | Change from FNA (1,000 AF) |
|---|---|---|---|
| Wet | 3,177 | 3,171 | -6 |
| Above Normal | 2,659 | 2,656 | -3 |
| Below Normal | 2,567 | 2,560 | -7 |
| Dry | 2,009 | 2,011 | 2 |
| Critical | 1,242 | 1,242 | 0 |
| All Years | 2,458 | 2,455 | -3 |

**Table 5-4. SWP Article 21 Deliveries under the San Luis Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | San Luis Reservoir Expansion (1,000 AF) | Change from FNA (1,000 AF) |
|---|---|---|---|
| Wet | 83 | 82 | -1 |
| Above Normal | 107 | 107 | 0 |
| Below Normal | 71 | 57 | -14 |
| Dry | 25 | 25 | 0 |
| Critical | 12 | 12 | 0 |
| All Years | 61 | 59 | -2 |

### 5.2.3 CVP/SWP Effects

The Reservoir Expansion Alternative has the potential to affect CVP/SWP operations beyond San Luis Reservoir and the contractors who take delivery of water from the reservoir. Changes in SOD allocations can affect other areas of the CVP and SWP. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following tables provide a high-level summary of changes throughout the CVP/SWP system. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B to this Appendix.

**Table 5-5. Summary of CVP/SWP System Effects under the San Luis Reservoir Expansion Alternative**

| Future No Action | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Delta Outflow (cfs) | 5,905 | 11,432 | 20,703 | 42,028 | 52,793 | 42,230 | 30,980 | 22,070 | 12,345 | 7,785 | 4,433 | 9,728 |
| Jones Pumping Plant (cfs) | 3,491 | 3,546 | 3,918 | 3,234 | 3,314 | 3,114 | 1,210 | 1,081 | 2,575 | 3,387 | 3,718 | 3,972 |
| Banks Pumping Plant (cfs) | 3,211 | 3,798 | 4,732 | 3,606 | 4,040 | 4,024 | 1,193 | 985 | 2,426 | 5,832 | 5,403 | 5,045 |
| Sac. River into Delta (cfs) | 10,870 | 15,725 | 21,534 | 29,935 | 36,387 | 30,746 | 22,316 | 19,041 | 15,950 | 18,013 | 14,204 | 17,822 |
| Sac. River at Keswick (cfs) | 6,211 | 6,913 | 6,488 | 8,357 | 10,648 | 8,336 | 7,035 | 8,114 | 10,768 | 12,754 | 10,088 | 8,125 |
| Sac River at NCP (cfs) | 6,012 | 9,018 | 11,278 | 13,679 | 15,379 | 14,107 | 8,840 | 7,088 | 5,647 | 6,248 | 5,280 | 7,841 |
| Feather River blw. Thermalito (cfs) | 2,538 | 1,999 | 2,457 | 4,043 | 4,291 | 5,284 | 3,033 | 3,629 | 3,660 | 7,061 | 4,838 | 5,376 |
| Lower Feather River (cfs) | 3,030 | 2,896 | 4,794 | 10,756 | 11,750 | 12,395 | 8,768 | 7,659 | 6,210 | 7,677 | 5,790 | 7,100 |
| American River at Nimbus (cfs) | 1,618 | 2,608 | 3,357 | 4,542 | 5,221 | 4,048 | 3,369 | 3,383 | 3,195 | 3,273 | 2,245 | 2,448 |
| American River at H. St. (cfs) | 1,442 | 2,444 | 3,219 | 4,385 | 5,033 | 3,855 | 3,088 | 3,044 | 2,805 | 2,722 | 1,852 | 2,135 |
| SJ River at Vernalis (cfs) | 2,710 | 2,605 | 3,248 | 4,821 | 6,203 | 7,165 | 7,473 | 5,747 | 4,609 | 3,188 | 2,032 | 2,312 |
| Shasta Storage (TAF) | 2,612 | 2,570 | 2,752 | 3,023 | 3,277 | 3,646 | 3,938 | 3,955 | 3,656 | 3,196 | 2,884 | 2,693 |
| Folsom Storage (TAF) | 457 | 431 | 456 | 473 | 493 | 592 | 719 | 838 | 803 | 671 | 591 | 505 |
| Oroville Storage (TAF) | 1,591 | 1,565 | 1,701 | 1,915 | 2,192 | 2,439 | 2,716 | 2,854 | 2,746 | 2,302 | 2,011 | 1,710 |
| CVP San Luis Storage (TAF) | 231 | 351 | 523 | 644 | 738 | 809 | 729 | 573 | 408 | 245 | 146 | 179 |
| SWP San Luis Storage (TAF) | 339 | 331 | 431 | 574 | 706 | 814 | 730 | 562 | 404 | 410 | 377 | 381 |
| **CVP Reservoir Expansion Alt.** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 5,906 | 11,422 | 20,697 | 42,001 | 52,730 | 42,156 | 30,978 | 22,070 | 12,344 | 7,788 | 4,432 | 9,724 |
| Jones Pumping Plant (cfs) | 3,511 | 3,511 | 3,922 | 3,291 | 3,347 | 3,221 | 1,218 | 1,081 | 2,602 | 3,390 | 3,716 | 3,971 |
| Banks Pumping Plant (cfs) | 3,230 | 3,800 | 4,725 | 3,573 | 4,055 | 3,996 | 1,193 | 985 | 2,400 | 5,840 | 5,403 | 5,048 |
| Sac. River into Delta (cfs) | 10,909 | 15,682 | 21,522 | 29,936 | 36,376 | 30,743 | 22,320 | 19,041 | 15,949 | 18,028 | 14,202 | 17,822 |
| Sac. River at Keswick (cfs) | 6,224 | 6,878 | 6,489 | 8,355 | 10,635 | 8,333 | 7,040 | 8,117 | 10,771 | 12,766 | 10,095 | 8,131 |
| Sac River at NCP (cfs) | 6,025 | 8,978 | 11,276 | 13,681 | 15,371 | 14,109 | 8,846 | 7,088 | 5,645 | 6,255 | 5,282 | 7,847 |
| Feather River blw. Thermalito (cfs) | 2,551 | 1,999 | 2,448 | 4,041 | 4,290 | 5,292 | 3,034 | 3,629 | 3,648 | 7,073 | 4,838 | 5,378 |
| Lower Feather River (cfs) | 3,044 | 2,896 | 4,785 | 10,753 | 11,749 | 12,403 | 8,769 | 7,658 | 6,198 | 7,689 | 5,791 | 7,104 |
| American River at Nimbus (cfs) | 1,630 | 2,603 | 3,356 | 4,544 | 5,222 | 4,047 | 3,369 | 3,383 | 3,207 | 3,269 | 2,240 | 2,438 |
| American River at H. St. (cfs) | 1,453 | 2,439 | 3,217 | 4,386 | 5,033 | 3,853 | 3,088 | 3,044 | 2,817 | 2,718 | 1,851 | 2,124 |
| SJ River at Vernalis (cfs) | 2,710 | 2,605 | 3,248 | 4,821 | 6,203 | 7,165 | 7,474 | 5,747 | 4,610 | 3,188 | 2,032 | 2,313 |
| Shasta Storage (TAF) | 2,611 | 2,570 | 2,752 | 3,023 | 3,277 | 3,647 | 3,939 | 3,955 | 3,656 | 3,196 | 2,884 | 2,693 |
| Folsom Storage (TAF) | 457 | 431 | 457 | 473 | 493 | 592 | 719 | 838 | 803 | 671 | 591 | 505 |
| Oroville Storage (TAF) | 1,591 | 1,566 | 1,702 | 1,916 | 2,194 | 2,440 | 2,717 | 2,855 | 2,748 | 2,303 | 2,012 | 1,711 |
| CVP San Luis Storage (TAF) | 238 | 356 | 527 | 651 | 748 | 825 | 745 | 587 | 421 | 254 | 153 | 186 |
| SWP San Luis Storage (TAF) | 338 | 331 | 431 | 571 | 705 | 812 | 728 | 561 | 401 | 408 | 376 | 380 |
| **Change from Future No Action** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 0 | -10 | -6 | -27 | -63 | -74 | -2 | 0 | -1 | 3 | 0 | -3 |
| Jones Pumping Plant (cfs) | 20 | -35 | 4 | 57 | 32 | 107 | 8 | 0 | 27 | 4 | -2 | -1 |
| Banks Pumping Plant (cfs) | 19 | 2 | -7 | -33 | 14 | -28 | 0 | 0 | -26 | 8 | 0 | 3 |
| Sac. River into Delta (cfs) | 39 | -43 | -13 | 2 | -11 | -3 | 4 | 0 | -1 | 15 | -2 | -1 |
| Sac. River at Keswick (cfs) | 13 | -35 | 1 | -2 | -12 | -3 | 6 | 3 | 4 | 12 | 7 | 6 |
| Sac River at NCP (cfs) | 13 | -40 | -2 | 3 | -8 | 1 | 6 | 1 | -1 | 7 | 2 | 6 |
| Feather River blw. Thermalito (cfs) | 14 | 0 | -9 | -3 | -1 | 8 | 1 | 0 | -13 | 11 | 0 | 2 |
| Lower Feather River (cfs) | 14 | 0 | -9 | -3 | -1 | 8 | 1 | 0 | -12 | 12 | 1 | 4 |
| American River at Nimbus (cfs) | 13 | -5 | -1 | 2 | 1 | -1 | -1 | 0 | 13 | -4 | -5 | -10 |
| American River at H. St. (cfs) | 11 | -5 | -1 | 1 | 1 | -1 | -1 | 0 | 13 | -5 | -1 | -10 |
| SJ River at Vernalis (cfs) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shasta Storage (TAF) | -2 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | -1 |
| Folsom Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | 1 |
| Oroville Storage (TAF) | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 |
| CVP San Luis Storage (TAF) | 7 | 5 | 4 | 8 | 10 | 16 | 15 | 14 | 13 | 10 | 7 | 7 |
| SWP San Luis Storage (TAF) | 0 | 0 | 0 | -3 | -1 | -2 | -2 | -1 | -3 | -2 | -2 | -1 |

Average monthly results presented in Table 5-5 show relatively small changes in reservoir levels, river flow, Delta inflow and outflow, and Delta exports. The primary change in CVP and SWP operations with the San Luis Reservoir

Expansion Alternative is an increase in Delta exports at both Jones Pumping Plant to capture available Delta surplus and store it in the additional storage capacity provided by the alternative. This increase in Jones Pumping Plant exports results in a reduction in Delta outflow in these same months, and in some instances, a reduction in Banks Pumping Plant exports by the SWP. These changes tend to increase the average monthly storage in the CVP portion of San Luis Reservoir and decrease the average monthly storage in the SWP portion. Total San Luis Reservoir storage goes below 300,000 acre-feet in 18 of the 82-year simulation in the San Luis Reservoir Expansion Alternative.

## 5.3 Water Operations Modeling Results: WEAP

Local SCVWD results from the WEAP model indicate minimal to no change in local operations and supply under the San Luis Reservoir Expansion Alternative, as shown in Table 5-6. This is largely expected given the small changes in San Felipe Division deliveries shown in Table 5-1. 'Change from FNA' values are calculated and rounded from values with additional precision compared to those presented in the table. As a result, 'Change from FNA' values may reflect a different value than the difference between the Future No Action and the San Luis Reservoir Expansion results shown in the table.

**Table 5-6. Annual Average WTP Delivery and Storage Conditions for the San Luis Reservoir Expansion Alternative as compared to the FNA.**

| Annual Average Values (1,000 acre-feet) | Future No Action | San Luis Res. Expansion | Change from FNA |
|---|---|---|---|
| **Total WTP Delivery/M&I Water Supply** | 129 | 129 | 0 |
| Unmet WTP Demand | 2 | 2 | 0 |
| Total Local Surface Storage | 90 | 90 | 0 |
| North County Groundwater Storage | 316 | 316 | 0 |
| Total Local Groundwater Storage | 464 | 464 | 0 |
| Total Semitropic Storage | 150 | 151 | 1 |
| **Total SCVWD Available Storage** | 704 | 705 | 1 |
| **Total SCVWD Emergency Supply** | 406 | 406 | 0 |

Figure 5-1 shows annual SCVWD WTP deliveries under the San Luis Reservoir Expansion Alternative. There is little change in annual WTP deliveries under this alternative.

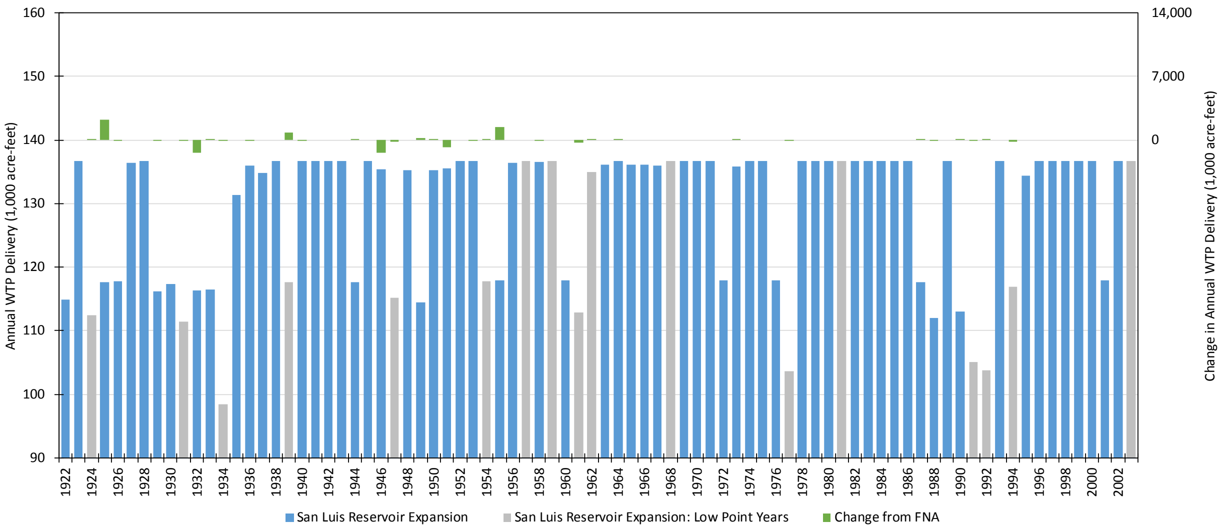


**Figure 5-1. Annual Water Treatment Plant Delivery and Change from the FNA**

# Chapter 6
# Treatment Alternative

The Treatment alternative includes infrastructure improvements to SCVWD water treatment facilities that would allow San Felipe Division diversions from San Luis Reservoir even when total storage in the reservoir is below 300,000 AF.

## 6.1 Modeling Approach and Assumptions

The Treatment Alternative would include the same assumptions as the Lower San Felipe Intake Alternative, with the addition of improvements to SCVWD water treatment facilities. San Luis Reservoir would continue to function as seasonal storage. This alternative allows delivery to San Felipe Division M&I contractors if San Luis Reservoir storage is maintained above dead pool. This operation was simulated in CalSim II by removing the constraint requiring San Luis Reservoir storage to be greater than 300,000 AF for delivery to San Felipe Division M&I contractors.

## 6.2 Water Operations Modeling Results

The Treatment Alternative was analyzed over an 82-year period to estimate the potential change in CVP deliveries due to the ability to continue deliveries to San Felipe M&I contractors during periods when San Luis Reservoir is below 300,000 AF. Overall results for both CalSim II and WEAP model runs are identical to those presented for the Lower San Felipe Intake Alternative. Please refer to results from Chapter 4 for effects to CVP deliveries, CVP/SWP system operations, and local SCVWD effects.

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# Chapter 7
# Pacheco Reservoir Expansion Alternative

The Pacheco Reservoir Expansion Alternative includes construction and operation of a new Pacheco dam and reservoir, pump station, conveyance facilities, and related miscellaneous infrastructure. The new dam and reservoir would be constructed on Pacheco Creek, 0.5 mile upstream from the existing North Fork Dam, and would inundate most of the existing Pacheco Reservoir. The proposed total storage for the new reservoir is 141,600 AF, with an active storage of 140,800 AF. The full pool elevation would be 694 feet and would inundate an additional 1,245 acres, for a total of 1,385 total acres inundated. Water would be collected in the new reservoir during the winter months from runoff from the local watershed area, and diversion of CVP supplies from the Pacheco Conduit, when needed.

## 7.1 Modeling Approach and Assumptions

The Pacheco Reservoir Expansion Alternative allows delivery to San Felipe Division CVP M&I contractors if San Luis Reservoir storage is maintained above dead pool. This operation was simulated in CalSim II by removing the constraint requiring San Luis Reservoir storage to be greater than 300,000 AF for delivery to San Felipe Division M&I contractors.

Operation of Pacheco Reservoir includes a transfer of 2,000 AF of San Felipe Division water supply to CVP SOD Refuge Supply in Below Normal years under the Accelerated Water Transfer Program. This operation is included in the CalSim II simulation.

## 7.2 Water Operations Modeling Results: CalSim II

The Pacheco Reservoir Expansion Alternative was analyzed over an 82-year period to estimate the potential change in CVP deliveries due to the ability to continue deliveries to San Felipe M&I contractors during periods when San Luis Reservoir is below 300,000 AF. The following sections summarize the effects of the alternative on CVP SOD M&I and agricultural water service contract deliveries and CVP/SWP system.

### 7.2.1 CVP Deliveries

The Pacheco Reservoir Expansion Alternative increases San Felipe Division CVP M&I water service contract deliveries by eliminating interruptions due to low-point issues. San Felipe Division CVP M&I deliveries increase because contractors can take delivery of water when San Luis Reservoir is below 300,000 AF.

The following tables summarize changes in deliveries to San Felipe Division CVP M&I contractors, CVP SOD agricultural water service contractors, and CVP SOD refuges under the Pacheco Reservoir Expansion Alternative.

**Table 7-1. San Felipe Division CVP M&I Deliveries under the Pacheco Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF ) | Pacheco Reservoir Expansion (1,000 AF ) | Change from FNA (1,000 AF ) |
|---|---|---|---|
| Wet | 114 | 115 | 1 |
| Above Normal | 98 | 103 | 5 |
| Below Normal | 95 | 100 | 5 |
| Dry | 90 | 93 | 2 |
| Critical | 73 | 76 | 3 |
| All Years | 97 | 100 | 3 |

Table 7-1 shows an average annual increase in San Felipe Division CVP M&I deliveries of 3,000 AF under the Pacheco Reservoir Expansion Alternative. Delivery increases occur only within the San Felipe Division. There is no meaningful change to CVP SOD M&I contractors outside the San Felipe Division because there is no meaningful change to CVP M&I allocations. Increased deliveries match interrupted San Felipe Division M&I deliveries, as presented in Table 3-1, except for below normal years when 2,000 AF of San Felipe M&I supply is shifted to CVP SOD refuge supply. 'Change from FNA' values are calculated and rounded from values with additional precision compared to those presented in the table. As a result, 'Change from FNA' values may reflect a different value than the difference between the Future No Action and Pacheco Reservoir Expansion results shown in the table.

**Table 7-2. CVP SOD Agricultural Deliveries under the Pacheco Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | Pacheco Reservoir Expansion (1,000 AF ) | Change from FNA (1,000 AF ) |
|---|---|---|---|
| Wet | 1,341 | 1,341 | 0 |
| Above Normal | 1,009 | 1,004 | -5 |
| Below Normal | 878 | 876 | -2 |
| Dry | 591 | 589 | -2 |
| Critical | 176 | 176 | 0 |
| All Years | 878 | 877 | -2 |

Table 7-2 shows an average annual decrease in CVP SOD agricultural service contract deliveries of 2,000 AF. Simulated deliveries decrease because under the FNA Alternative interrupted San Felipe Division M&I deliveries remain in San Luis Reservoir and are available to be allocated to agricultural water service contractors in subsequent years. Under the Pacheco Reservoir Expansion Alternative, this interrupted supply is instead delivered to San Felipe Division M&I contractors, resulting in slightly lower CVP SOD agricultural deliveries. ‘Change from FNA’ values are calculated and rounded from values with additional precision compared to those presented in the table. As a result, ‘Change from FNA’ values may reflect a different value than the difference between the Future No Action and Pacheco Reservoir Expansion results shown in the table.

**Table 7-3. CVP SOD Refuge Deliveries under the Pacheco Reservoir Expansion Alternative**

| Sacramento Valley Index | Future No Action (1,000 AF) | Pacheco Reservoir (1,000 AF ) | Change from FNA (1,000 AF ) |
|---|---|---|---|
| Wet | 280 | 280 | 0 |
| Above Normal | 275 | 275 | 0 |
| Below Normal | 278 | 280 | 2 |
| Dry | 275 | 275 | 0 |
| Critical | 249 | 249 | 0 |
| All Years | 273 | 273 | 0 |

Table 7-3 shows an average annual increase in CVP SOD refuge deliveries of 2,000 AF in Below Normal years. This additional refuge delivery is part of the Pacheco Reservoir Expansion operations plan, which dedicates 2,000 AF of San Felipe Division CVP M&I supply in Below Normal years to CVP SOD refuges. This supply comes out of total SCVWD deliveries, as shown and discussed above in Table 7-1.

### 7.2.2 CVP/SWP Effects

The Pacheco Reservoir Expansion Alternative has the potential to affect CVP/SWP operations beyond San Luis Reservoir and the contractors who take delivery of water from the reservoir. As described in the previous section, interrupted M&I deliveries under the FNA tend to increase allocations and deliveries to other CVP contractors relative to the Pacheco Reservoir Expansion Alternative. Changes in SOD allocations can affect other areas of the CVP and, in some instances, the SWP due to requirements in the Coordinated Operation Agreement. These changes have the potential to affect resources in other parts of the system. Therefore, changes in river flows, reservoir storage, Delta outflow, and Delta export operations were quantified and reviewed in support of the environmental documentation. The following tables provide a high-level summary of changes throughout the CVP/SWP system. More detailed results were provided and reviewed by resource area specialists and are illustrated in figures located in Attachment B to this Appendix.

**Table 7-4. Summary CVP/SWP System Effects under the Pacheco Reservoir Expansion Alternative**

| Future No Action | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Delta Outflow (cfs) | 5,905 | 11,432 | 20,703 | 42,028 | 52,793 | 42,230 | 30,980 | 22,070 | 12,345 | 7,785 | 4,433 | 9,728 |
| Jones Pumping Plant (cfs) | 3,491 | 3,546 | 3,918 | 3,234 | 3,314 | 3,114 | 1,210 | 1,081 | 2,575 | 3,387 | 3,718 | 3,972 |
| Banks Pumping Plant (cfs) | 3,211 | 3,798 | 4,732 | 3,606 | 4,040 | 4,024 | 1,193 | 985 | 2,426 | 5,832 | 5,403 | 5,045 |
| Sac. River into Delta (cfs) | 10,870 | 15,725 | 21,534 | 29,935 | 36,387 | 30,746 | 22,316 | 19,041 | 15,950 | 18,013 | 14,204 | 17,822 |
| Sac. River at Keswick (cfs) | 6,211 | 6,913 | 6,488 | 8,357 | 10,648 | 8,336 | 7,035 | 8,114 | 10,768 | 12,754 | 10,088 | 8,125 |
| Sac River at NCP (cfs) | 6,012 | 9,018 | 11,278 | 13,679 | 15,379 | 14,107 | 8,840 | 7,088 | 5,647 | 6,248 | 5,280 | 7,841 |
| Feather River blw. Thermalito (cfs) | 2,538 | 1,999 | 2,457 | 4,043 | 4,291 | 5,284 | 3,033 | 3,629 | 3,660 | 7,061 | 4,838 | 5,376 |
| Lower Feather River (cfs) | 3,030 | 2,896 | 4,794 | 10,756 | 11,750 | 12,395 | 8,768 | 7,659 | 6,210 | 7,677 | 5,790 | 7,100 |
| American River at Nimbus (cfs) | 1,618 | 2,608 | 3,357 | 4,542 | 5,221 | 4,048 | 3,369 | 3,383 | 3,195 | 3,273 | 2,245 | 2,448 |
| American River at H. St. (cfs) | 1,442 | 2,444 | 3,219 | 4,385 | 5,033 | 3,855 | 3,088 | 3,044 | 2,805 | 2,722 | 1,852 | 2,135 |
| SJ River at Vernalis (cfs) | 2,710 | 2,605 | 3,248 | 4,821 | 6,203 | 7,165 | 7,473 | 5,747 | 4,609 | 3,188 | 2,032 | 2,312 |
| Shasta Storage (TAF) | 2,612 | 2,570 | 2,752 | 3,023 | 3,277 | 3,646 | 3,938 | 3,955 | 3,656 | 3,196 | 2,884 | 2,693 |
| Folsom Storage (TAF) | 457 | 431 | 456 | 473 | 493 | 592 | 719 | 838 | 803 | 671 | 591 | 505 |
| Oroville Storage (TAF) | 1,591 | 1,565 | 1,701 | 1,915 | 2,192 | 2,439 | 2,716 | 2,854 | 2,746 | 2,302 | 2,011 | 1,710 |
| CVP San Luis Storage (TAF) | 231 | 351 | 523 | 644 | 738 | 809 | 729 | 573 | 408 | 245 | 146 | 179 |
| SWP San Luis Storage (TAF) | 339 | 331 | 431 | 574 | 706 | 814 | 730 | 562 | 404 | 410 | 377 | 381 |
| **Pacheco Reservoir** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 5,908 | 11,434 | 20,703 | 42,021 | 52,783 | 42,227 | 30,976 | 22,070 | 12,345 | 7,784 | 4,433 | 9,729 |
| Jones Pumping Plant (cfs) | 3,496 | 3,548 | 3,920 | 3,236 | 3,317 | 3,114 | 1,210 | 1,081 | 2,576 | 3,386 | 3,716 | 3,984 |
| Banks Pumping Plant (cfs) | 3,211 | 3,794 | 4,733 | 3,606 | 4,043 | 4,025 | 1,193 | 985 | 2,427 | 5,832 | 5,403 | 5,044 |
| Sac. River into Delta (cfs) | 10,877 | 15,726 | 21,537 | 29,933 | 36,386 | 30,744 | 22,313 | 19,041 | 15,951 | 18,011 | 14,202 | 17,836 |
| Sac. River at Keswick (cfs) | 6,219 | 6,913 | 6,489 | 8,352 | 10,643 | 8,335 | 7,031 | 8,114 | 10,768 | 12,752 | 10,086 | 8,137 |
| Sac River at NCP (cfs) | 6,020 | 9,018 | 11,278 | 13,678 | 15,381 | 14,106 | 8,836 | 7,088 | 5,647 | 6,247 | 5,278 | 7,854 |
| Feather River blw. Thermalito (cfs) | 2,539 | 1,999 | 2,457 | 4,044 | 4,291 | 5,283 | 3,033 | 3,628 | 3,659 | 7,059 | 4,836 | 5,374 |
| Lower Feather River (cfs) | 3,031 | 2,896 | 4,794 | 10,756 | 11,750 | 12,395 | 8,768 | 7,658 | 6,211 | 7,676 | 5,790 | 7,100 |
| American River at Nimbus (cfs) | 1,616 | 2,609 | 3,358 | 4,542 | 5,221 | 4,049 | 3,369 | 3,383 | 3,195 | 3,273 | 2,244 | 2,449 |
| American River at H. St. (cfs) | 1,441 | 2,446 | 3,219 | 4,385 | 5,033 | 3,855 | 3,088 | 3,044 | 2,805 | 2,723 | 1,852 | 2,136 |
| SJ River at Vernalis (cfs) | 2,710 | 2,605 | 3,248 | 4,821 | 6,203 | 7,165 | 7,473 | 5,747 | 4,609 | 3,188 | 2,032 | 2,312 |
| Shasta Storage (TAF) | 2,611 | 2,569 | 2,751 | 3,022 | 3,276 | 3,646 | 3,938 | 3,955 | 3,656 | 3,197 | 2,884 | 2,693 |
| Folsom Storage (TAF) | 457 | 431 | 456 | 473 | 493 | 592 | 719 | 838 | 803 | 671 | 591 | 505 |
| Oroville Storage (TAF) | 1,591 | 1,565 | 1,701 | 1,915 | 2,192 | 2,439 | 2,716 | 2,854 | 2,746 | 2,302 | 2,011 | 1,710 |
| CVP San Luis Storage (TAF) | 230 | 349 | 521 | 642 | 736 | 808 | 728 | 572 | 407 | 244 | 145 | 178 |
| SWP San Luis Storage (TAF) | 339 | 331 | 431 | 574 | 706 | 814 | 730 | 562 | 404 | 410 | 377 | 381 |
| **Change from Future No Action** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** |
| Delta Outflow (cfs) | 3 | 2 | 0 | -7 | -11 | -3 | -4 | 0 | 0 | 0 | 1 | 1 |
| Jones Pumping Plant (cfs) | 5 | 3 | 2 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | -2 | 12 |
| Banks Pumping Plant (cfs) | -1 | -4 | 1 | -1 | 3 | 1 | 0 | 0 | 0 | 0 | -1 | 0 |
| Sac. River into Delta (cfs) | 7 | 1 | 2 | -2 | -1 | -2 | -3 | 0 | 1 | -2 | -2 | 14 |
| Sac. River at Keswick (cfs) | 8 | -1 | 1 | -5 | -5 | -1 | -4 | 0 | 0 | -2 | -2 | 13 |
| Sac River at NCP (cfs) | 8 | 0 | 1 | -1 | 1 | -1 | -4 | 0 | 0 | -1 | -2 | 13 |
| Feather River blw. Thermalito (cfs) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | -1 | -1 | -3 | -2 | -1 |
| Lower Feather River (cfs) | 1 | 0 | 0 | 0 | 0 | -1 | 0 | 0 | 0 | 0 | 0 | 0 |
| American River at Nimbus (cfs) | -2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| American River at H. St. (cfs) | -1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| SJ River at Vernalis (cfs) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shasta Storage (TAF) | -1 | -1 | -1 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Folsom Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oroville Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CVP San Luis Storage (TAF) | -2 | -2 | -2 | -2 | -2 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |
| SWP San Luis Storage (TAF) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Results presented in Table 7-4 show only small changes in the CVP/SWP system.

## 7.3 Water Operations Modeling Results: WEAP

The additional San Felipe deliveries under the Pacheco Reservoir Expansion Alternative provide additional imported supply into the SCVWD system as summarized by the WEAP results in Table 7-5. The additional supply helps to increase the total WTP deliveries, while also boosting local surface, groundwater, and Semitropic storage levels. Total local surface storage is much higher as a result of the expansion of the existing Pacheco Reservoir. This provides an important boost not only local surface water supply, but also to

SCVWD emergency supplies, which are approximately 102,000 AF higher compared to the FNA. 'Change from FNA' values are calculated and rounded from values with additional precision compared to those presented in the table. As a result, 'Change from FNA' values may reflect a different value than the difference between the Future No Action and Pacheco Reservoir Expansion results shown in the table.

**Table 7-5. Annual Average WTP Delivery and Storage Conditions for the Pacheco Reservoir Expansion Alternative as compared to the FNA.**

| Annual Average Values (1,000 acre-feet) | Future No Action | New Pacheco Reservoir | Change from FNA |
|---|---|---|---|
| **Total WTP Delivery/M&I Water Supply** | 129 | 129 | 0 |
| Unmet WTP Demand | 2 | 1 | 0 |
| Total Local Surface Storage | 90 | 187 | 97 |
| North County Groundwater Storage | 316 | 321 | 5 |
| Total Local Groundwater Storage | 464 | 471 | 7 |
| Total Semitropic Storage | 150 | 153 | 3 |
| **Total SCVWD Available Storage** | 704 | 811 | 107 |
| **Total SCVWD Emergency Supply** | 406 | 508 | 102 |

Annual WTP deliveries increase in most low point years, as shown in Figure 7-1. Results are similar to the changes in WTP deliveries under the Lower San Felipe Intake Alternative (Figure 4-1).

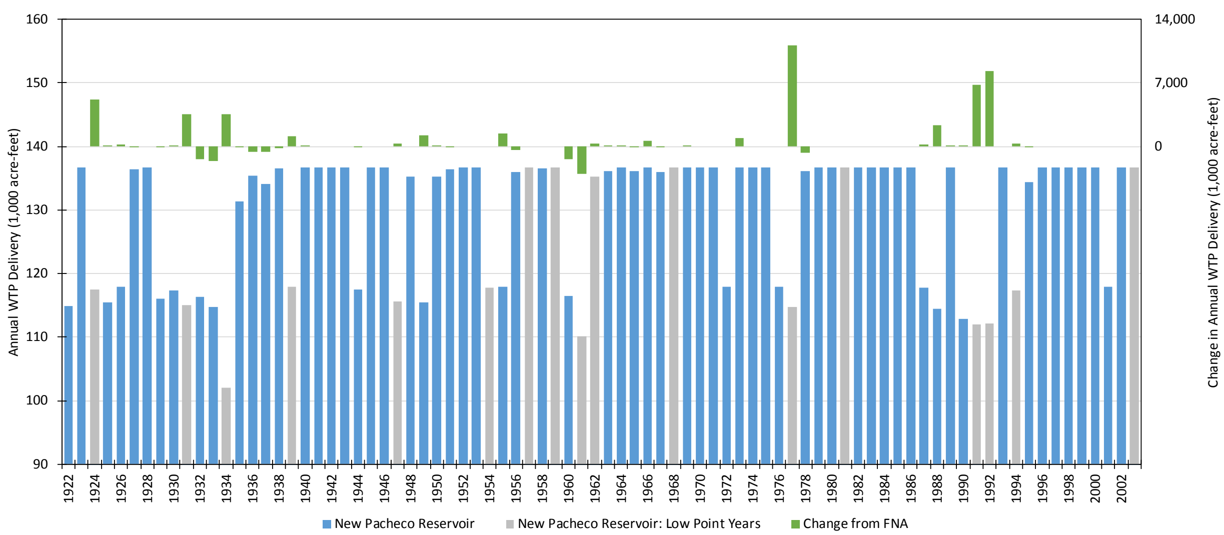


**Figure 7-1. Annual Water Treatment Plant Delivery and Change from the FNA**

# Attachment A
## CalSim II Assumptions for Future No Action Conditions

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| | Period of Simulation: 82 years (1922-2003) |
|---|---|
| | **Future Level Study** |
| **HYDROLOGY** | |
| **Level of Development** | 2020 Level, *DWR Bulletin 160-98*[1] |
| Sacramento River Region Demands | |
| CVP | Land use based, limited by full contract |
| SWP (FRSA) | Land use based, limited by full contract |
| Non-Project | Land use based |
| Woodland-Davis Clean Water Agency | Included |
| Antioch | Pre-1914 water right |
| CVP Refuges | Firm Level 2 water needs |
| American River Basin Demands | |
| Water rights | 2020 Level |
| CVP | 2020 Level, full contracts including Freeport Regional Water Project and Sacramento River Water Reliability Project |
| San Joaquin River Basin Demands | |
| Friant Unit | Limited by contract amounts, based on current allocation policy |
| Lower Basin | Land use based with district level operations and constraints |
| Stanislaus River Basin[2] | Land use based, with New Melones Interim Operations Plan and NMFS biological opinion (June 2009), Actions 3.1.2 and 3.1.3[5] |
| South of Delta Demands | |
| CVP | Full contract |
| Contra Costa Water District | 195 taf/yr |
| SWP (with North Bay Aqueduct) | 4.1 maf/yr |
| SWP Article 21 Demand | Metropolitan Water District of Southern California up to 200 taf/month (Dec-Mar), KCWA demand up to 180 taf/month and others up to 34 taf/month |
| **FACILITIES** | |
| Red Bluff Diversion Dam | Fish Passage Improvement Project in place with 2,500 cfs capacity |
| Freeport Regional Water Project | Included with diversions to EBMUD |
| Banks Pumping Capacity | Physical capacity is 10,300 cfs, 6,680 cfs permitted capacity up to 8,500 cfs (Dec 15th–Mar 15th) depending on Vernalis flow conditions[3] additional capacity of 500 cfs (up to 7,180 cfs) allowed for Jul–Sep for reducing impact of NMFS biological opinion on SWP (Jun 2009), Action 4.2.1[5] |
| Jones Pumping Capacity | Exports up to 4,600 cfs permit capacity in all months |
| Delta-Mendota Canal-California Aqueduct Intertie | Included with 400 cfs capacity |
| Los Vaqueros Reservoir Capacity | 160 taf |
| South Bay Aqueduct | South Bay Aqueduct Enlargement to 430 cfs |
| **REGULATORY STANDARDS** | |
| Trinity River | |
| Minimum Flow below Lewiston Dam | Trinity EIS Preferred Alternative (369-815 taf/yr) |
| Trinity Reservoir End-of-September Minimum Storage | Trinity EIS Preferred Alternative (600 taf as able) |

| | Period of Simulation: 82 years (1922-2003) |
|---|---|
| | **Future Level Study** |
| Clear Creek | |
| Minimum Flow below Whiskeytown Dam | Downstream water rights, 1963 Reclamation Proposal to USFWS and NPS, predetermined Central Valley Project Improvement Act 3406(b)(2) flows and NMFS biological opinion (June 2009) Action I.1.1[5] |
| Upper Sacramento River | |
| Shasta Lake End-of-September Minimum Storage | NMFS 2004 Winter-run biological opinion (1900 taf), predetermined Central Valley Project Improvement Act 3406(b)(2) flows, and NMFS biological opinion (Jun 2009) Action I.2.1[5] |
| Minimum Flow below Keswick Dam | Flows for SWRCB Water Rights Order 90-5 and 1993 Winter-run biological opinion temperature control, predetermined Central Valley Project Improvement Act 3406(b)(2) flows, and NMFS biological opinion (Jun 2009), Action I.2.2[5] |
| Feather River | |
| Minimum Flow below Thermalito Diversion Dam | 2006 Settlement Agreement (700/800 cfs) |
| Minimum Flow below Thermalito Afterbay outlet | 1983 DWR, DFG Agreement (750-1700 cfs) |
| Yuba River | |
| Minimum flow below Daguerre Point Dam | D-1644 Operations (Lower Yuba River Accord)[4] |
| American River | |
| Minimum Flow below Nimbus Dam | American River Flow Management as required by NMFS biological opinion (Jun 2009), Action 2.1[5] |
| Minimum Flow at H Street Bridge | SWRCB D-893 |
| Lower Sacramento River | |
| Minimum Flow near Rio Vista | SWRCB D-1641 |
| Mokelumne River | |
| Minimum Flow below Camanche Dam | Federal Energy Regulatory Commission 2916-029, 1996 Joint Settlement Agreement (100 – 325 cfs) |
| Minimum Flow below Woodbridge Diversion Dam | Federal Energy Regulatory Commission 2916-029, 1996 Joint Settlement Agreement (25 – 300 cfs) |
| Stanislaus River | |
| Minimum Flow below Goodwin Dam | 1987 Reclamation, DFG agreement, and flows required for NMFS biological opinion (Jun 2009) Actions III.1.2 and III.1.3[5] |
| Minimum Dissolved Oxygen | SWRCB D-1422 |
| **REGULATORY STANDARDS** | |
| Merced River | |
| Minimum Flow below Crocker-Huffman Diversion Dam | Davis-Grunsky (180 – 220 cfs, Nov – Mar) and Cowell Agreement |
| Minimum Flow at Shaffer Bridge | Federal Energy Regulatory Commission 2179 (25-100 cfs) |
| Tuolumne River | |
| Minimum Flow at Lagrange Bridge | Federal Energy Regulatory Commission 2299-024, 1995 Settlement Agreement (94-301 taf/yr) |
| San Joaquin River | |
| San Joaquin River Restoration | Full flows |
| Maximum Salinity near Vernalis | SWRCB D-1641 |
| Minimum Flow near Vernalis | SWRCB D-1641, NMFS biological opinion (Jun 2009), Action 4.2.1[5] |

| | Period of Simulation: 82 years (1922-2003) |
|---|---|
| | **Future Level Study** |
| Sacramento River-San Joaquin River Delta | |
| Delta Outflow Index (Flow and Salinity) | SWRCB D-1641, USFWS biological opinion (Dec 2008), Action 4[5] |
| Delta Cross Channel Gates | SWRCB D-1641, NMFS biological opinion (Jun 2009) Action 4.1.2[5] |
| Delta Exports | SWRCB D-1641, NMFS biological opinion (Jun 2009) Action 4.2.1[5] |
| Combined Flow in Old and Middle River | USFWS biological opinion (Dec 2008), Actions 1–3 and NMFS biological opinion (Jun 2009), Action 4.2.3[5] |
| **OPERATIONS CRITERIA** | |
| **Subsystem** | |
| Upper Sacramento River | |
| Flow Objective for Navigation (Wilkins Slough) | NMFS biological opinion (Jun 2009) Action I.4[5]; 3,250 – 5,000 cfs based on CVP water supply condition |
| American River | |
| Folsom Dam Flood Control | Variable 400/670 without outlet modifications |
| Feather River | |
| Flow at Mouth | Maintain DFG/DWR flow target above Verona or 2800 cfs Apr-Sep, dependent on Oroville inflow and FRSA allocation |
| **System-wide** | |
| CVP Water Allocation | |
| CVP Settlement and Exchange | 100% (75% in Shasta Critical years) |
| CVP Refuges | 100% (75% in Shasta Critical years) |
| CVP Agriculture | 100% - 0% based on supply; additionally limited due to D-1641, USFWS biological opinion (Dec 2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| CVP Municipal & Industrial | 100% - 0% based on supply; additionally limited due to D-1641, USFWS biological opinion (Dec 2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| **OPERATIONS CRITERIA** | |
| **SWP Water Allocation** | |
| North of Delta (FRSA) | Contract specific |
| South of Delta | Based on supply, Monterey Agreement; allocations limited due to D-1641, USFWS biological opinion (Dec2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| CVP/SWP Coordinated Operations | |
| Sharing of Responsibility for In Basin Use | 1986 Coordinated Operations Agreement |
| Sharing of Surplus Flows | 1986 Coordinated Operations Agreement |
| Sharing of Restricted Export Capacity | Equal sharing of export capacity under SWRCB D-1641, USFWS biological opinion (Dec 2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| Transfers | |
| Lower Yuba River Accord[6] | Yuba River acquisitions for reducing impact of NMFS biological opinion export restrictions on SWP |

[1] The Sacramento Valley hydrology used in the Future Conditions CalSim II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of future-level projected land-use assumptions are being coordinated with the California Water Plan Update for future models.

[2] The CalSim II model representation for the Stanislaus River does not necessarily represent Reclamation's current or future operational policies. A suitable plan for supporting flows has not been developed for NMFS biological opinion (Jun 2009), Action 3.1.3.

[3] Current US Army Corps of Engineers permit for Harvey O. Banks Pumping Plant allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during Dec 15th–Mar 15th up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.

[4] D-1644 and the Lower Yuba River Accord are assumed to be implemented for Future Conditions. The Yuba River is not dynamically modeled in CalSim II. Yuba River hydrology and availability of water acquisitions under the Lower Yuba River Accord are based on modeling performed and provided by the Lower Yuba River Accord EIS/EIR study team.

[5] In cooperation with USBR, NMFS, USFWS, and DGF, the DWR has developed assumptions for implementation of the USFWS biological opinion (December 15, 2008) and NMFS biological opinion (June 4, 2009) in CalSim II.

[6] Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks Pumping Plant during Jul–Sep, are assumed to be used to reduce as much of the effect of the April–May Delta export actions on SWP contractors as possible.

# San Luis Low Point Improvement Project Environmental Impact Statement / Environmental Impact Report

## Appendix B: Attachment B, Comparison of Future No Action Conditions and Project Alternatives at Future LOD

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**Figure 1: Comparison of Trinity Storage for Lower San Felipe Intake Alternative**

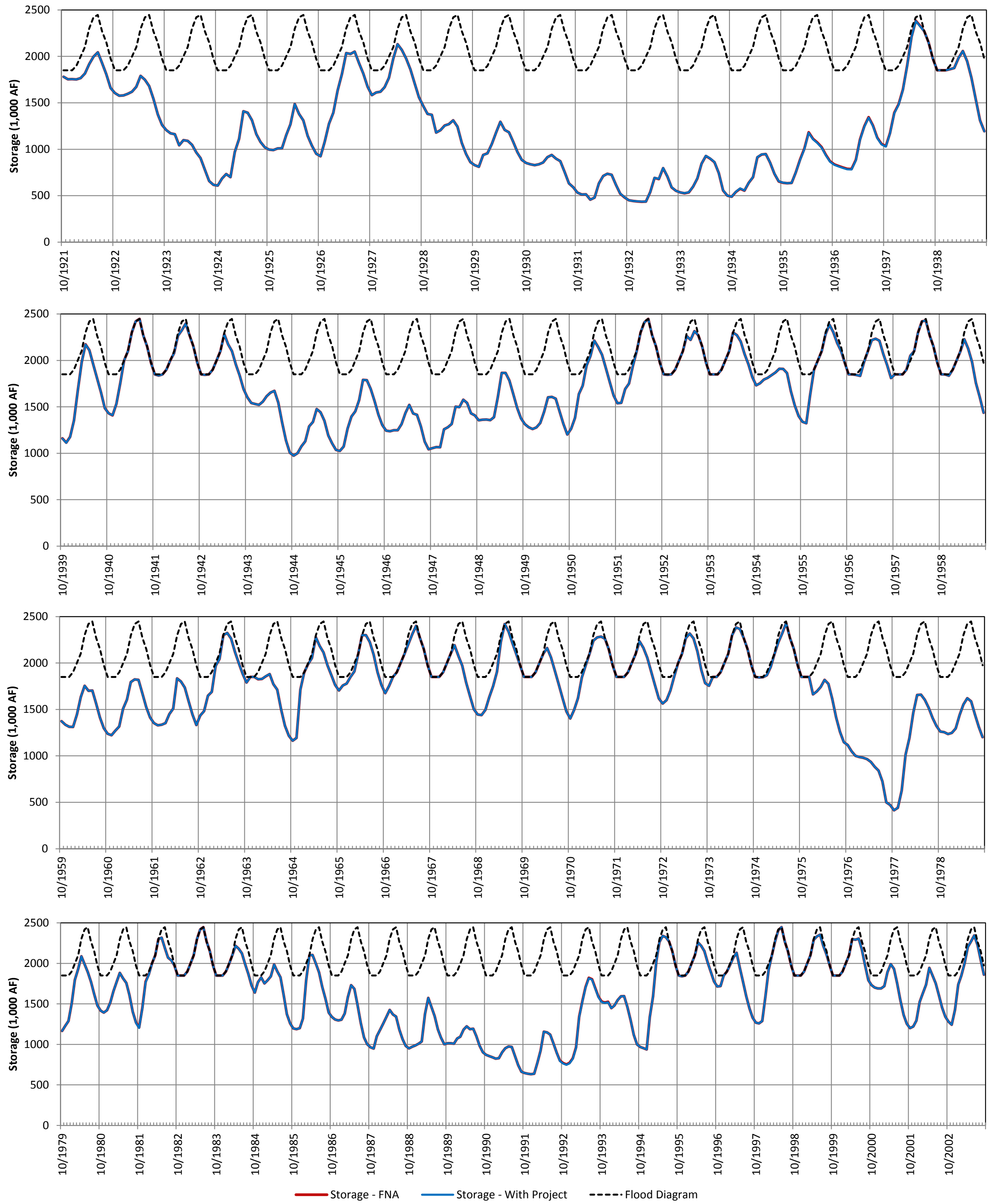


**Figure 2: Comparison of Shasta Storage for Lower San Felipe Intake Alternative**

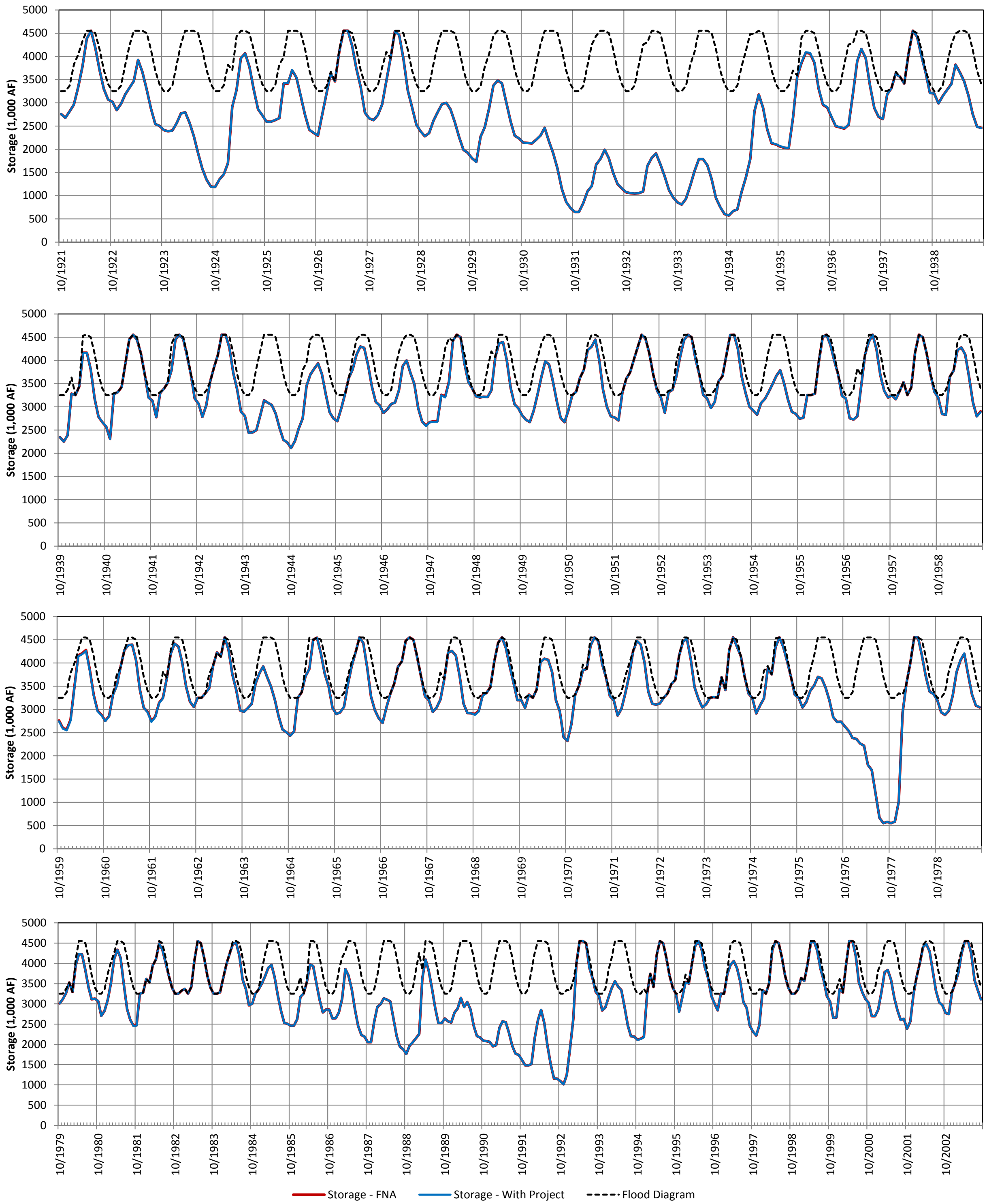


**Figure 3: Comparison of Folsom Storage for Lower San Felipe Intake Alternative**

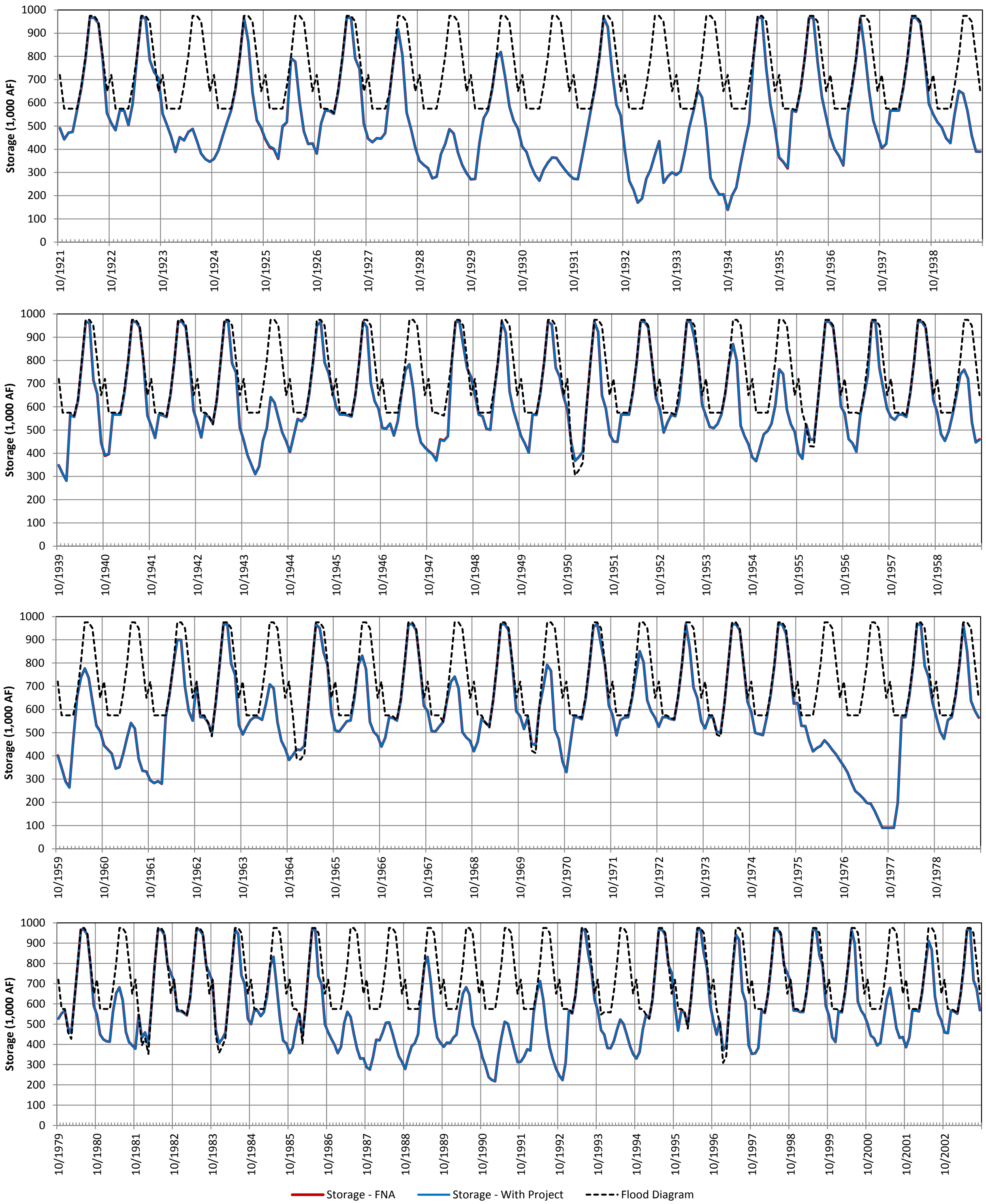


**Figure 4: Comparison of Oroville Storage for Lower San Felipe Intake Alternative**

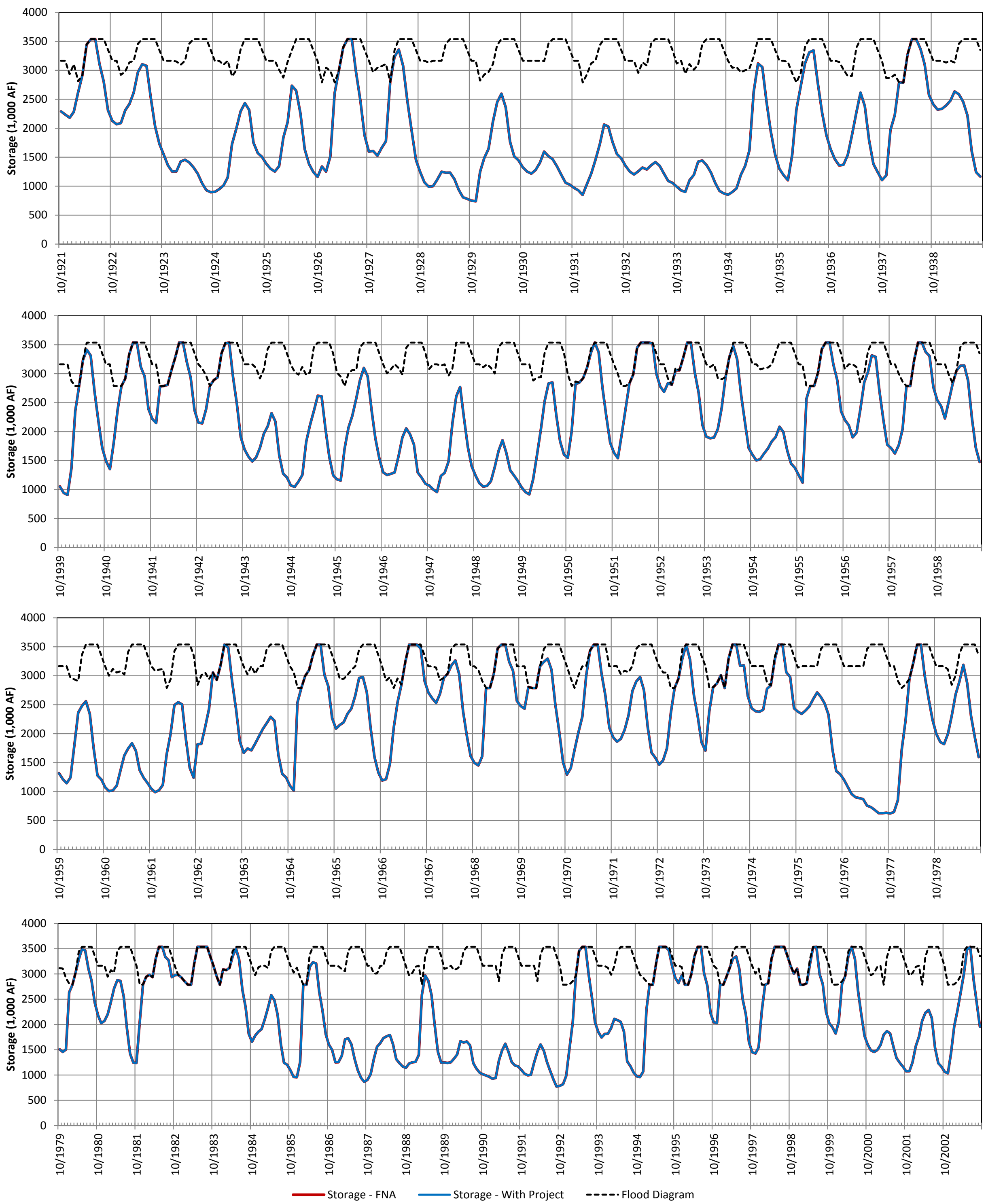


**Figure 5: Comparison of Sacramento River below Keswick Flow for Lower San Felipe Intake Alternative**

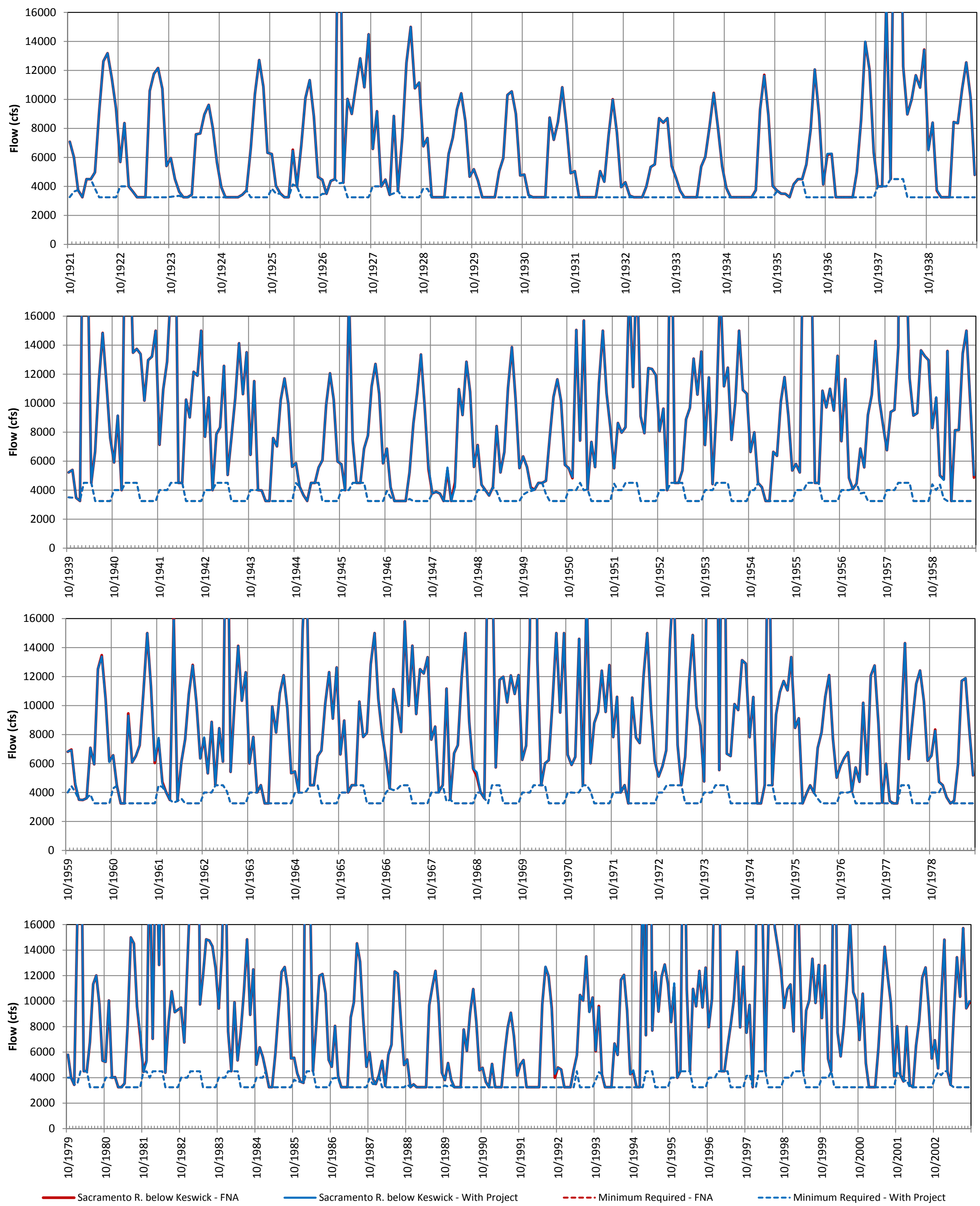


**Figure 6: Comparison of Sacramento River at Wilkins Slough Flow for Lower San Felipe Intake Alternative**

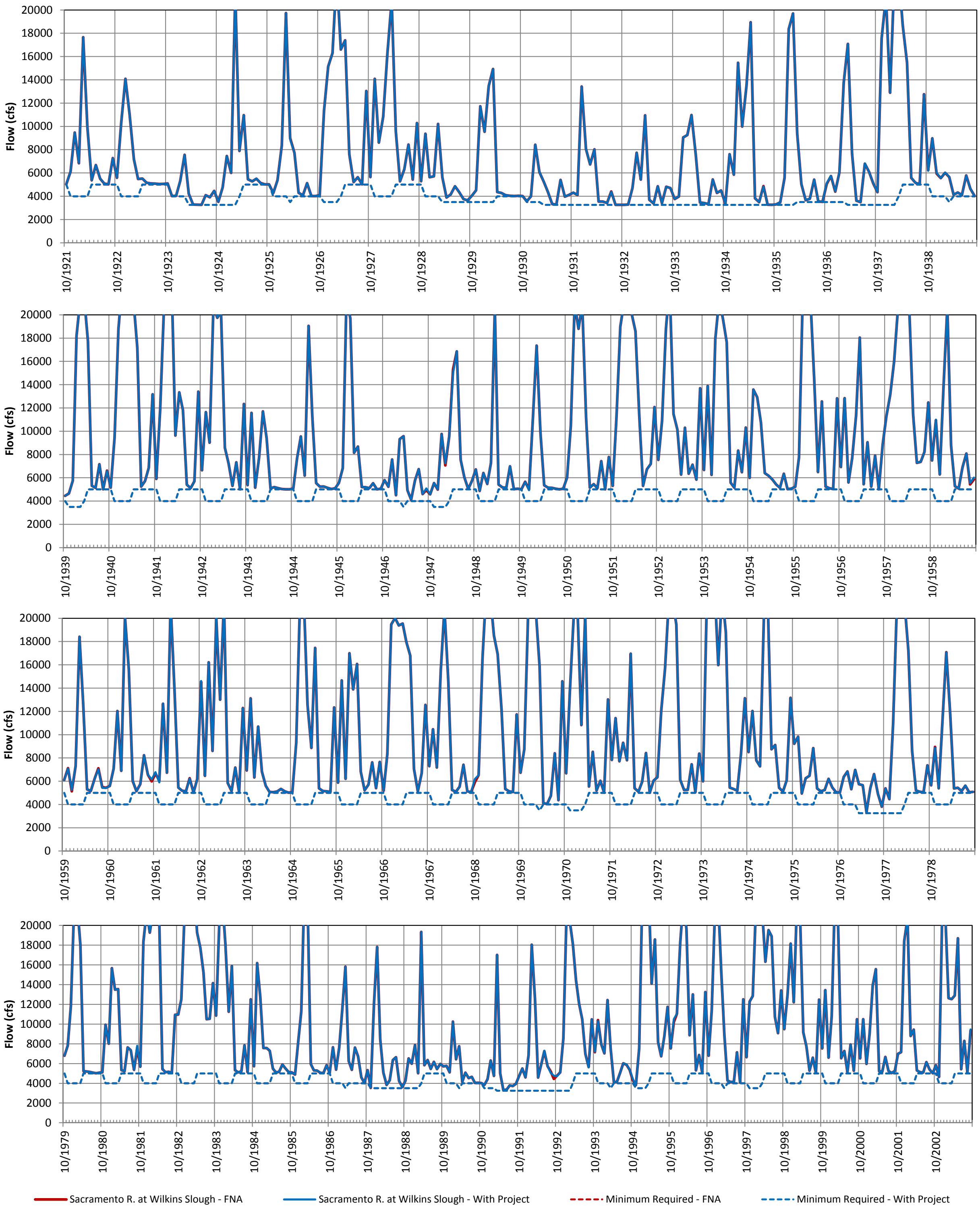


**Figure 7: Comparison of American River below Nimbus Flow for Lower San Felipe Intake Alternative**

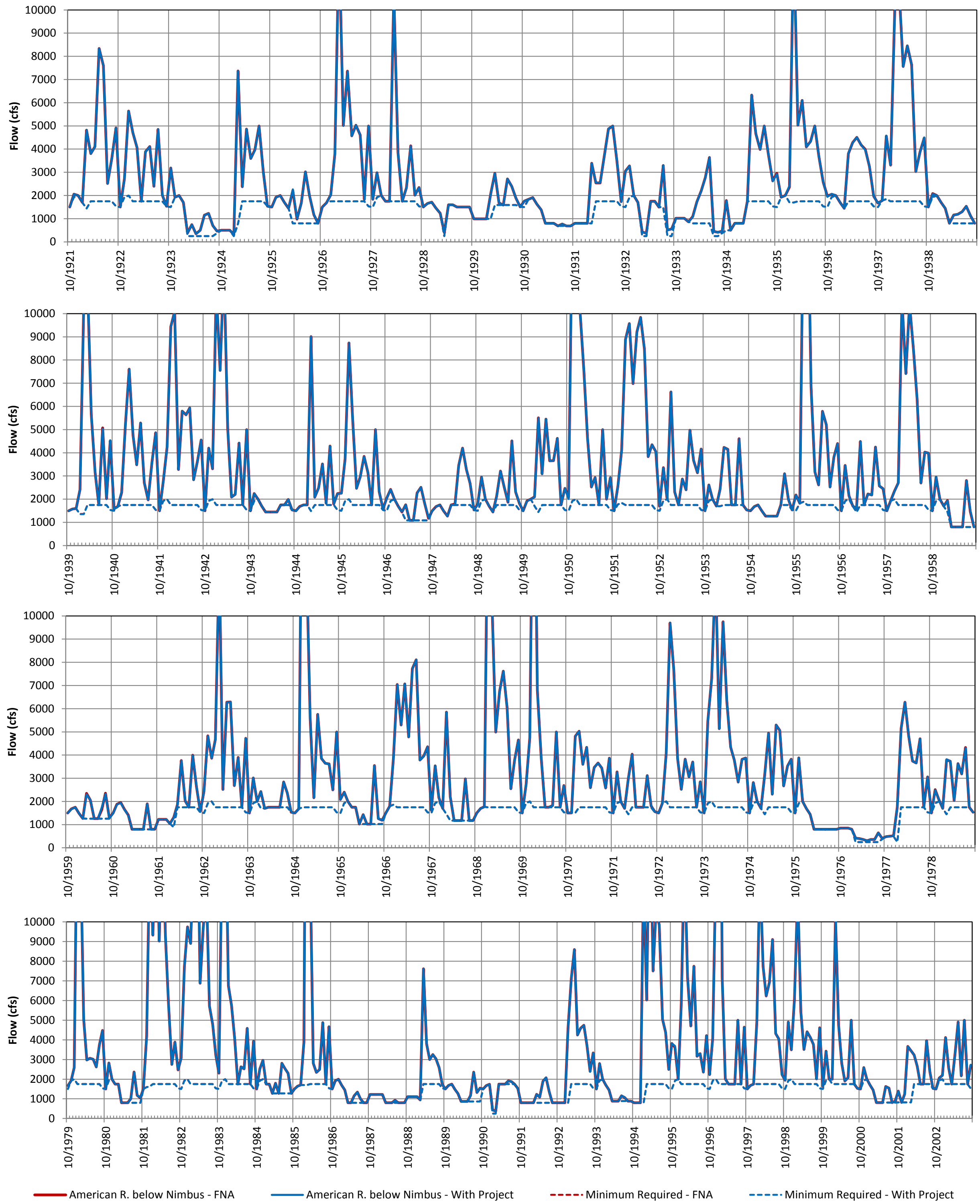


**Figure 8: Comparison of Lower Feather River Flow for Lower San Felipe Intake Alternative**

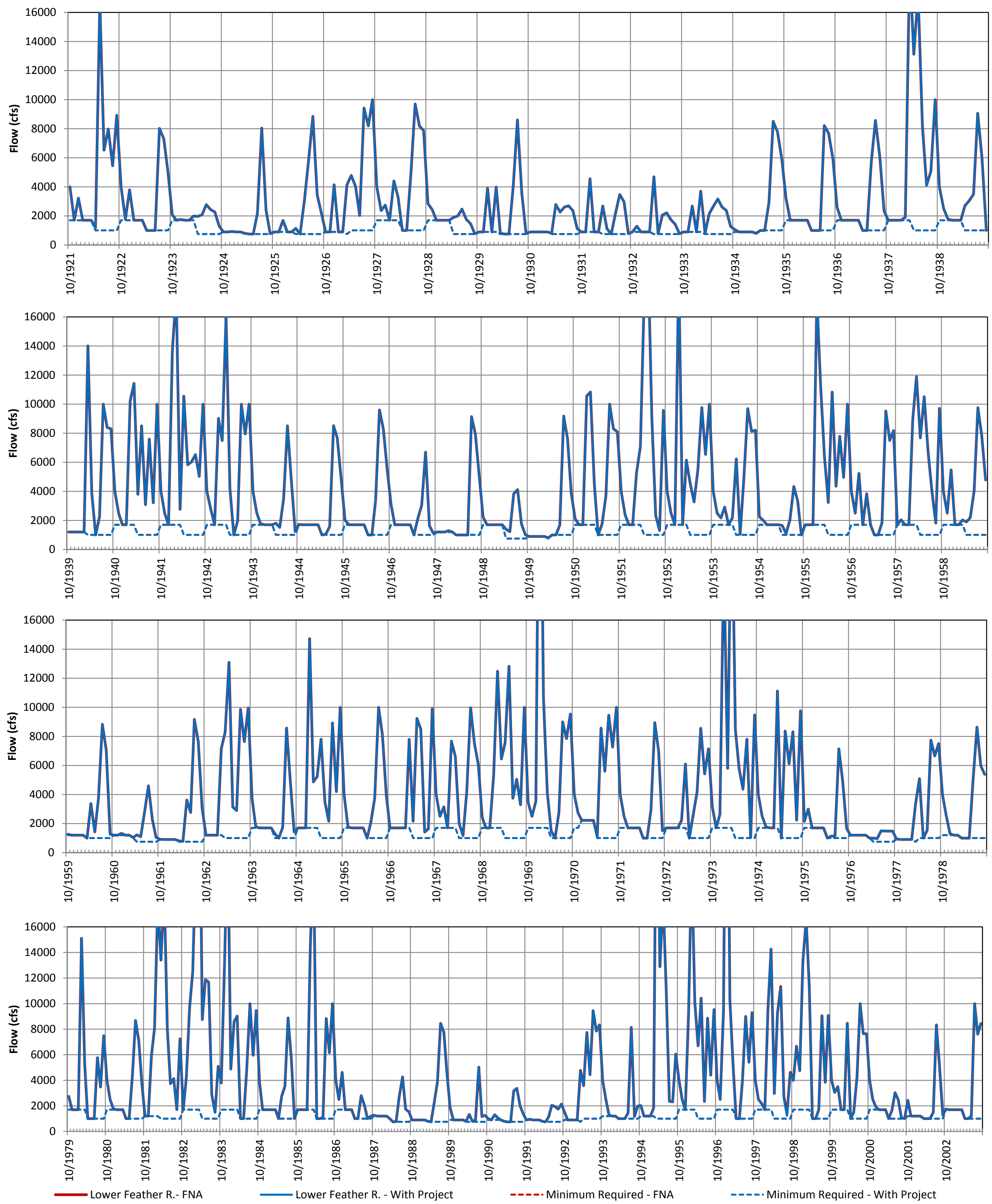


**Figure 9: Comparison of Delta Inflow for Lower San Felipe Intake Alternative**

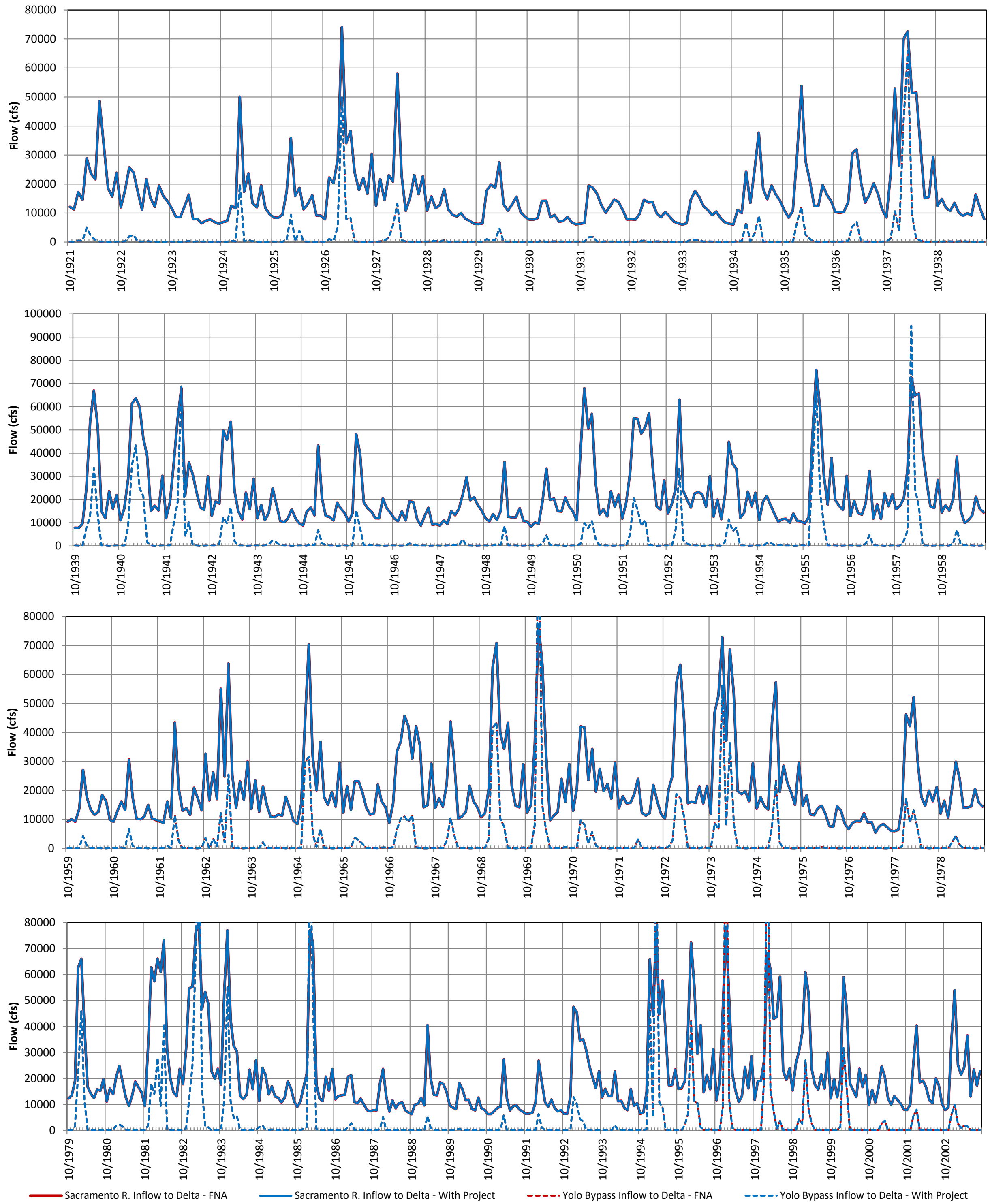


**Figure 10: Comparison of Delta Outflow for Lower San Felipe Intake Alternative**

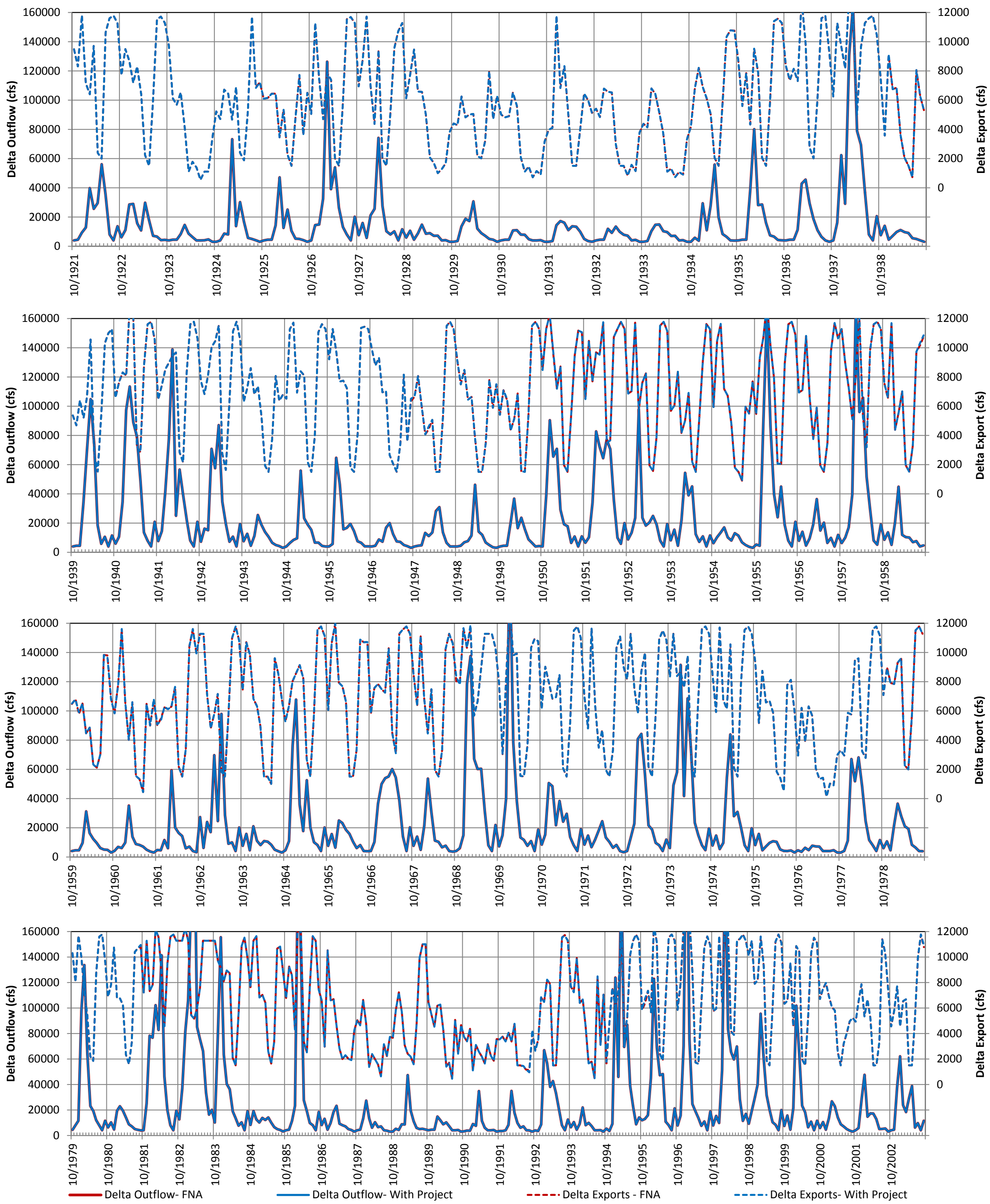


**Figure 11: Comparison of San Luis Reservoir Storage for Lower San Felipe Intake Alternative**

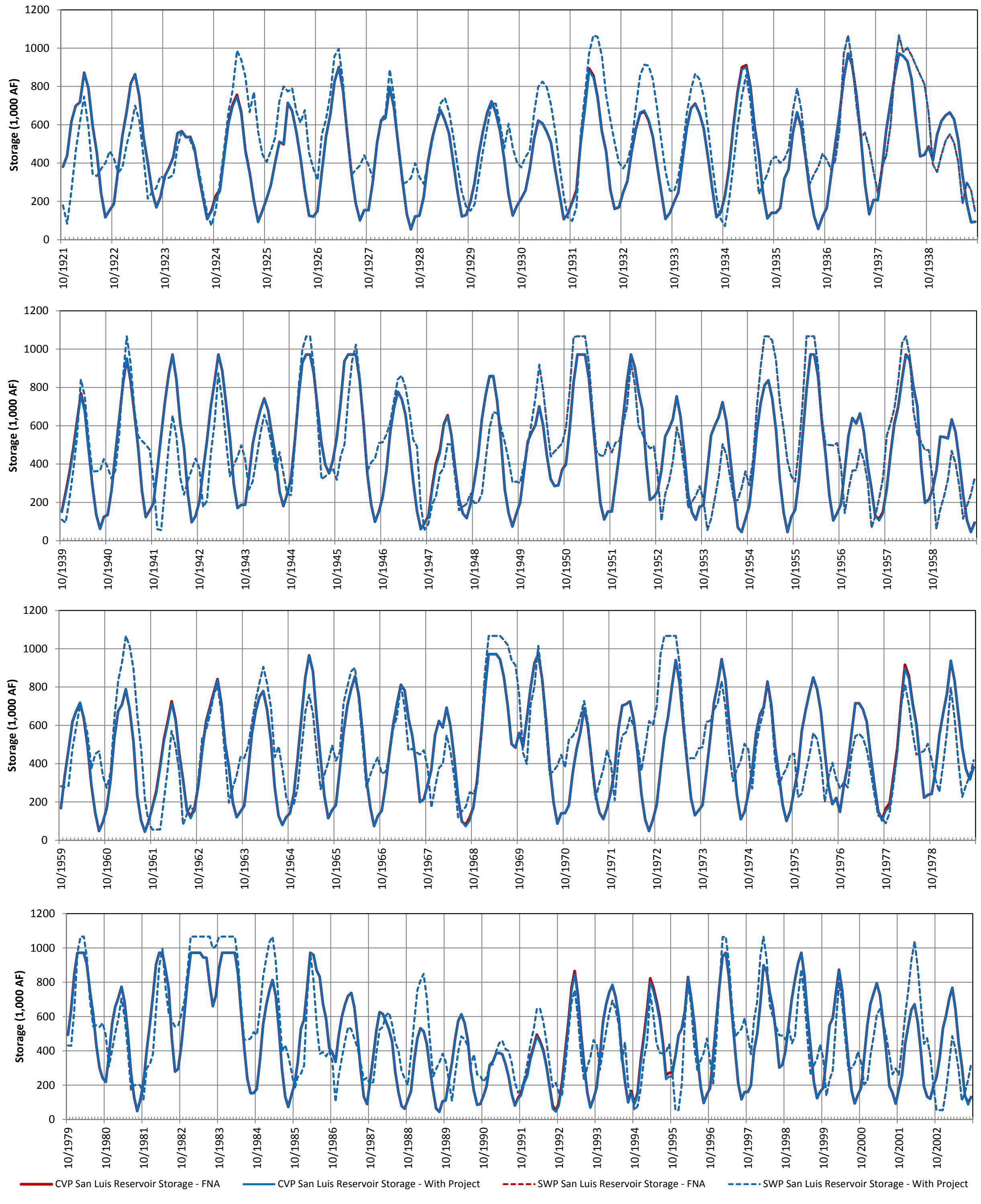


**Figure 12: Comparison of Trinity Storage for San Luis Reservoir Expansion Alternative**

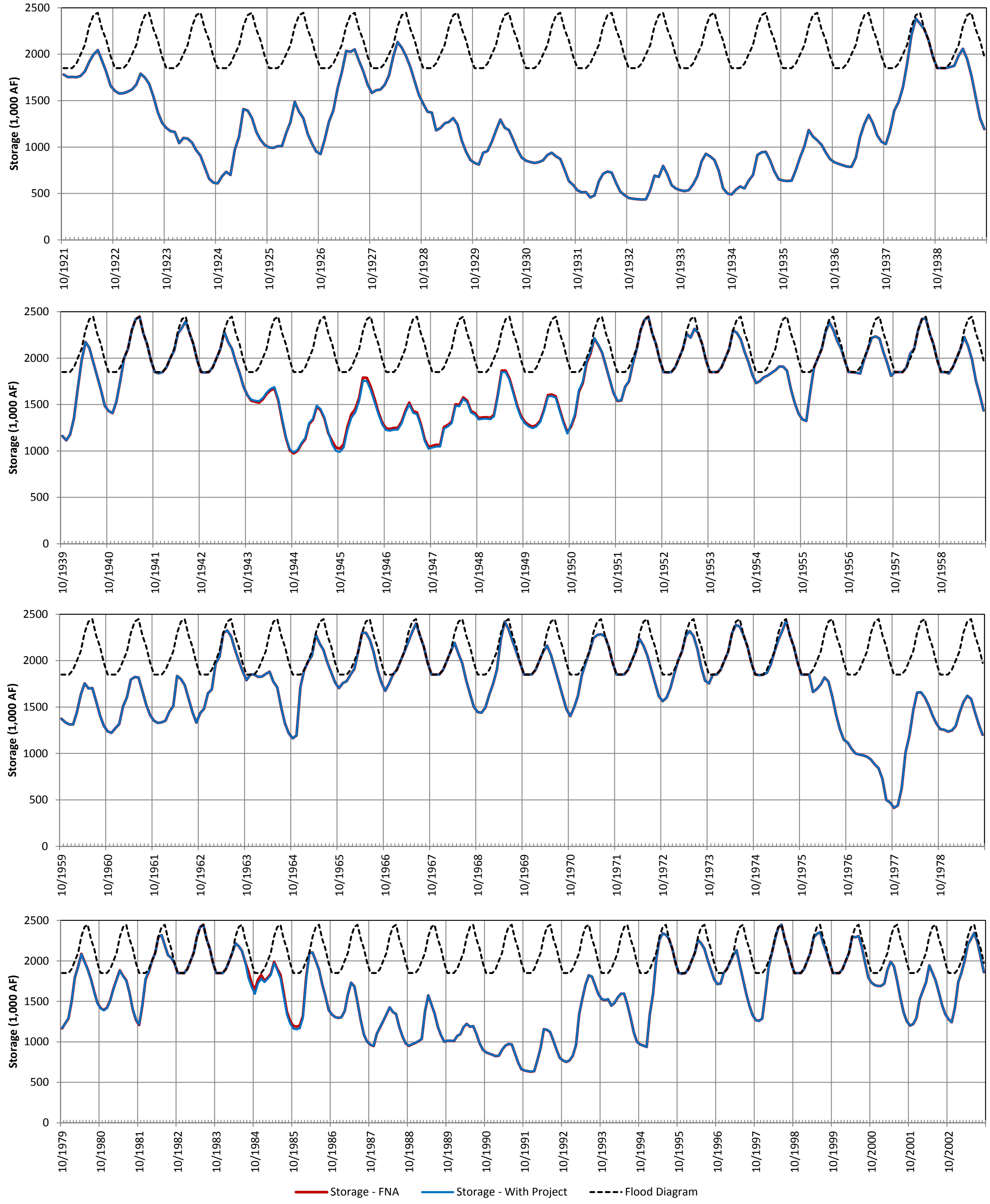


**Figure 13: Comparison of Shasta Storage for San Luis Reservoir Expansion Alternative**

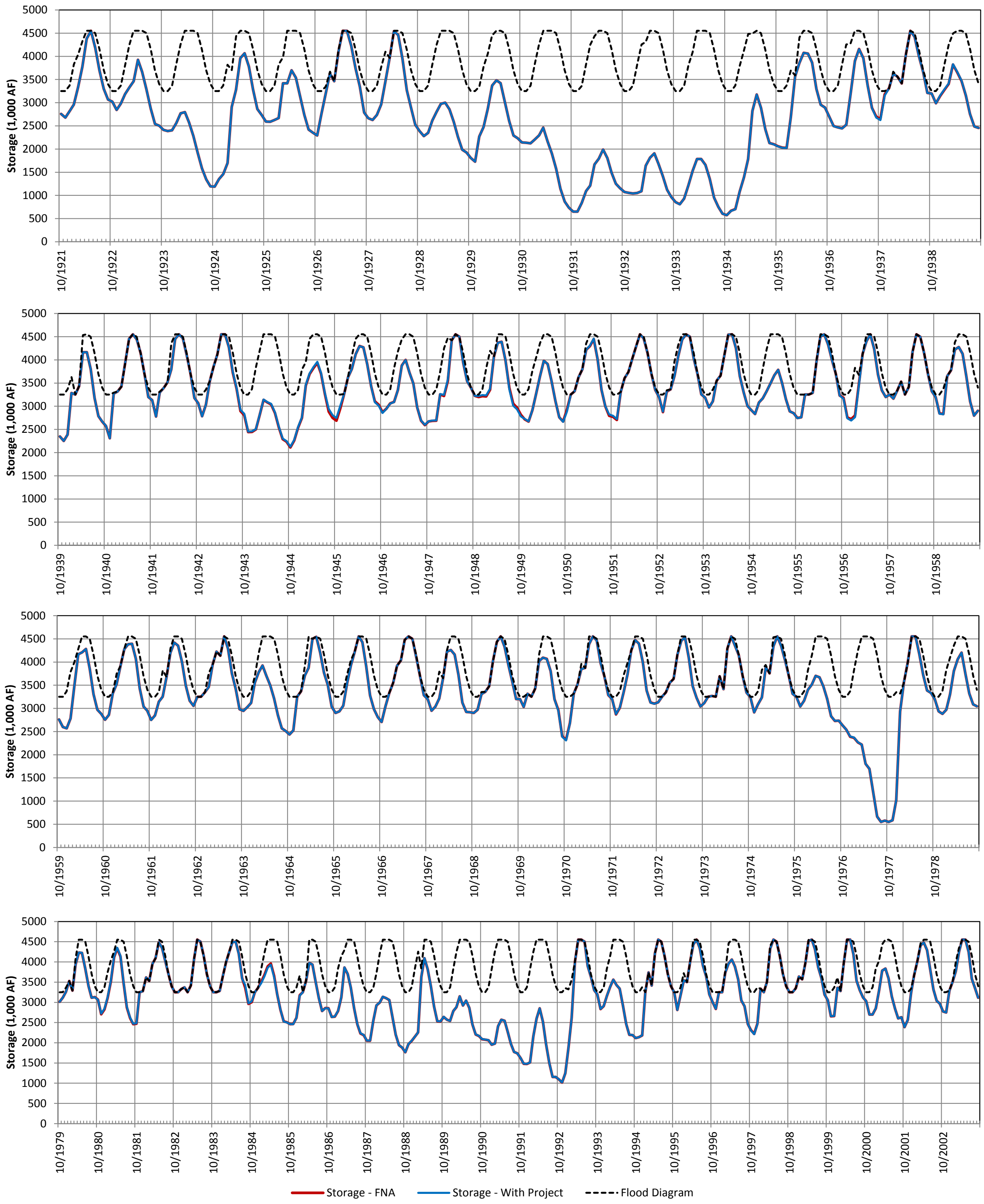


**Figure 14: Comparison of Folsom Storage for San Luis Reservoir Expansion Alternative**

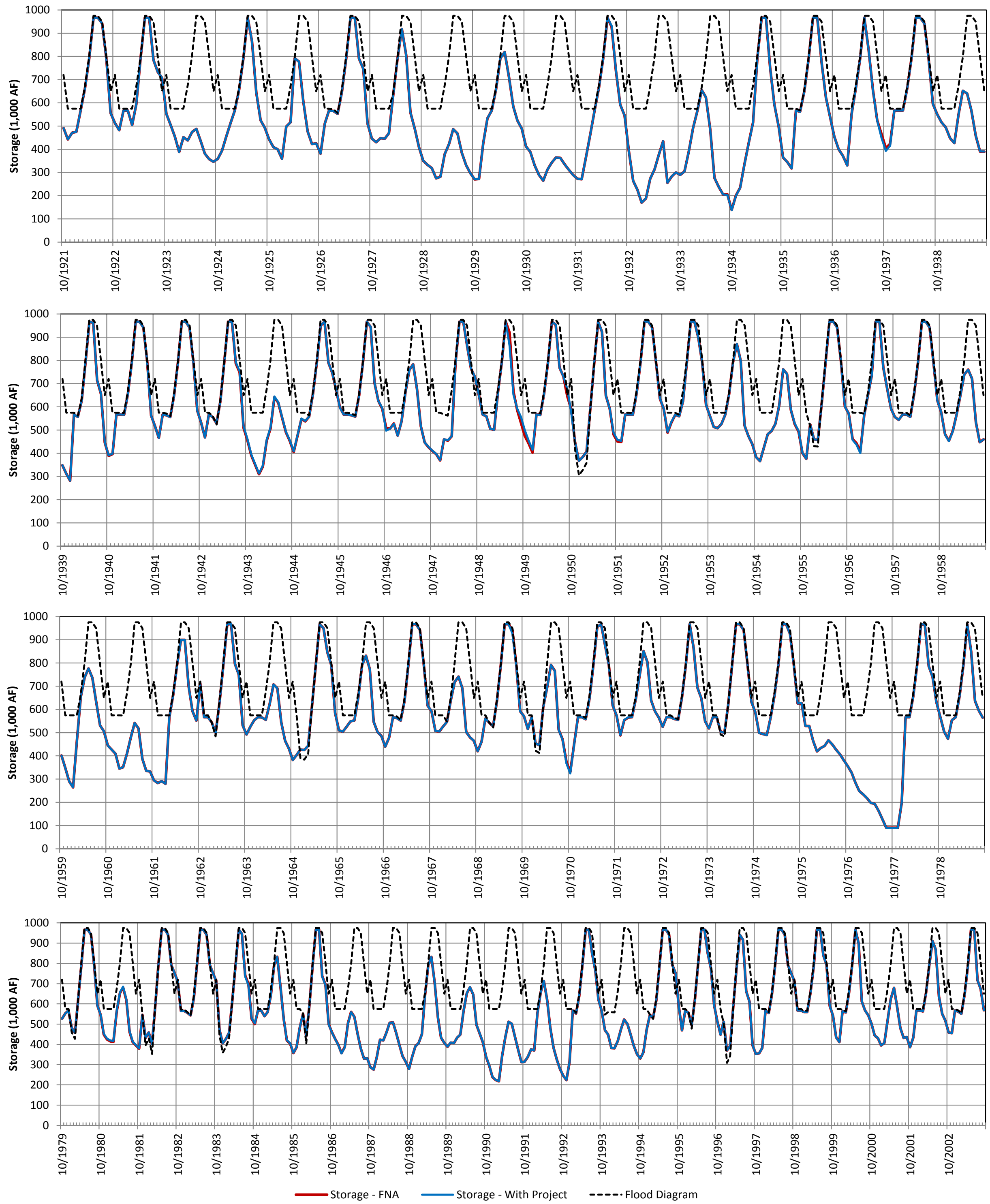


**Figure 15: Comparison of Oroville Storage for San Luis Reservoir Expansion Alternative**

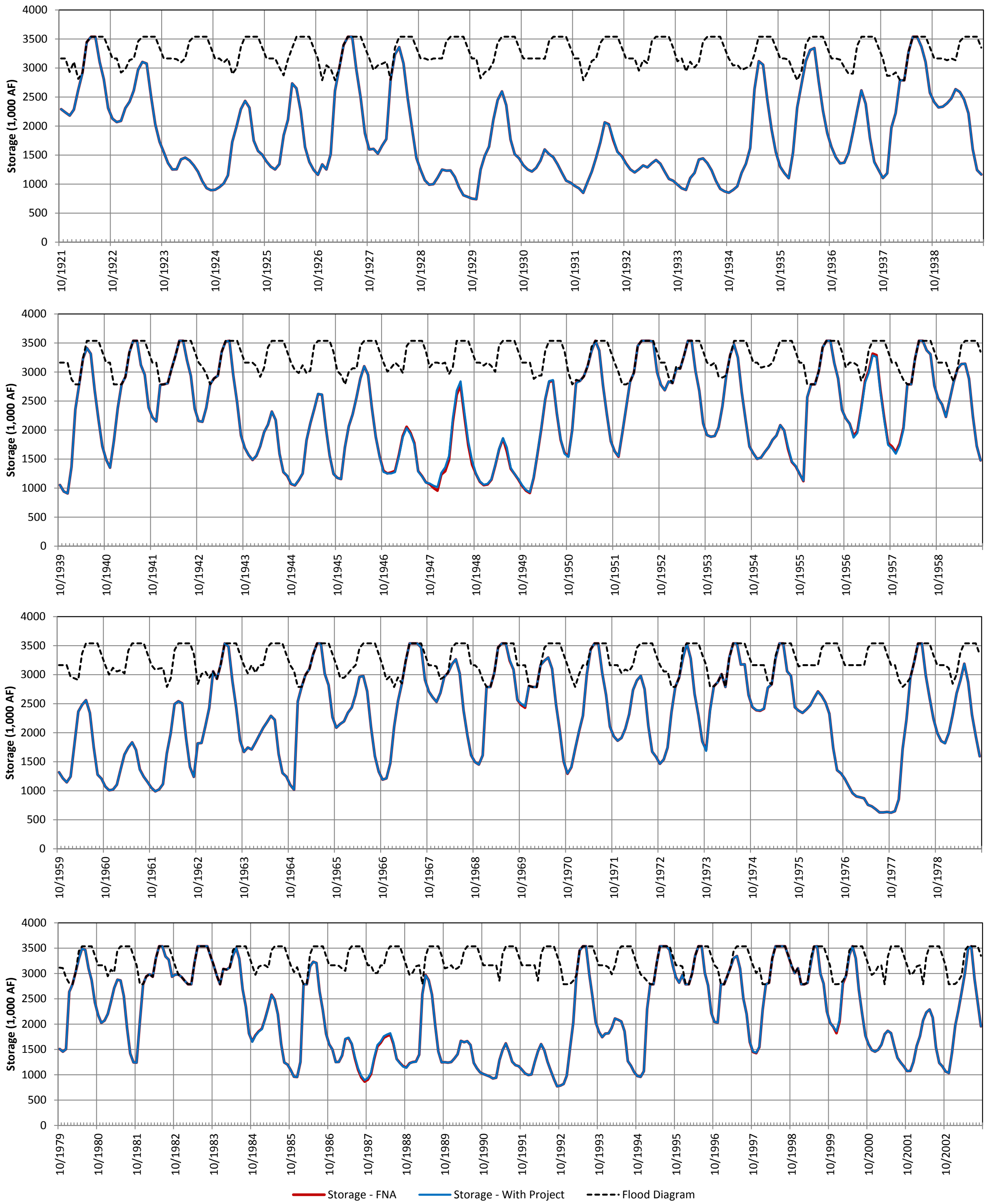


**Figure 16: Comparison of Sacramento River below Keswick Flow for San Luis Reservoir Expansion Alternative**

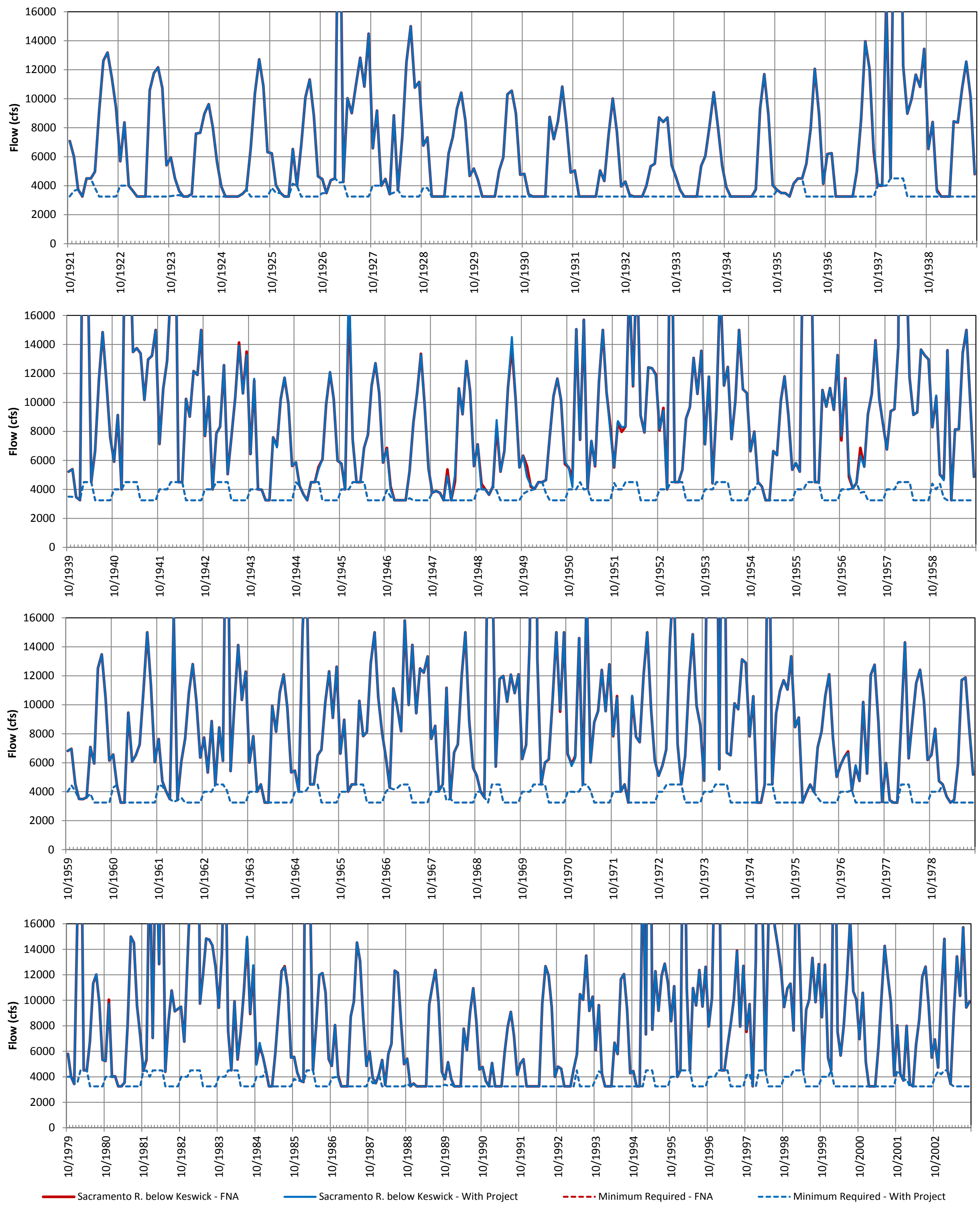


**Figure 17: Comparison of Sacramento River at Wilkins Slough Flow for San Luis Reservoir Expansion Alternative**

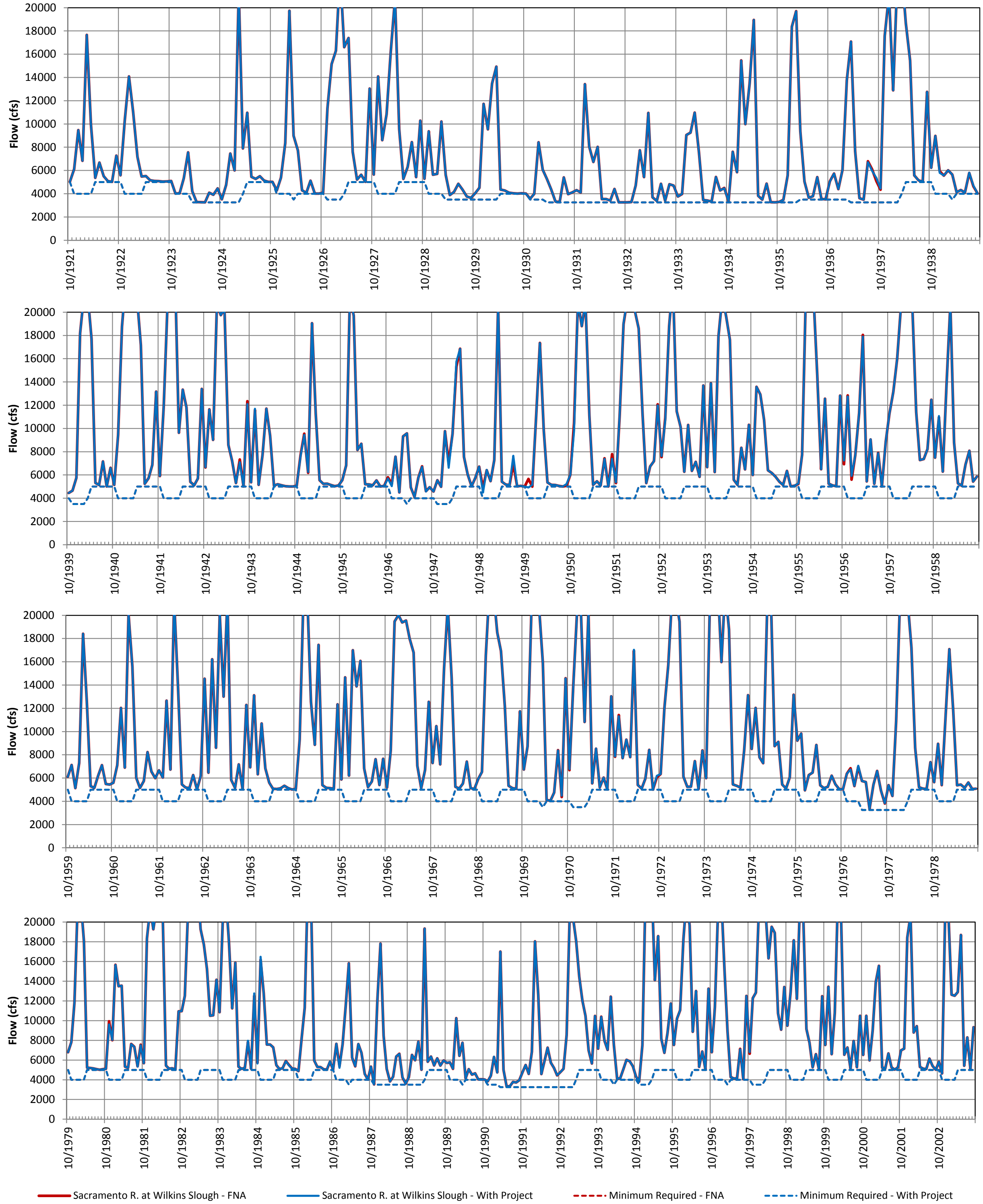


**Figure 18: Comparison of American River below Nimbus Flow for San Luis Reservoir Expansion Alternative**

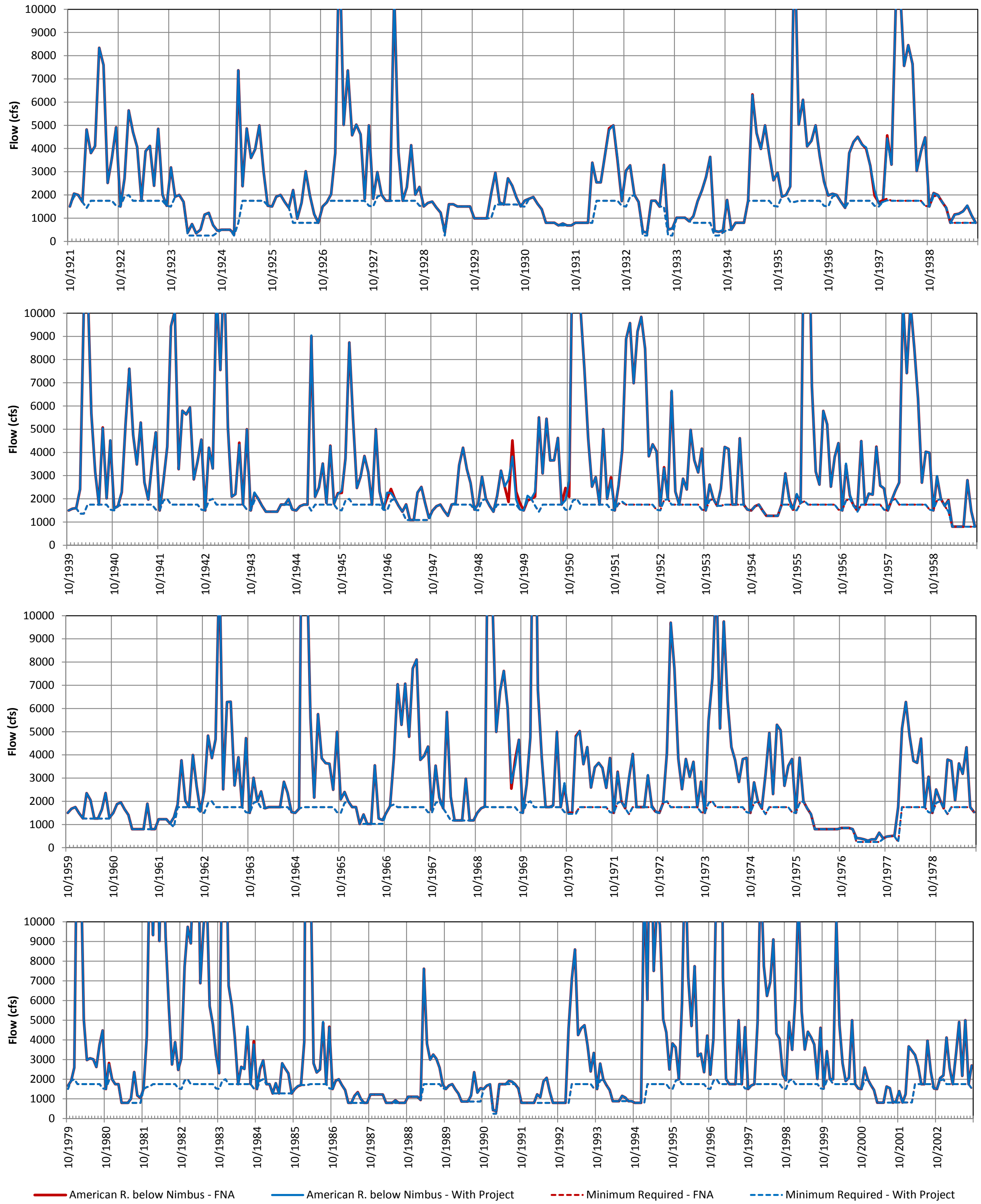


**Figure 19: Comparison of Lower Feather River Flow for San Luis Reservoir Expansion Alternative**

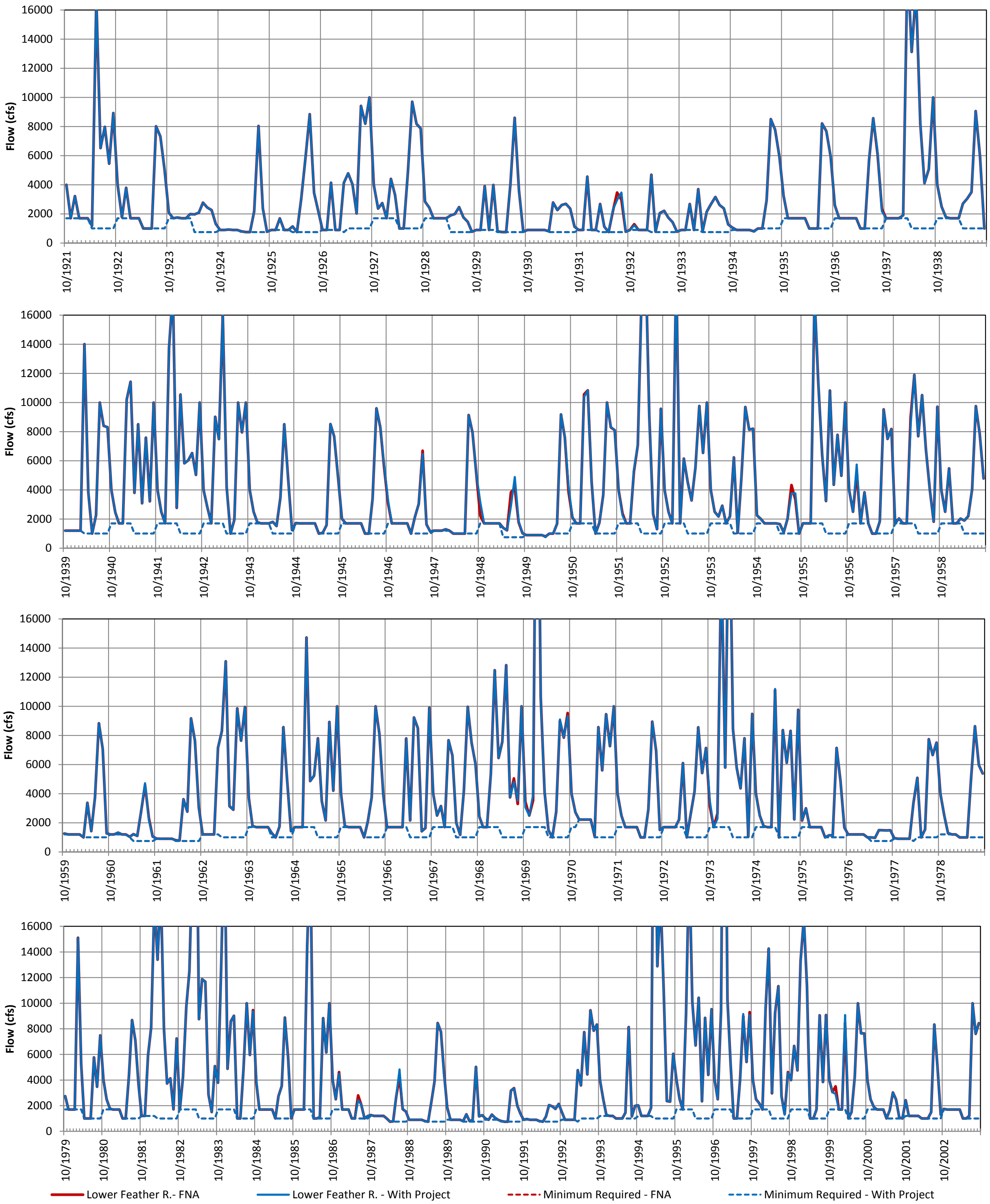


**Figure 20: Comparison of Delta Inflow for San Luis Reservoir Expansion Alternative**

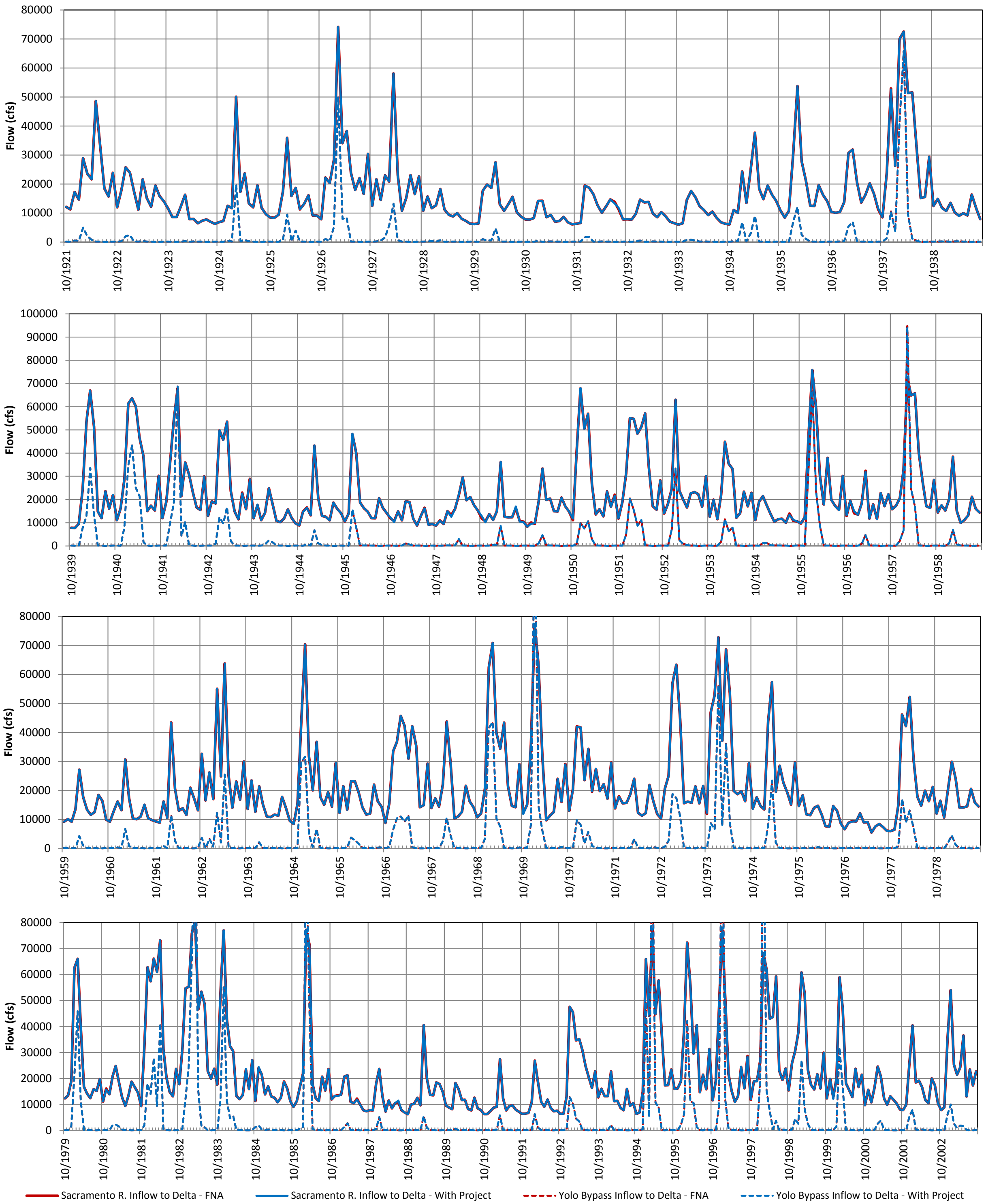


**Figure 21: Comparison of Delta Outflow for San Luis Reservoir Expansion Alternative**

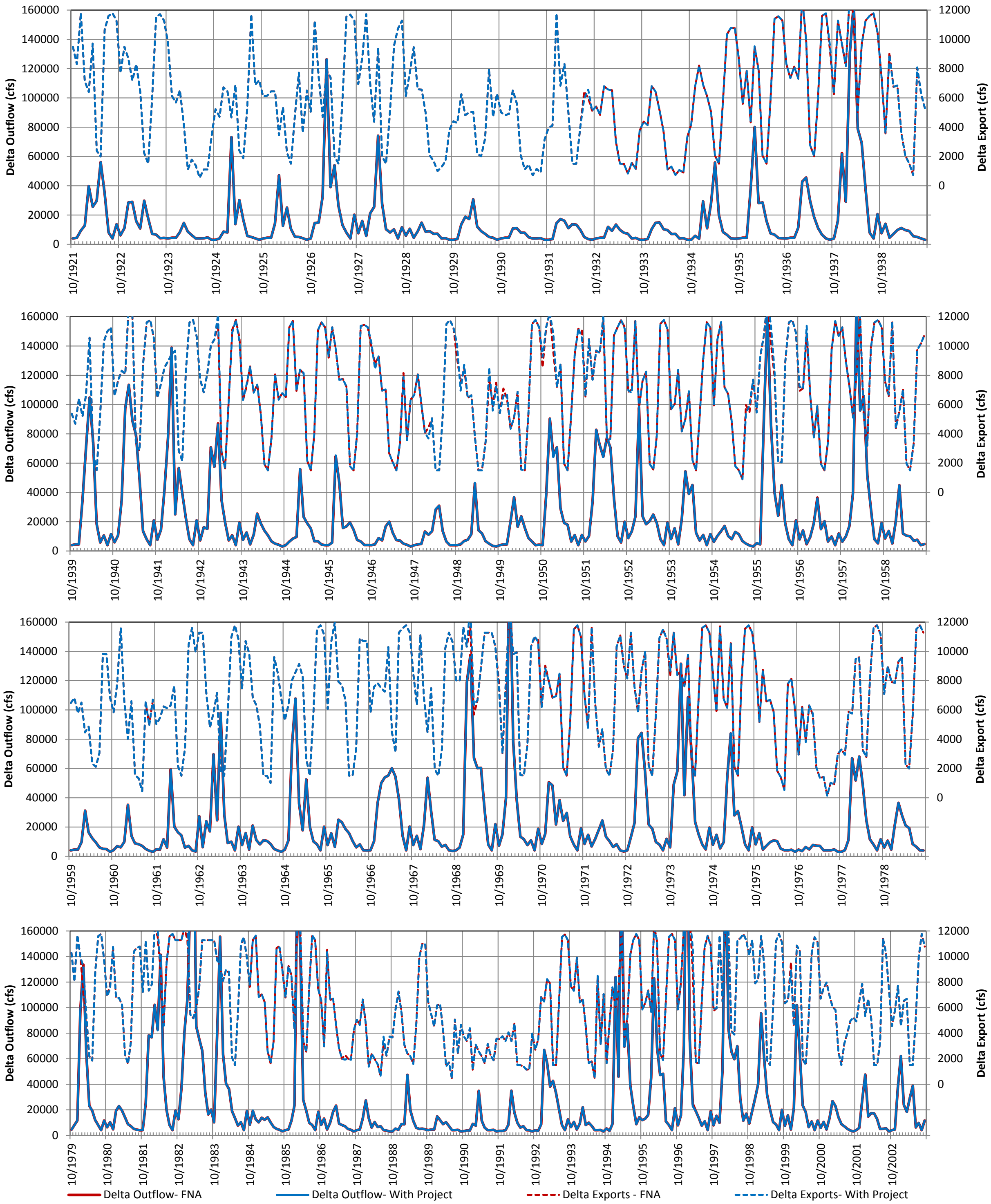


**Figure 22: Comparison of San Luis Reservoir Storage for San Luis Reservoir Expansion Alternative**

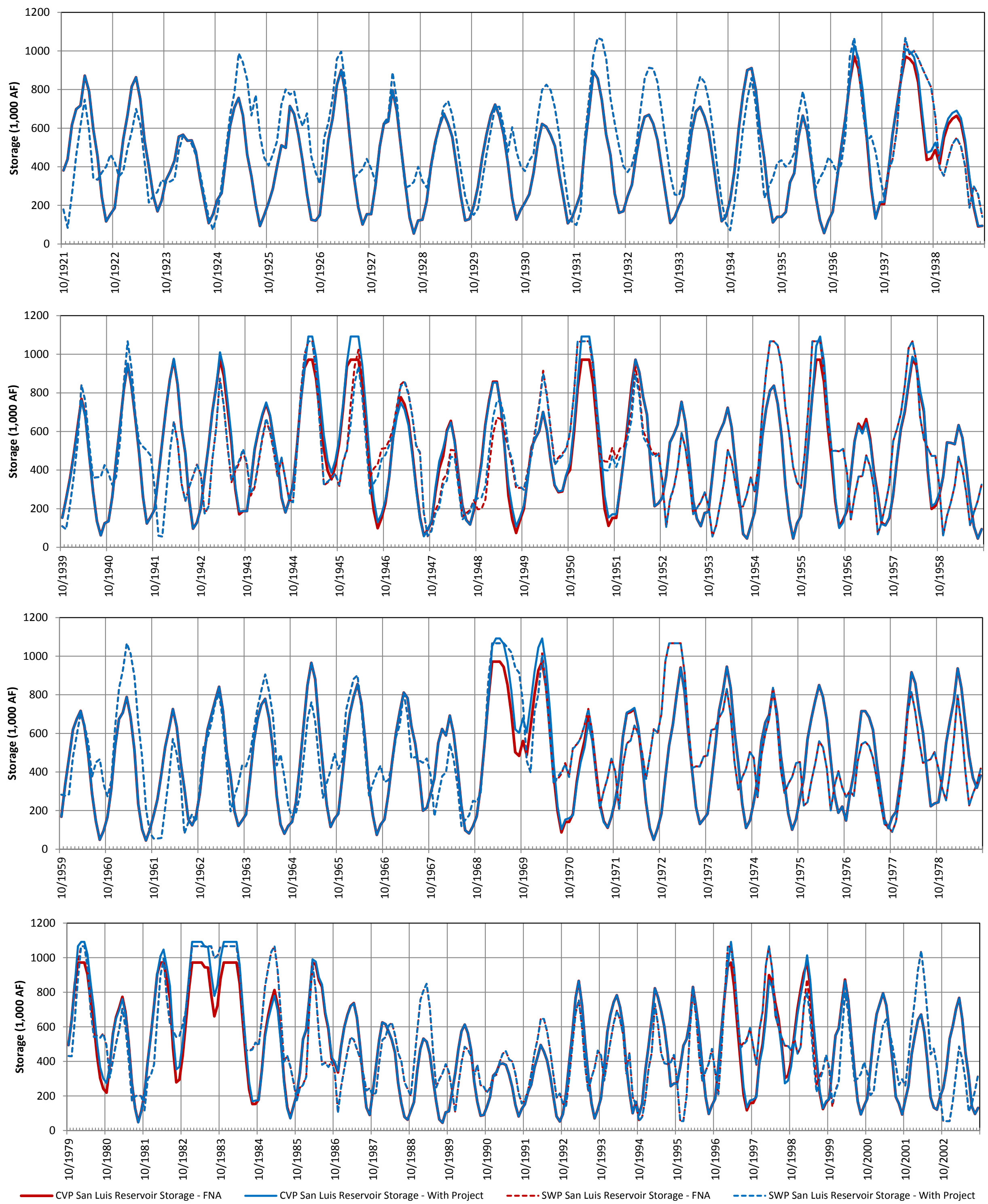


**Figure 23: Comparison of Trinity Storage for Pacheco Reservoir Expansion Alternative**

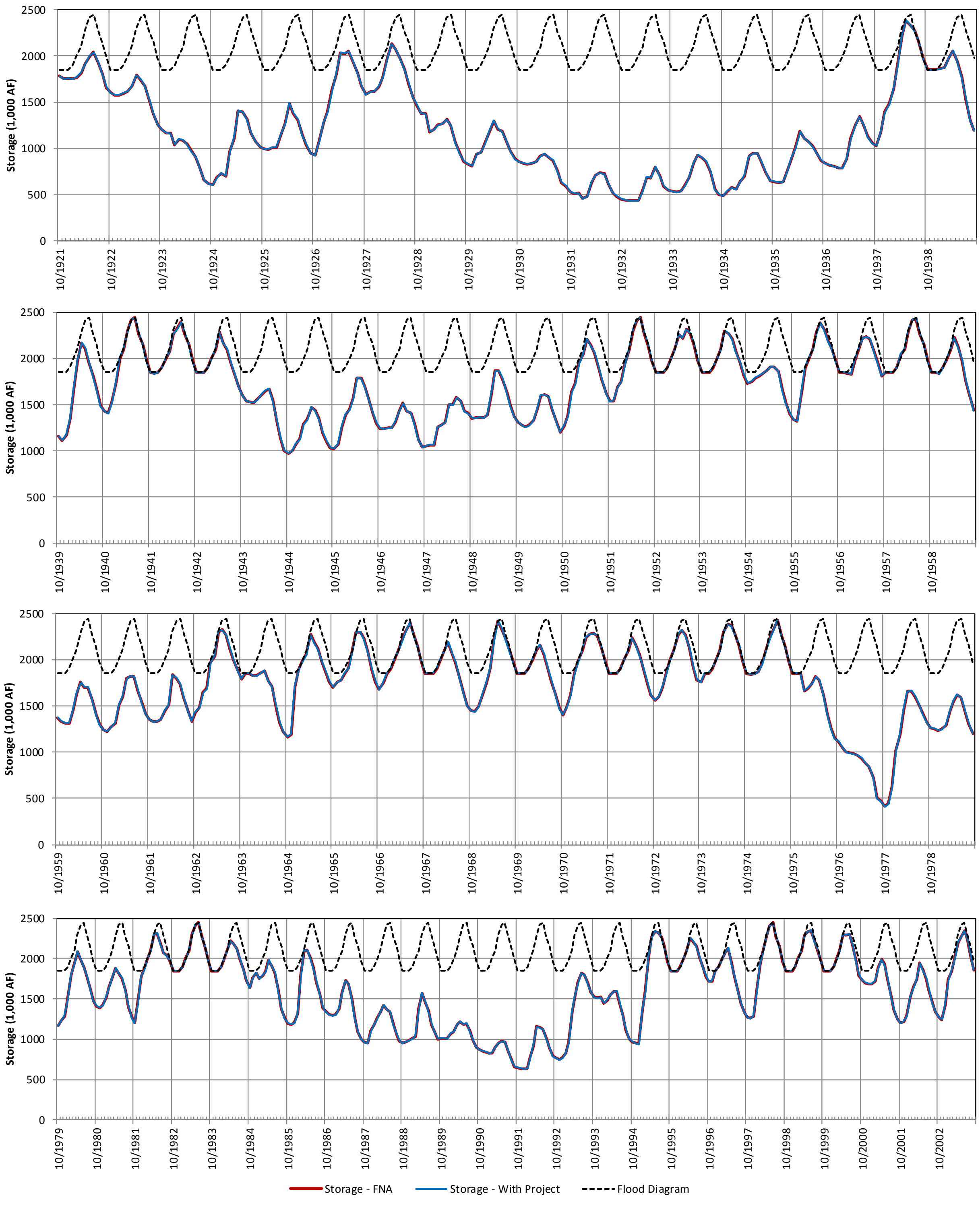


**Figure 24: Comparison of Shasta Storage for Pacheco Reservoir Expansion Alternative**

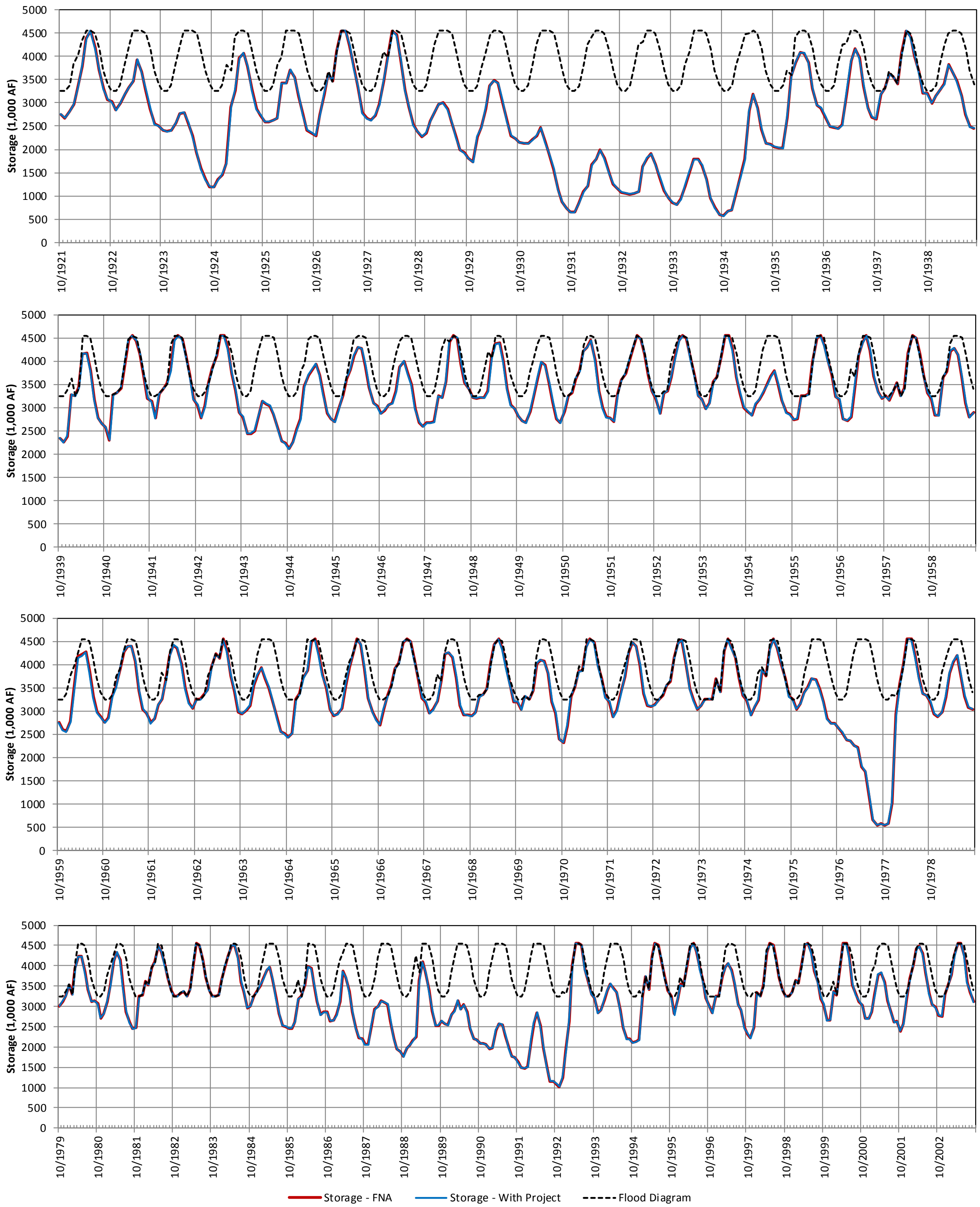


**Figure 25: Comparison of Folsom Storage for Pacheco Reservoir Expansion Alternative**

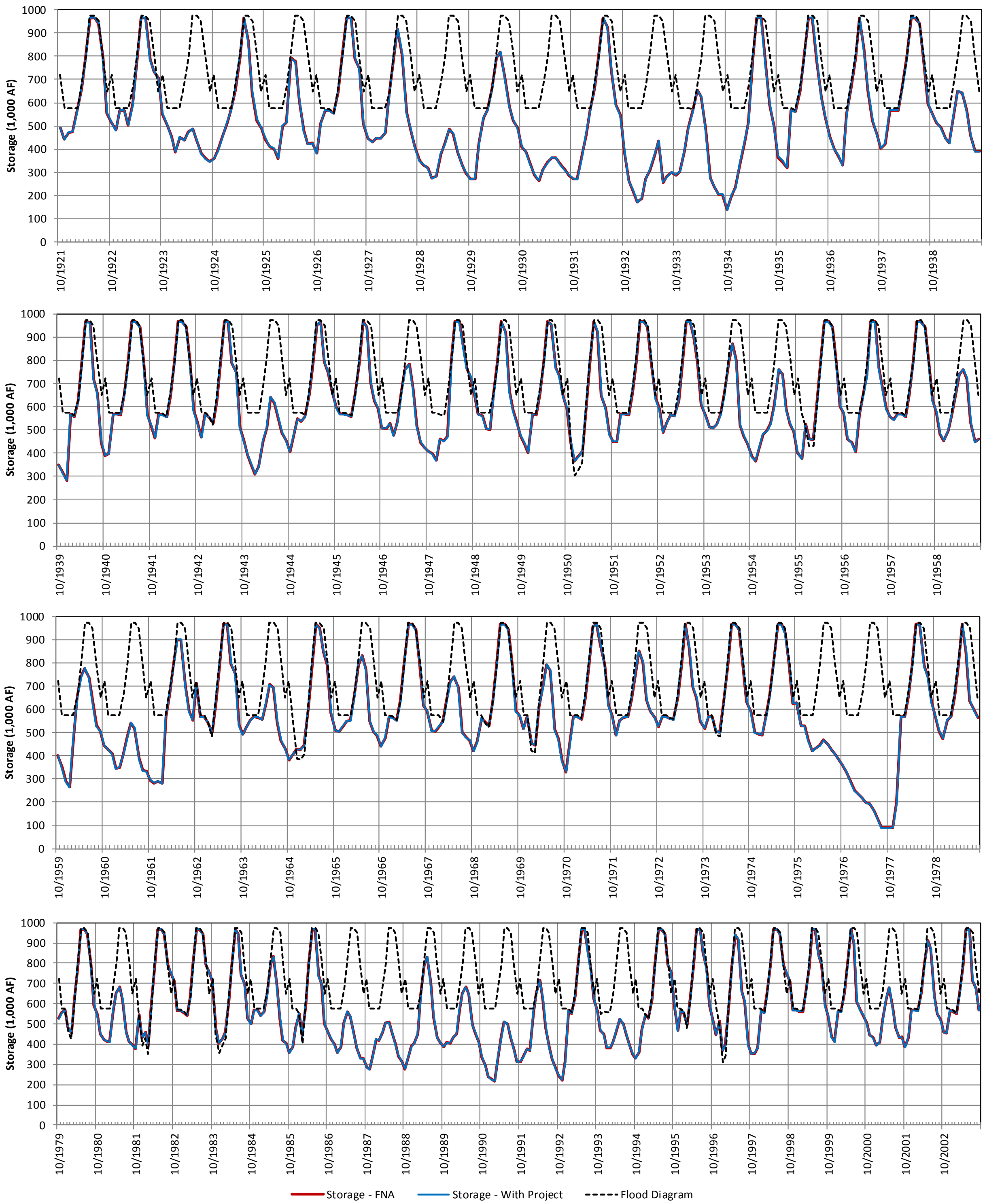


**Figure 26: Comparison of Oroville Storage for Pacheco Reservoir Expansion Alternative**

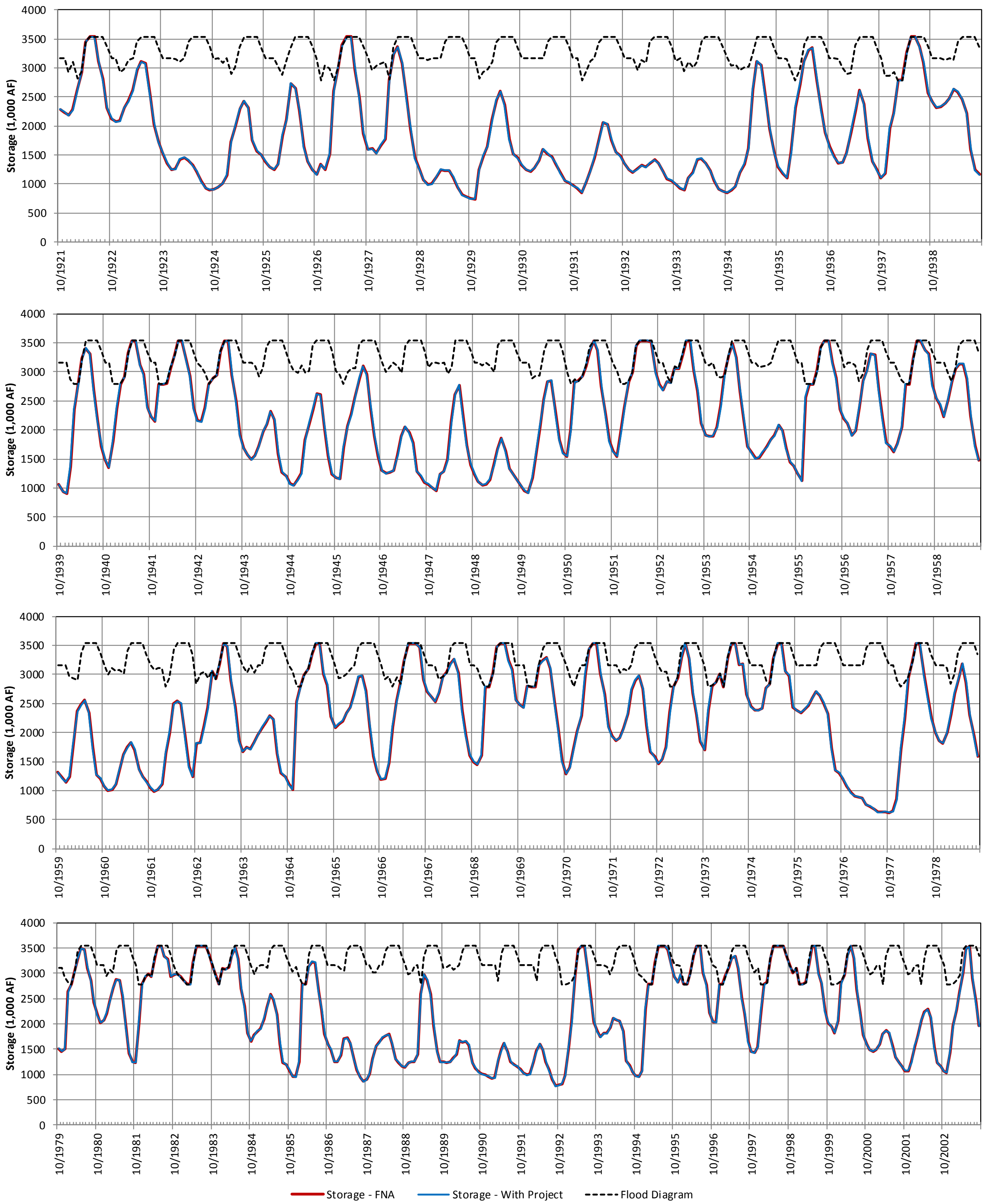


**Figure 27: Comparison of Sacramento River below Keswick Flow for Pacheco Reservoir Expansion Alternative**

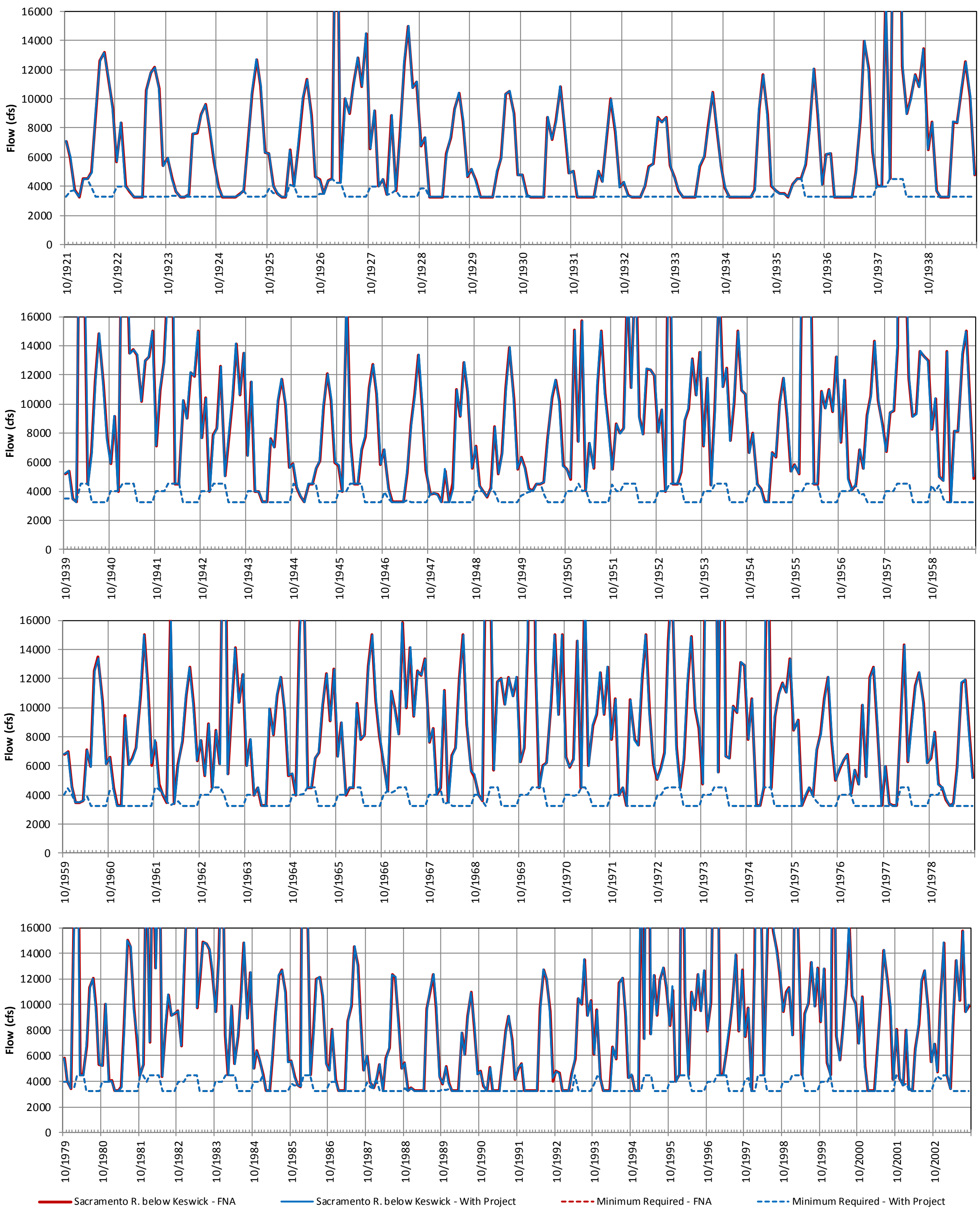


**Figure 28: Comparison of Sacramento River at Wilkins Slough Flow for Pacheco Reservoir Expansion Alternative**

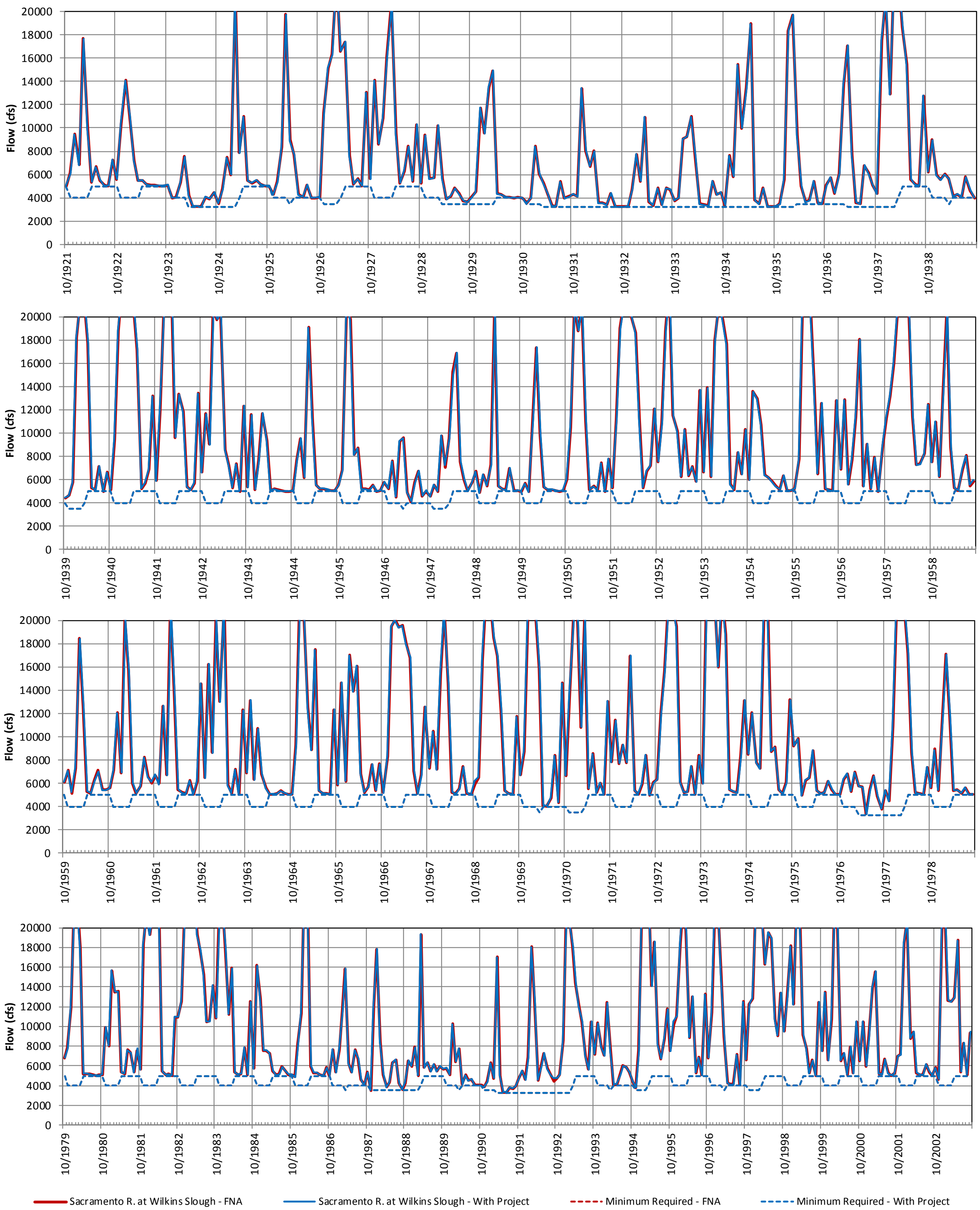


**Figure 29: Comparison of American River below Nimbus Flow for Pacheco Reservoir Expansion Alternative**

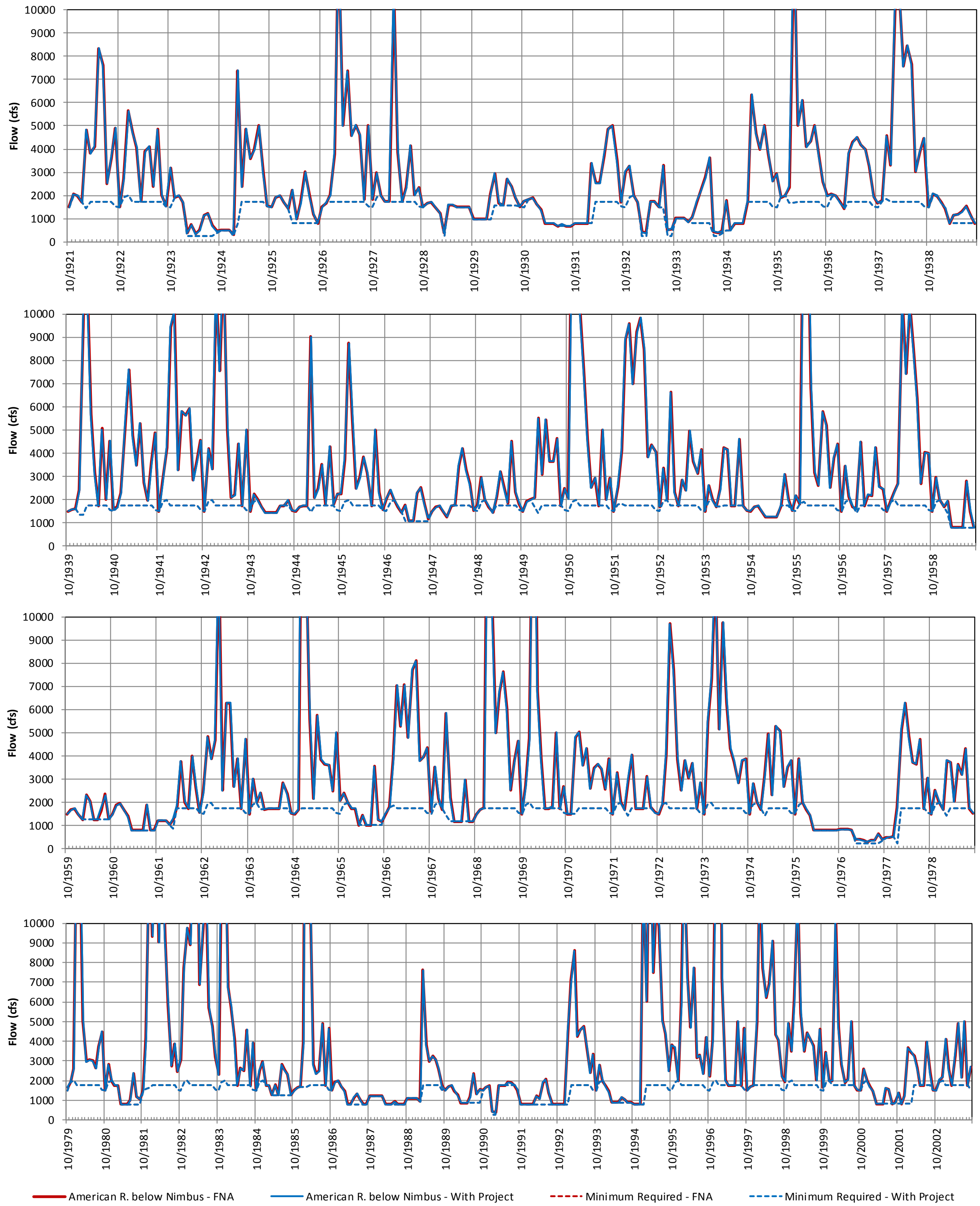


**Figure 30: Comparison of Lower Feather River Flow for Pacheco Reservoir Expansion Alternative**

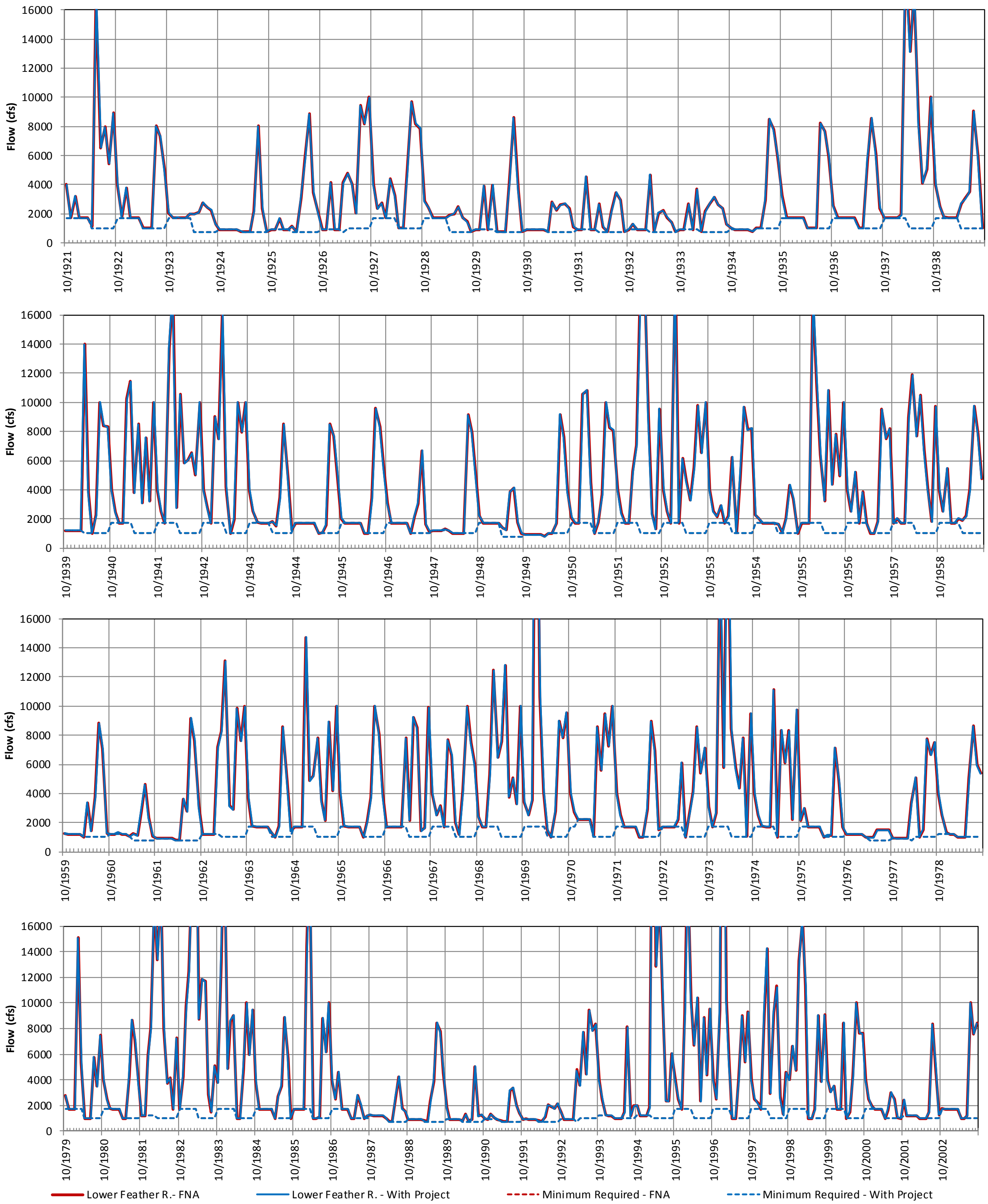


**Figure 31: Comparison of Delta Inflow for Pacheco Reservoir Expansion Alternative**

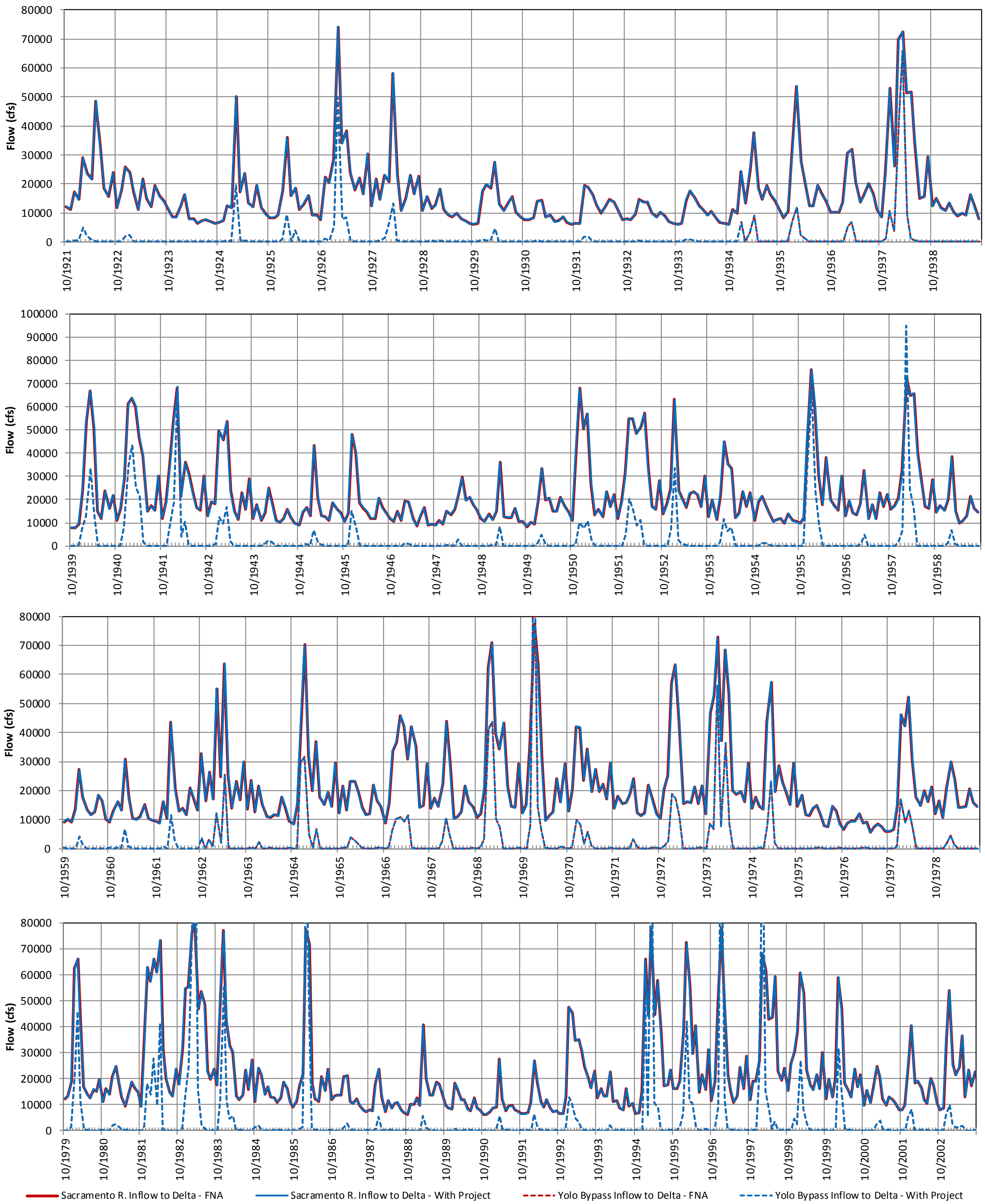


**Figure 32: Comparison of Delta Outflow for Pacheco Reservoir Expansion Alternative**

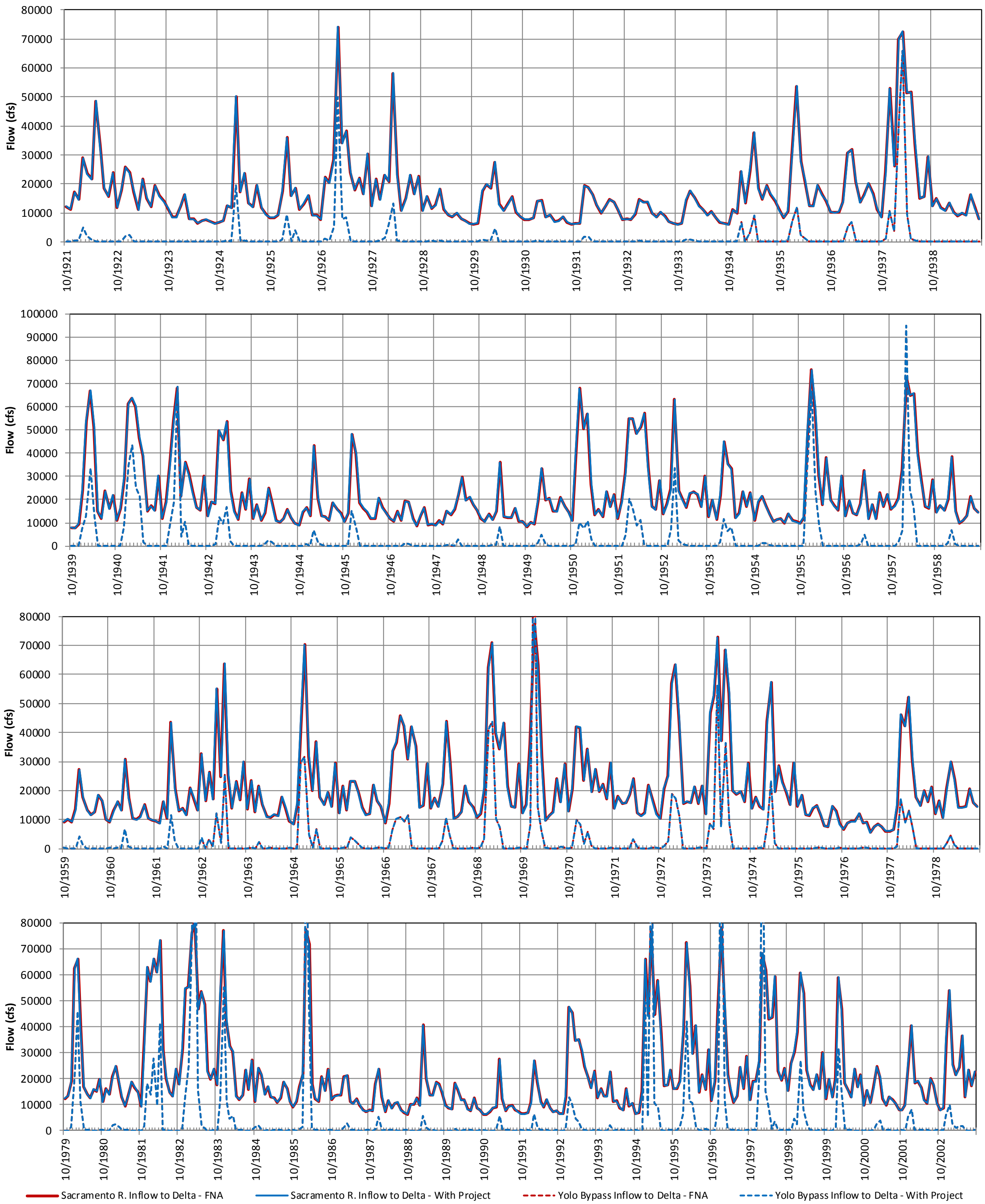
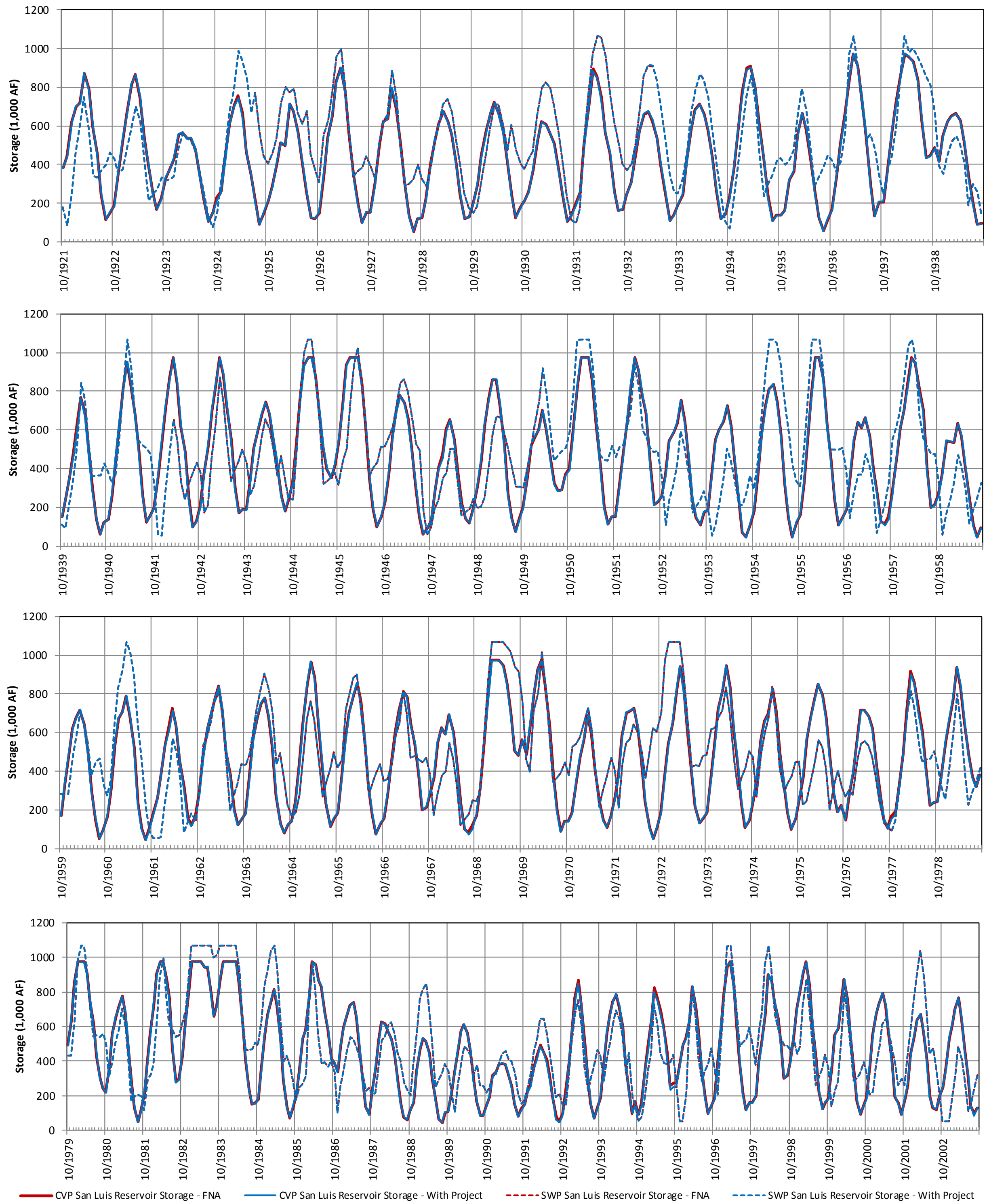


**Figure 33: Comparison of San Luis Reservoir Storage for Pacheco Reservoir Expansion Alternative**



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# Attachment C
## Improvements to CalSim San Luis Operations Technical Memorandum

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MBK ENGINEERS

Water Resources ◆ Flood Control ◆ Water Rights

# TECHNICAL MEMORANDUM

**DATE:** July 16, 2015

**SUBJECT:** Improvements to CalSim San Luis Operations

**PREPARED BY:** Dan Easton

**REVIEWED BY:** Walter Bourez and Jennifer Wilson



MBK Engineers was tasked with improving San Luis operations in CalSim. At the December 2014 scoping meeting with CalSim modelers and Central Valley Project (CVP) and State Water Project (SWP) operators, issues with CalSim San Luis operations were outlined, and it was decided that there was not sufficient budget to resolve all issues under this task order. As such, the three key items listed below were selected for MBK to address and determine whether significant improvements could be made.

1. Reduce frequency of drawing San Luis to dead pool and shorting South-of-Delta (SOD) contract deliveries by improving the export forecasts used in SWP and CVP allocations.
2. Reduce excessive carryover in CVP San Luis during the critical period (particularly the 1930's) through reasonable increases in service contractor allocations.
3. Refine rulecurve formulations used to balance storage between North-of-Delta (NOD) project reservoirs and San Luis Reservoir.

While the problems outlined at the meeting have been present in CalSim for years, MBK used Reclamation's latest CalSim baseline generated on January 27, 2015 as a starting point. For the rest of this document, this baseline will be referred to as CalSim_27JAN2015, and the model edited to address the above three issues will be referred to as CalSim_27JAN2015_Revised. Any reference to CalSim in general includes CalSim_27JAN2015 and preceding versions.

## Refinement of CVP and SWP export forecasts used in CalSim allocation logic to reduce SOD contract delivery shortages

Since implementation of the smelt and salmon biological opinions, CalSim tended to over-allocate water to SOD CVP and SWP contractors in many years of the simulation. Although this does not occur in every year, it happens enough to skew results in water supply planning analysis. Over-allocation can result in breaking San Luis (drawing San Luis down to dead pool) and shorting project contractors. Figure 1 and Figure 2 relate annual SOD contractor shortages and San Luis low point for both the CVP and SWP, respectively, as simulated by CalSim_27JAN2015. CVP San Luis storage is drawn to dead pool (dashed line) in 15 years of the 82-year simulation; SWP San Luis storage is drawn to dead pool in 21 years of the simulation. Annual shortages to CVP contractors range as high as 100 thousand acre-feet (TAF). Running debt to SWP contractors reaches higher than 400 TAF in year 1995 of the simulation and greater than 100 TAF in several other years.

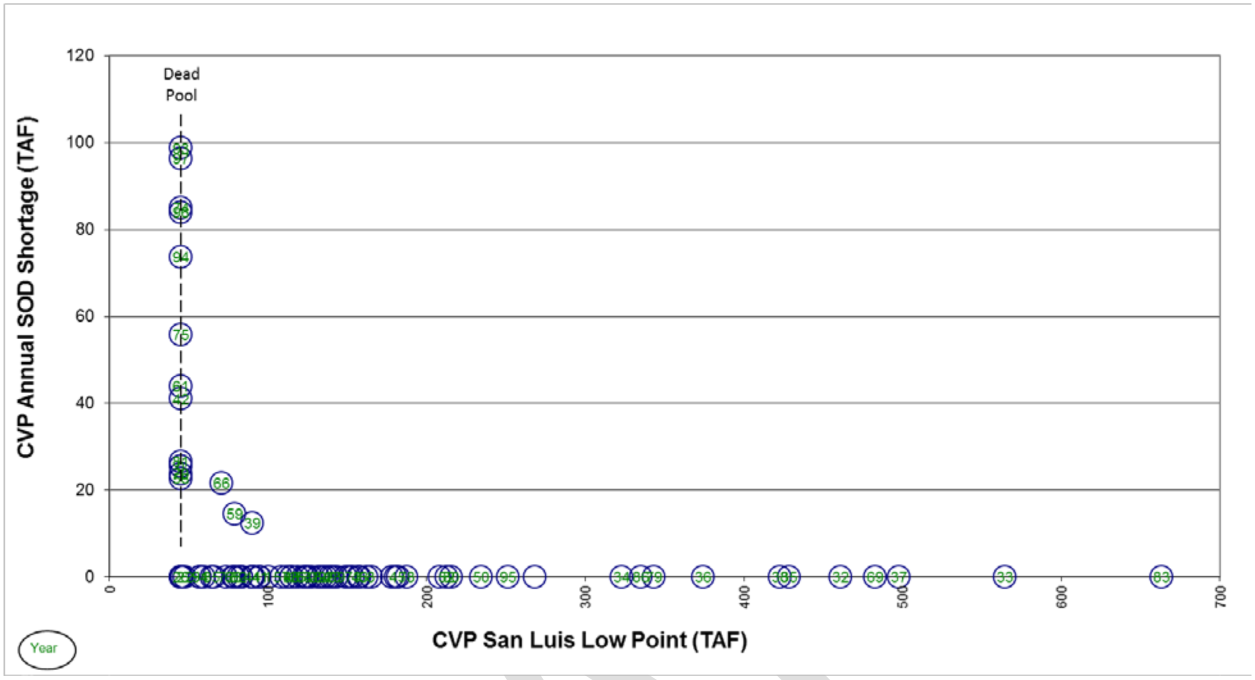


**Figure 1. CVP annual SOD shortage versus CVP San Luis storage low point as simulated in CalSim_27JAN2015**

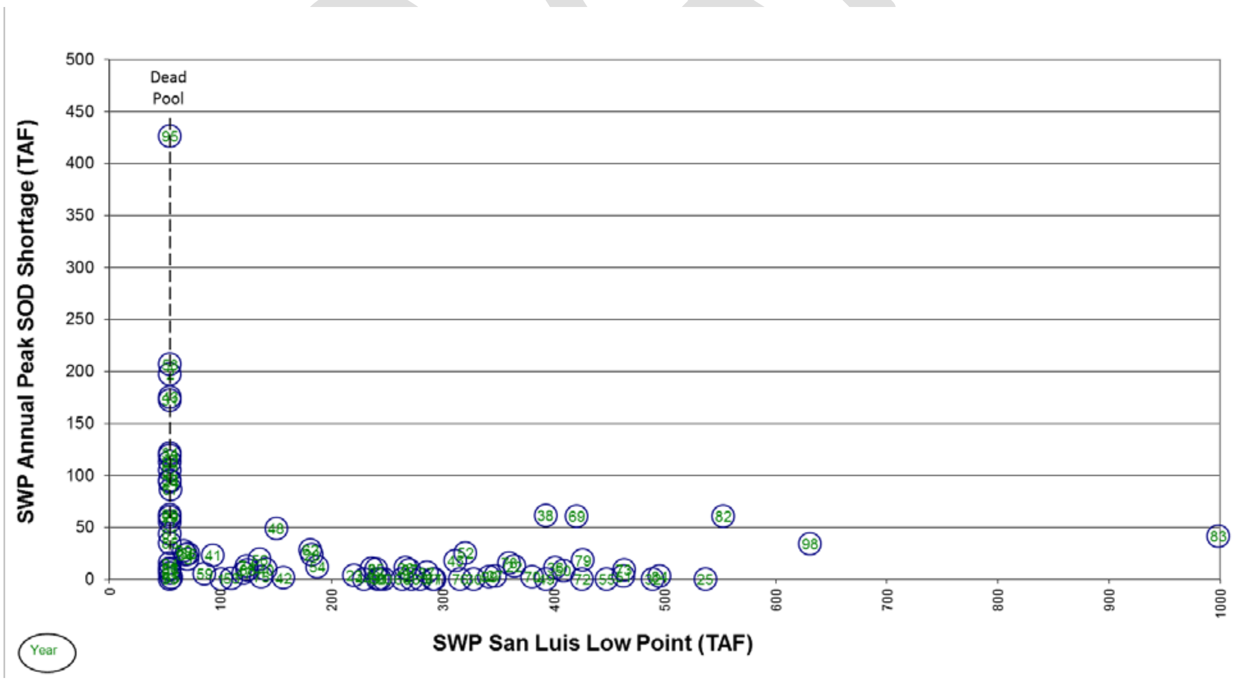


**Figure 2. SWP annual maximum SOD shortage versus SWP San Luis storage low point as simulated in CalSim_27JAN2015**

Over-allocation in CalSim can be traced back to the model methodology used for both the SWP Table A allocations and CVP SOD Agriculture (Ag) and Municipal and Industrial (M&I) allocations.

The CalSim allocation methodology (used for both the CVP and SWP) combines the Water Supply Index – Delivery Index (WSI-DI)–based allocation with an export forecast–based allocation. The minimum of the two is the final allocation for each project in each contract year. (Note that the CalSim model allocation methodology bears minimal resemblance to the methodology used in real-time allocations.)

The WSI-DI–based allocation assesses aggregate supply (forecasted inflow plus storage), but it does not adequately address limitations of available export capacity necessary to move the NOD supply to SOD contractors. Conversely, the export forecast–based allocation is intended to address export capacity limitations, but the current implementation has limited accuracy. Also, the export forecast–based allocation does not consider demand for export capacity. In other words, the export estimate does not consider whether or not the projects would release stored water from upstream reservoirs to make use of the available export capacity. If NOD storage is low, the projects will not want to release stored water to support exports. This should be explicitly incorporated into the allocation decisions, and it currently is not in CalSim.

The purpose of combining the WSI-DI allocation with an export forecast–based allocation was to have each allocation method cover the weaknesses of the other. However, as seen in current CalSim results (Figure 1 and Figure 2), this has not been accomplished. Ideally, the allocation methodology used in CalSim should better reflect real-time operations methodologies where consideration of supply, demand, conveyance capacity, and carryover in upstream reservoirs are physically integrated. This has been attempted by the Department of Water Resources (DWR) in the form of its Forecast Allocation Model (FAM), but it is beyond the scope of this contract.

The objective is to improve allocation decisions with the current methodology thereby preventing drawing San Luis to dead pool and shorting contractors. The most appropriate improvement is to create a more accurate export forecast—one that takes into account both the availability of and the demand for export capacity. However, before potential improvements are discussed, it is important to examine the CVP and SWP export forecast currently used in CalSim.

During the CVP allocation season (March–May), the current version of CalSim has only two possible export forecasts: one when it is a wet year as classified by the San Joaquin River (SJR) 60-20-20 index; and another when it is critical, dry, below normal, or above normal year classification. Table 1 shows the export estimates for each month from March to August. The export forecast–based allocation sums the export estimates from the current month through August.

In Table 1, only April, May, and June are conditioned on the SJR 60-20-20 index because those are the months where exports are most likely controlled by either the SJR inflow-export (IE) ratio or Old and Middle River (OMR) flow requirements. The sum total of the export estimates from April to June in a wet year is 516 TAF (2,000 cubic feet per second [cfs], 2,000 cfs, and 4,600 cfs); in a non-wet year the sum total is 240 TAF (1,000 cfs, 1,000 cfs, and 2,000 cfs). Such a coarse export estimate does not adequately account for the variability in SJR hydrology or in the conditionality of the SJR IE ratio or OMR flow regulations. It also does not reflect the information that operators have at hand to refine their forecasts, which include current SJR flows at Vernalis, forecasted operations on the SJR and its tributaries, and ongoing discussions with the U.S. Fish and Wildlife Service (FWS) about fish take, trawl data and expected OMR flow requirements.

**Table 1. Monthly CVP export estimates found in the CalSim_27JAN2015 lookup table ExportEstimate_CVP**

| CalSim Baseline CVP Export Forecast for SOD Ag and M&I Allocation | | | |
|---|---|---|---|
| Month | Export Estimate (cfs) | Wet SJR Export Estimate (cfs) | Delivery Pattern Fraction |
| MAR | 2500 | 0 | 0.68 |
| APR | 1000 | 2000 | 0.622 |
| MAY | 1000 | 2000 | 0.553 |
| JUN | 2000 | 4600 | 0 |
| JUL | 4600 | 0 | 0 |
| AUG | 4600 | 0 | 0 |

The July and August export estimates for the CVP are listed in Table 1 at 4,600 cfs, which is Jones Pumping Plant's full capacity. Obviously this will never be an underestimate of simulated Jones pumping in July and August, but it is often an overestimate. Even though 4,600 cfs capacity is available, the CVP does not always want to release water from upstream reservoirs to fill that capacity. CalSim overestimates exports in these months with the expectation that the WSI-DI–based allocation will prevent an over-allocation. The WSI-DI does serve as a backstop in many years, but there are many years when it does not limit the export estimate based on available supply.

Figure 3 compares annual CVP SOD delivery shortage with the error in the CVP export forecast used in the export forecast–based allocation. The CVP export forecast error is calculated as the April–August CVP export forecast minus the modeled total April–August CVP Jones Pumping Plant exports. As shown in Figure 3, the error is both negative and positive but skews positive. There are no shortages when the export forecast is an underestimate of exports (negative error). There are 15 years with shortages when the forecast is an overestimate. However, the shortages in three of those years — 1939, 1959, and 1966, the three lowest shortages not equal to zero — have nothing to do with over-allocation but a quirk in the SJR model formulation. The remaining 12 are all due to over-allocation, both from the WSI-DI–based approach and the export forecast approach.

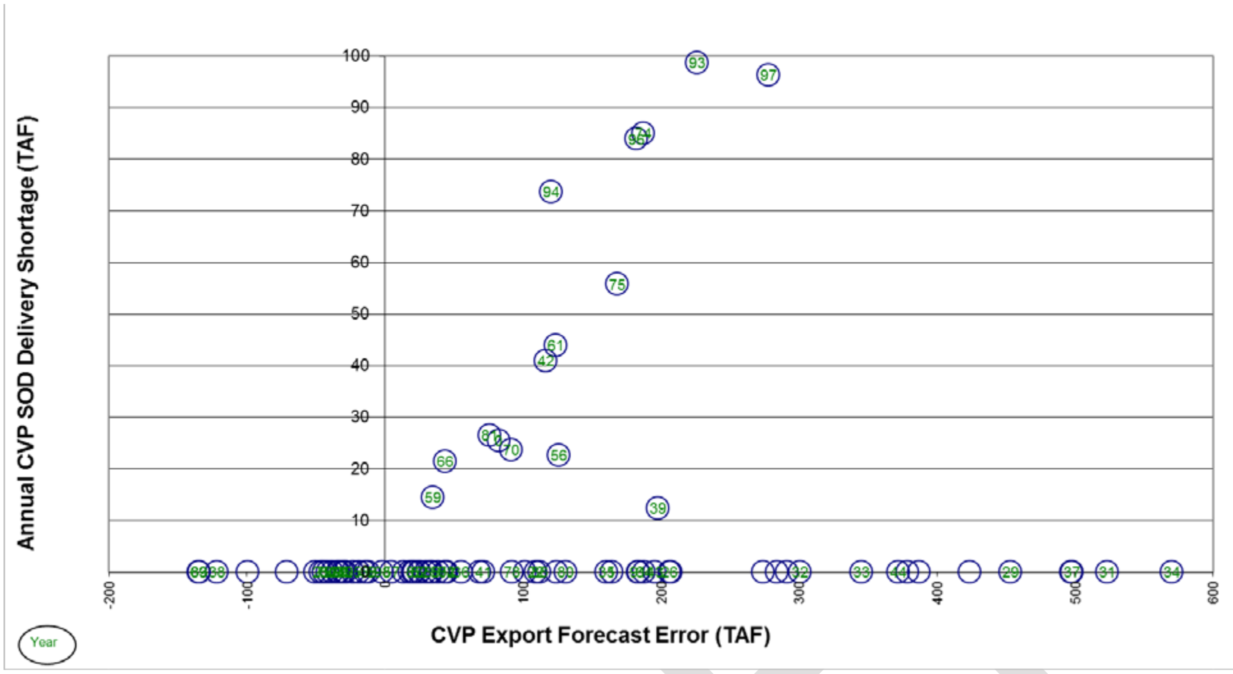


Figure 3. Annual CVP SOD delivery shortage versus CVP export forecast error in CalSim_27JAN2015

Problems with the SWP export forecast are similar to those explained above for the CVP. Table 2 lists the monthly SWP export estimates from January to August. Whereas the CVP contract year begins in March, the SWP contract year begins in January along with SWP allocations. Like the CVP, export estimates are conditioned on the SJR 60-20-20 index in April, May, and June. Unlike the CVP, the SWP export forecast logic adds a flood condition on the SJR in April and May. The flood condition is triggered when flow at Vernalis exceeds 16,000 cfs in March, April, or May. However, even with this added nuance, this is still a very coarse export forecast that does not capture the refinement inherent in real-time operations or what is needed in the model.

Table 2. Monthly SWP export estimates found in the CalSim_27JAN2015 lookup table ExportEstimate_SWP

| **CalSim Baseline SWP Export Forecast for Table A Allocation** | | | | |
|---|---|---|---|---|
| Month | Export Estimate (cfs) | Wet SJR Export Estimate (cfs) | Flood SJR Export Estimate (cfs) | Delivery Pattern Fraction |
| JAN | 3750 | 0 | 0 | 0.737 |
| FEB | 4250 | 0 | 0 | 0.721 |
| MAR | 4250 | 0 | 0 | 0.695 |
| APR | 1000 | 2000 | 6000 | 0.657 |
| MAY | 1000 | 2000 | 6000 | 0.566 |
| JUN | 2500 | 6000 | 0 | 0 |
| JUL | 7000 | 0 | 0 | 0 |
| AUG | 7000 | 0 | 0 | 0 |

The SWP export forecast for July and August is 7,000 cfs as listed in Table 2. This exceeds permitted capacity of 6,680 cfs in these months, and simulated SWP exports in CalSim_27JAN2015 never exceed permitted capacity in July and August. In fact, simulated July and August SWP exports are often significantly below permitted capacity. The explanation for this is the same as it was for the CVP: just because capacity is available does not mean the SWP wants to use it; that depends on the storage condition of Oroville, and the export forecast in Table 2 does not consider such details.

Figure 4 compares SWP SOD shortage with export forecast error. Export forecast error was again calculated by subtracting April–August total SWP exports from the forecasted exports. Only 1979 had an underestimate of forecasted exports, and that underestimate was slight. In all other years the SWP export forecasts were overestimates with some errors greater than 1 million acre-feet (MAF). The greatest delivery shortage occurred in a wet year, 1995 (Figure 4). The delivery shortage was approximately 425 TAF; it was the result of a 500 TAF overestimate of exports. (Many of the shortages shown that are below 70 TAF in Figure 4 are not due to over-allocation and breaking San Luis; they are due to insufficient California Aqueduct capacity to meet the assumed demand pattern. These are of less concern than the shortages caused by breaking San Luis.)

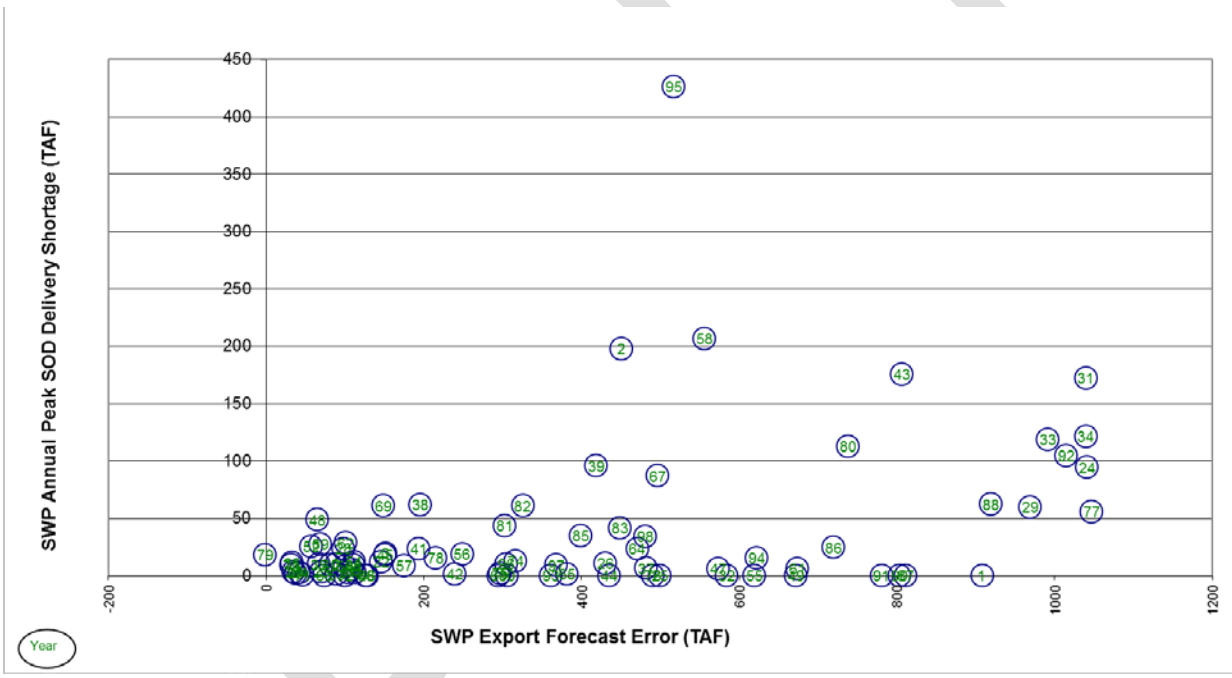


**Figure 4. SWP annual peak SOD delivery shortage versus SWP export forecast error in CalSim_27JAN2015**

To improve on the export forecasts, it is recognized that more detail is necessary. The two CVP and three SWP export forecast possibilities currently provided in CalSim do not adequately cover the different circumstances found from one year to the next. What follows is a proposal for deriving export forecasts that vary by year and month that will take into account hydrologic, regulatory, and operational variability. The methodology is similar to the WSI-DI procedure in that it requires infrequent iterations of CalSim, and it is best described as a series of steps.

## STEP 1

Set the CVP and SWP export forecasts equivalent to Health and Safety (H&S) minimum export levels (800 cfs for the CVP and 300 cfs for the SWP). As such, the respective April to August export forecasts are approximately 240 TAF for the CVP and 90 TAF for the SWP. Run CalSim with this initial export forecast.

## STEP 2

Use the CalSim CVP and SWP export results (D418 and D419_SWP, respectively) from Step 1 as new export estimates and re-run CalSim. Repeat until the maximum difference between aggregate export estimates and cumulative simulated exports is less than 100 TAF. Many previous trials indicate this will likely take three iterations. The first iteration (Step 1) uses the H&S export estimate, and the second and third use the CalSim-generated export estimates. A spreadsheet has been set up to process CalSim output into export forecast input for the purpose of expediting this process.

## STEP 3

Refine export estimates as necessary to achieve desired balance of contract deliveries and storage carryover. This refinement of export forecasts can be done by an automated procedure or manually. A combination of both was employed in this analysis.

Ideally, the procedure would stop at Step 2. Understanding why the procedure progresses to Step 3 requires an understanding of the logic of the first two steps. Starting with the H&S export forecast in Step 1 ensures very low allocations for both projects in all years of that simulation. As such, export of available Delta supplies without supplemental reservoir release – or export of incidental Delta inflow – are sufficient in almost every year to meet allocated deliveries and San Luis carryover targets. So the final result of that first iteration and the iterations that follow in Step 2 is a lower bound on the SWP and CVP export forecasts. In any year that moving additional water from NOD reservoirs is not desired, the final export forecast derived in Step 2 also represents an upper bound. But in those years where NOD stored water and SOD export capacity are available, the export forecast must be increased to drive higher allocations and movement of that additional water through rulecurve. (Rulecurve will be discussed later in this memo.) There are also very wet years such as 1983, when a full San Luis prevented additional exports during the iterative process. A boost in the export forecast increases allocations and deliveries, which allows for higher exports when San Luis is full. Given the reasons for refinement, the only changes to the export forecasts going from Step 2 to Step 3 were increases.

The final CVP and SWP export forecasts derived from the three-step methodology are listed in Table 3 and Table 4. While these forecasts extend through the period of record (1922–2003), the tables show a small sample (1922–1931) for the sake of brevity. Each export forecast provided by year and month represents cumulative exports from the given month through August. As such, the export forecast can easily be retrieved from a lookup table or DSS timeseries (either data retrieval mechanism will work) and directly input into the current SWP and CVP export-based allocation logic (some minor edits were made for the new format of the export forecasts). Note the variability of the SWP and CVP export forecasts from a wet year like 1922, to a below-normal year like 1928, and to a critical year like 1931 (all SJR 60-20-20 index–based classifications). This is a significant change from the rough forecasts found in CalSim_27JAN2015.

**Table 3. Sample CVP export forecast derived from the three-step process and used in CalSim_27JAN2015_Revised**

| Modified CVP Export Forecast for SOD Ag and M&I Allocation (cumulative from current simulation month to August) | | | |
|---|---|---|---|
| | Cumulative Export Estimate (TAF) | | |
| Year | MAR | APR | MAY |
| 1922 | 1255 | 972 | 901 |
| 1923 | 1083 | 883 | 817 |
| 1924 | 388 | 269 | 180 |
| 1925 | 1039 | 856 | 784 |
| 1926 | 622 | 339 | 271 |
| 1927 | 1062 | 835 | 775 |
| 1928 | 935 | 652 | 592 |
| 1929 | 501 | 338 | 269 |
| 1930 | 551 | 395 | 329 |
| 1931 | 325 | 261 | 189 |

**Table 4. Sample SWP export forecast derived from the three-step process and used in CalSim_27JAN2015_Revised**

| Modified SWP Export Forecast for Table A Allocation (cumulative from current simulation month to August) | | | | | |
|---|---|---|---|---|---|
| | Cumulative Export Estimate (TAF) | | | | |
| Year | JAN | FEB | MAR | APR | MAY |
| 1922 | 2025 | 1805 | 1729 | 1409 | 1325 |
| 1923 | 1634 | 1413 | 1318 | 1117 | 1038 |
| 1924 | 412 | 232 | 111 | 93 | 75 |
| 1925 | 1227 | 1029 | 1049 | 800 | 709 |
| 1926 | 1179 | 981 | 1015 | 990 | 905 |
| 1927 | 1687 | 1542 | 1425 | 1192 | 1119 |
| 1928 | 1695 | 1482 | 1432 | 1132 | 1062 |
| 1929 | 684 | 482 | 299 | 136 | 67 |
| 1930 | 1209 | 1061 | 922 | 767 | 704 |
| 1931 | 508 | 308 | 152 | 88 | 71 |

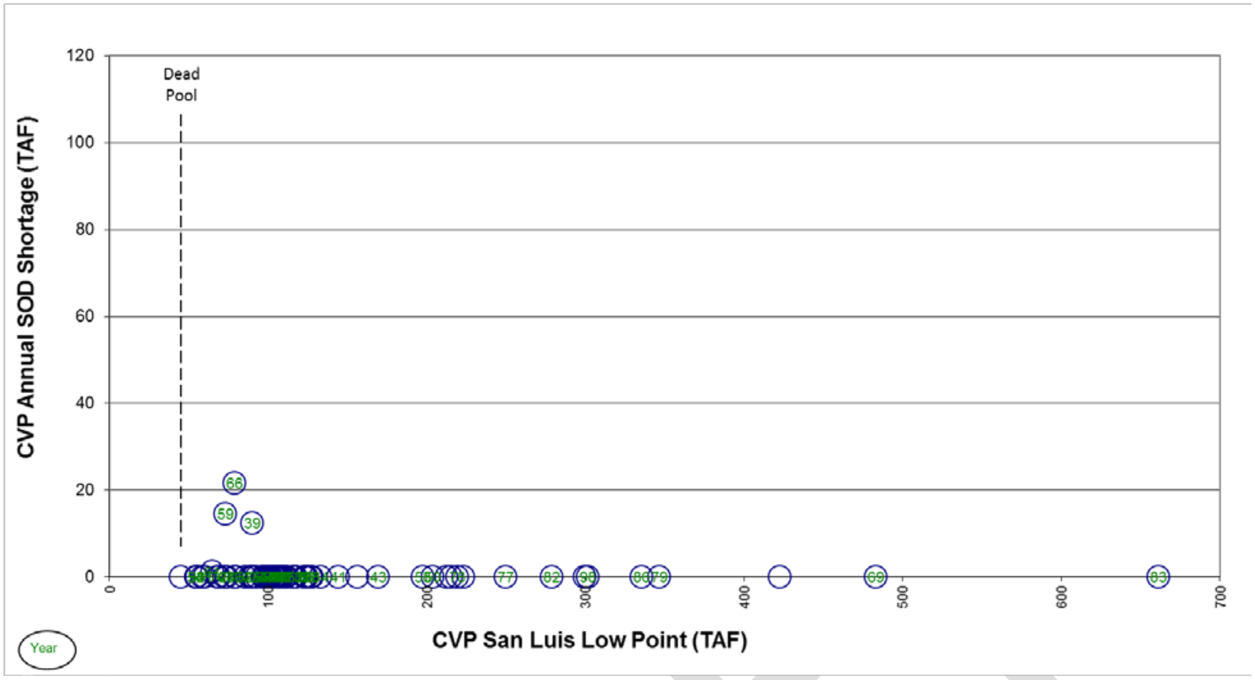


**Figure 5. CVP annual SOD shortage versus CVP San Luis storage low point as simulated in CalSim_27JAN2015_Revised**

Figure 5 and Figure 6 compare annual shortage and San Luis low point as simulated in CalSim_27JAN2015_Revised with the updated export forecasts listed above. CVP San Luis is drawn to dead pool only once and no shortage occurs in that year. The only years with CVP SOD shortages are 1939, 1959, and 1966; as discussed previously, the shortages are not caused by over-allocation but a quirk in the SJR model formulation. The SWP is drawn to dead pool in four years, but there are shortages in only two of them. (The two dead pool data points where the shortage is zero overlap.) All SWP shortages shown are reasonably small and are almost entirely caused by insufficient California Aqueduct capacity to meet the simulated delivery pattern. This type of shortage is of less concern than those caused by breaking San Luis. To gage the improvement in San Luis operations and reductions in project SOD delivery shortages due to the updated export forecasts, compare Figure 5 to Figure 1 and Figure 6 to Figure 2.

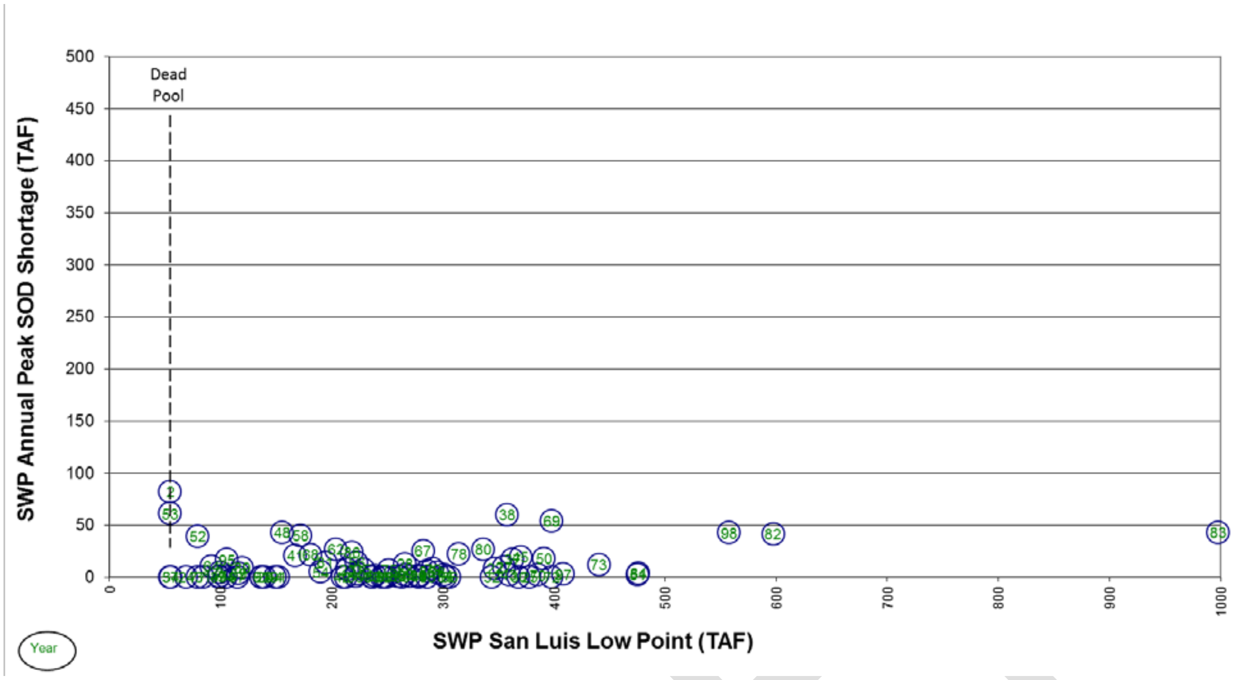


**Figure 6. SWP annual maximum SOD shortage versus SWP San Luis storage low point as simulated in CalSim_27JAN2015_Revised**

Export forecast error was shown to be large for both the CVP (Figure 3) and SWP (Figure 4) in CalSim_27JAN2015. Reducing export forecast error was essential to the prevention of breaking San Luis and shorting SOD contractors. Figure 7 relates CVP SOD delivery shortage to CVP export forecast error in CalSim_27JAN2015_Revised. As shown, most of the CVP export forecast errors fall under 100 TAF. Those errors above 100 TAF were edited in Step 3 of the proposed export forecast methodology to refine the balance between deliveries and carryover. Figure 8 relates SWP SOD delivery shortage to SWP export forecast error in CalSim_27JAN2015_Revised. The forecast error in three years is above 200 TAF: 1952, 1982, and 1983. It was recognized that in all three of these years there was sufficient water and export capacity to meet a 100% Table A allocation. The export forecast in each was set sufficiently high so that it would not prevent a full allocation. The rest of the SWP export forecast errors were less than 200 TAF. The refinements in Step 3 were responsible for pushing the errors above 100 TAF.

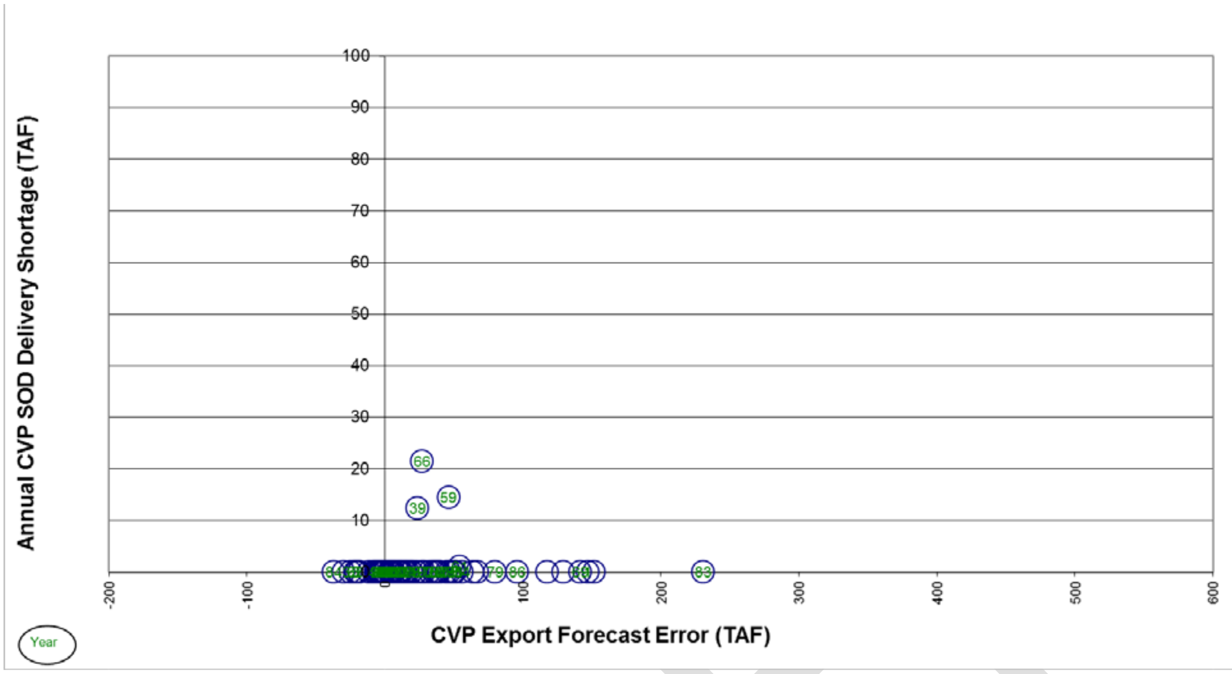


**Figure 7. Annual CVP SOD delivery shortage versus CVP export forecast error in CalSim_27JAN2015_Revised**

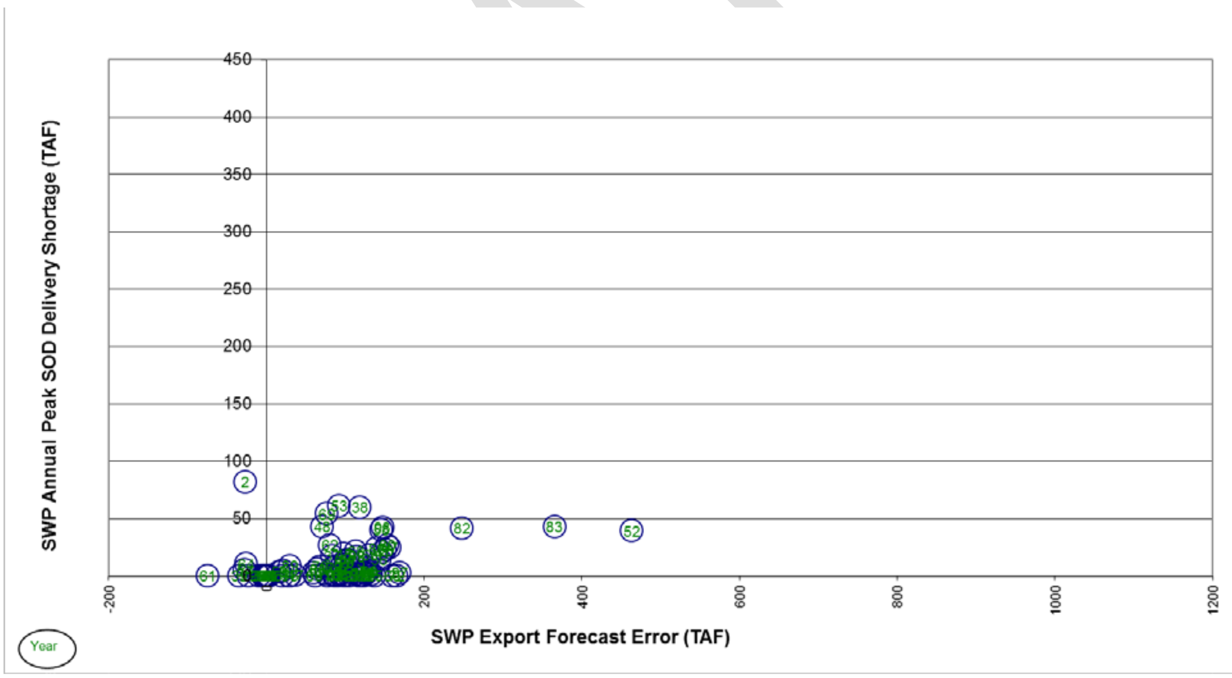


**Figure 8. SWP annual peak SOD delivery shortage versus SWP export forecast error in CalSim_27JAN2015_Revised**

## CalSim CVP Allocation Logic Refinement

Other adjustments were made to CalSim_27JAN2015_Revised in addition to the update of the export forecasts used in CVP and SWP allocations. One was a refinement to the CVP allocation procedure to reduce instances where there are low CVP SOD service contract allocations in years that end in excessively high San Luis carryover. Figure 9 links CVP San Luis low point with combined Shasta and Folsom carryover as simulated in CalSim_27JAN2015. Six of the annual data points are highlighted in red due the relatively high San Luis low point and low CVP SOD Ag Service allocation (see Figure 10 for the allocation associated with each data point). The highlighted years are 1932–1937, and the SOD Ag Service allocations in these years range from 4% in 1932 to 43% in 1936. The San Luis low point is above 300 TAF throughout this period and reaches almost 600 TAF in 1932. San Luis also fills during critical periods, thereby constraining CVP export of valuable winter surplus. Clearly, higher deliveries could be made SOD without impacting upstream storage; so it is advantageous to determine why the current model does not perform this operation, and what change can be made to more efficiently use available water.

The problem within the model is caused by dry conditions north of the American River and wetter conditions from the American River south. Such a hydrologic imbalance leaves Shasta and Trinity storage low but keeps San Luis storage high through export of surplus originating on the American and San Joaquin Rivers. Low Shasta and Trinity storage results in a low WSI-DI–based allocation. A low WSI-DI allocation supersedes a higher export-based allocation (recall that the model uses the minimum), and SOD service contractor allocations end up being governed by the dry conditions to the north even though there is sufficient water SOD to meet higher demand.

In the end, this is entirely the result of a modeling artifact. It is standard policy within the CVP that NOD service contractor allocations will be equal to or greater than SOD service contractor allocations. The issue lies with how this policy is applied in the model. NOD service contractor allocations are calculated using the WSI-DI method; SOD service contractor allocations are calculated as the minimum of the WSI-DI–based allocation and the export forecast–based allocation. This, at times, artificially constrains system-wide allocations based solely on low conditions at Shasta and Trinity.

In other words, the model ignores the details that operators would consider in developing a real-time service contractor allocation. Note that NOD Ag Service contracts along the Sacramento River total 377 TAF. As such, a NOD Ag Service allocation increase of 1 percent would expose Shasta and Trinity to a combined 4 TAF of additional drawdown. Also consider that SOD Ag Service contracts total 1,987 TAF. Therefore a 1 percent increase in SOD Ag Service allocations would require 20 TAF of combined drawdown in San Luis and/or increased exports. If in actual operations the CVP operators see the potential to boost SOD Ag Service allocations by 100 TAF due to high San Luis storage levels—an allocation increase of approximately 5 percentage points. There may be concern about boosting NOD Ag Service allocations by an equal percentage, but the operators would understand that such an increase would only result in an additional 20 TAF of load on Shasta and Trinity. There are certainly cases where such a tradeoff would be made, and years 1932–1937 as simulated in CalSim_27JAN2015 appear to be such cases.

The modification applied in CalSim_27JAN2015_Revised was to conditionally reformulate CVP Ag Service allocations in contract years 1932–1937. In these years, allocations for both NOD and SOD service contractors are allowed to be driven by the export-based methodology when appropriate. This does not circumvent the standard policy of maintaining NOD service contractor allocations at or above SOD allocations; this policy is maintained. The result of this change in allocation formulation is shown in Figure 11 and Figure 12. The data points highlighted in red correspond to the same annual data points highlighted in Figure 9 and Figure 10. The San Luis low point in these years has been significantly reduced in CalSim_27JAN2015_Revised as compared to CalSim_27JAN2015 and the impact to upstream carryover is acceptable.

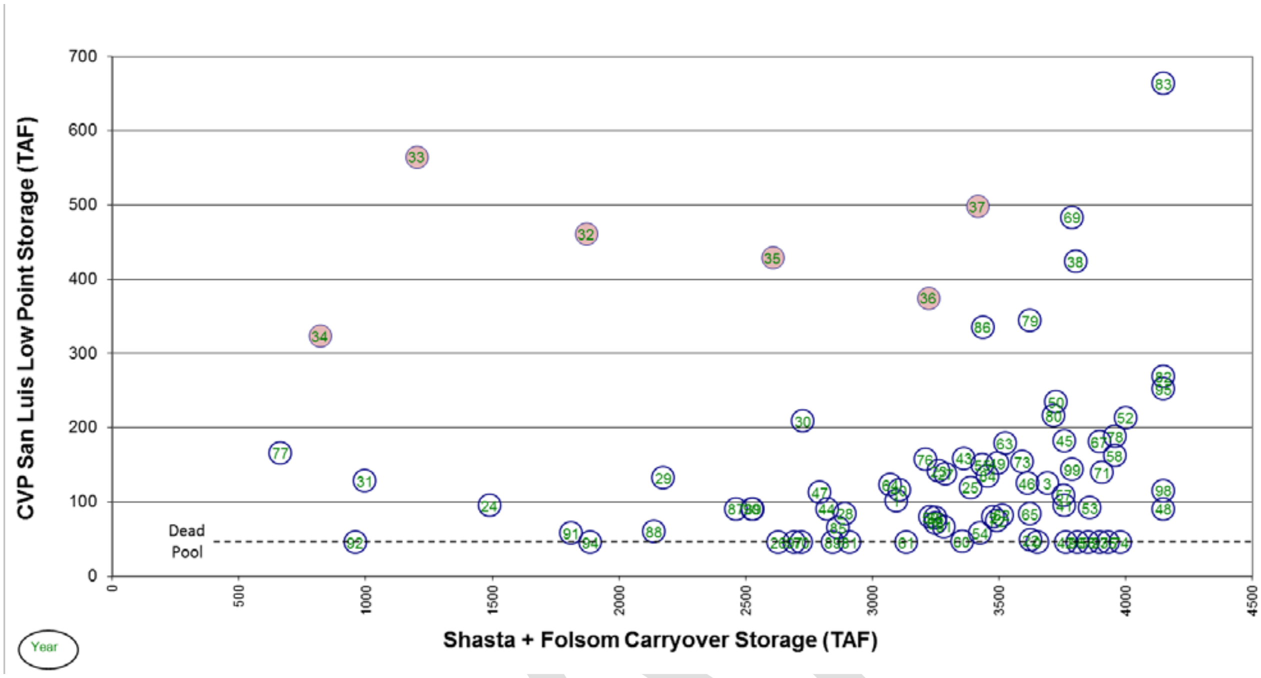


**Figure 9. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015 with contract year data label**

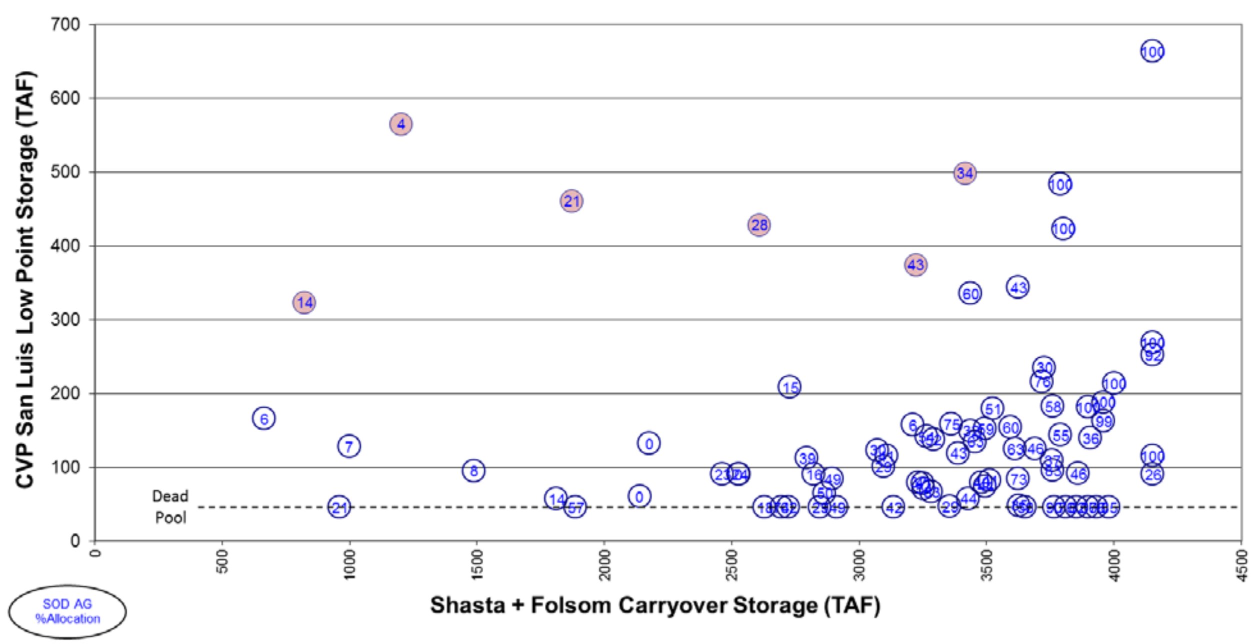


**Figure 10. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015 with SOD Ag Service allocation data label**

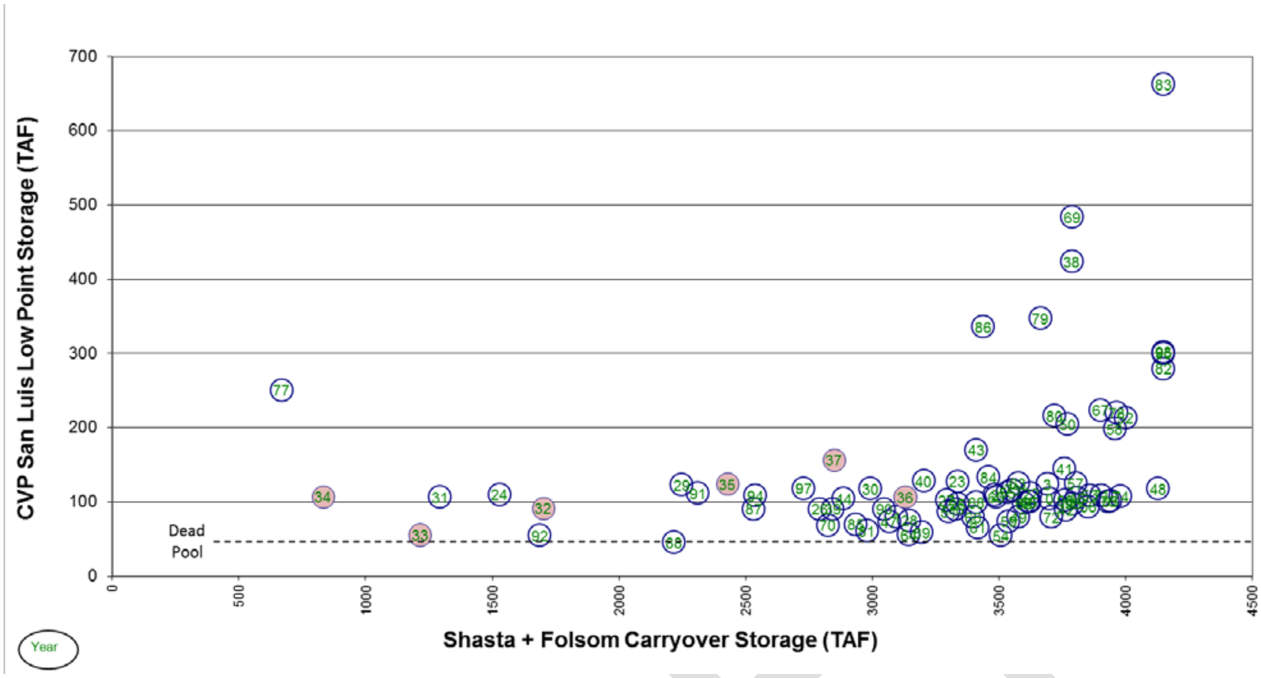


Figure 11. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015_Revised with contract year data label

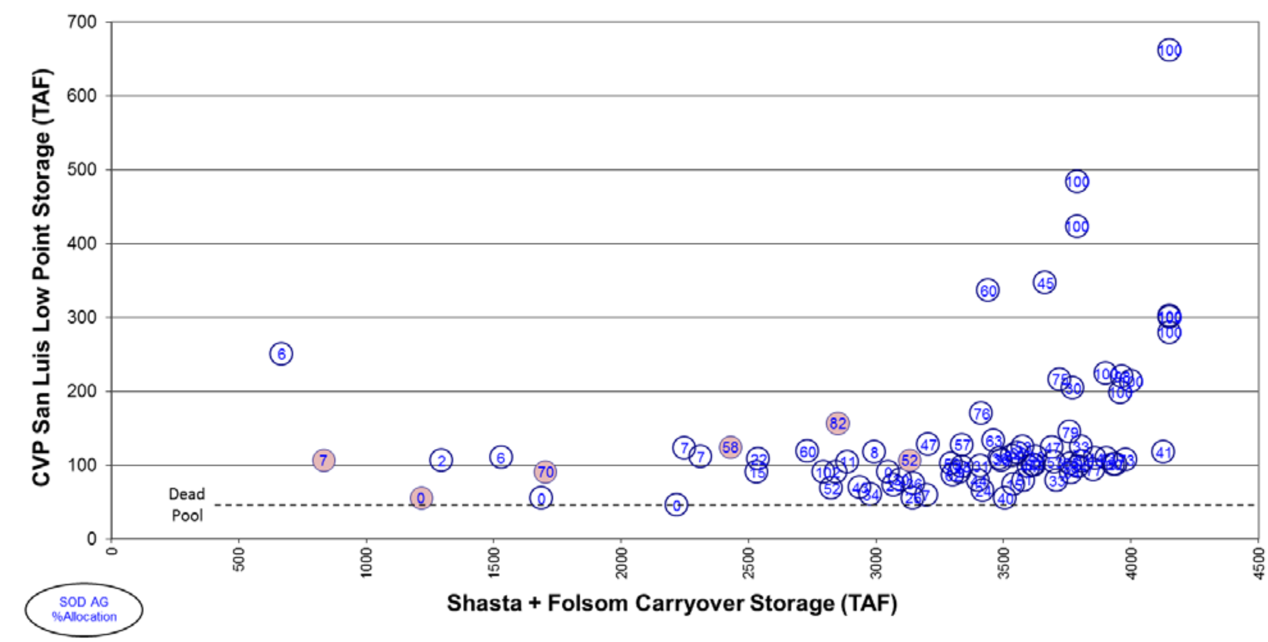


Figure 12. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015_Revised with SOD Ag Service allocation data label

As discussed above, CalSim_27JAN2015_Revised results as plotted in Figure 5, Figure 6, Figure 7, Figure 8, Figure 11, and Figure 12 were significantly influenced by the revised export forecast used in CVP and SWP allocations and the reformulation of CVP allocation logic in 1932–1937. Two more changes were also made to CalSim_27JAN2015_Revised that affected results. However, while important to NOD-SOD storage balance, these changes are less significant than those already discussed. The first of these additional edits is refinement of San Luis rulecurve for the SWP and CVP, and the second is an adjustment to operational logic under an ANN negative carriage constraint; these edits are detailed below.

## RULECURVE

The purpose of rulecurve is to prioritize balance between NOD storage and San Luis for both the CVP and SWP. Rulecurve controls upstream release for export when there is a choice between storing water in upstream reservoirs and releasing water for export and storing it in San Luis. Operational constraints such as flood pool, minimum instream flow requirements, export regulations, H&S pumping requirements, and physical pump capacity override rulecurve; and when any of these control operations, choices for balancing NOD storage are limited.

During the winter, rulecurve is set to encourage the filling of San Luis though it rarely controls. Incidental Delta inflow typically drives San Luis filling during the rainy season. Upstream reservoir releases are often controlled by flood pool or minimum flow requirements, and exports are controlled by OMR flow requirements or maximum pumping capacity. Since rulecurve does not play a significant role in driving winter San Luis operations, there was no need to modify wintertime rulecurve logic.

Where rulecurve does make a difference (or should make a difference) is during irrigation season when there are windows of opportunity to coordinate upstream reservoir releases with Delta exports. During the summer, SOD project demand typically exceeds Delta exports. As such, SOD project demand is met with a combination of Delta exports and San Luis releases, and if rulecurve is controlling, it influences the balance between Delta exports and San Luis reservoir releases. If rulecurve is set lower, exports decrease and San Luis releases increase. When set higher, the opposite occurs. Ideally the combination of San Luis releases and project exports over the irrigation season is sufficient to satisfy project allocations and San Luis targeted carryover storage, and rulecurve should be set to encourage the appropriate balance.

Therefore, formulation of rulecurve during the irrigation season should boil down to an export scheduling problem, to be solved by determining how much to export within a season to achieve delivery and carryover goals, how to distribute these exports from month to month, and where to set SWP and CVP rulecurve to encourage those Delta exports and the supporting upstream releases. The problem with the current irrigation season rulecurve formulations in CalSim is that they do not consider the amount of exports needed over the season. In fact, for both the SWP and CVP, the rulecurve formulation assumes exports of 60 TAF per month whether that is sufficient to meet operational objectives or not. Rulecurve levels are driven by this export assumption.

The implemented fix to the irrigation season rulecurve formulation is to incorporate export scheduling in CalSim_27JAN2015_Revised; SWP and CVP formulations vary slightly. With the CVP, exports need to be scheduled to ensure the project can meet peak summer demand and prevent San Luis low point issues through the end of September. The SWP has similar concerns, but must also consider Article 56 carryover into the next calendar year with the added complication of Feather River flow limitations for half of October and all of November that can interfere with the

State's ability to make Oroville releases for export. So while the CVP's export scheduling formulation extends from May through September, the SWP's starts in April and extends through December. As an example, the SWP export schedule–based rulecurve formulation for the months of April–December is outlined below.

First, needed exports are calculated from the beginning of the current month of the simulation through the end of December (Required_Exports_NowtoDec (TAF)).

(1) Required_Exports_NowtoDec = max(0, remainDem_SOD + remain_evap + remain_loss + max(110, carryover_final + 55) – Beg_Month_SWP_San_Luis_Storage)

Where

- remainDem_SOD is the remaining Table A allocations to be delivered from now to the end of December (TAF)
- remain_evap is an estimate of total evaporation over the rest of the calendar year (TAF)
- remain_loss is an estimate of the total California Aqueduct losses over the rest of the calendar year (TAF)
- 110 is the SWP San Luis carryover target (TAF)
- carryover_final is the quantity of water needed in San Luis at the end of December to make Article 56 deliveries (TAF)
- 55 is SWP San Luis dead pool capacity (TAF)
- Beg_Month_SWP_San_Luis_Storage is SWP San Luis storage at the beginning of the current month of simulation (TAF)

Next, the amount that should be exported this month (Required_Exports (TAF)) in order to achieve the export goal for the remainder of the calendar year (Required_Exports_NowtoDec) is calculated. Assume exports will be scheduled uniformly over the remaining months of the calendar year, except for half of October and all of November due to Feather River flow restrictions. During the Feather River flow restrictions, we assume Banks pumping is held to the H&S level (300 cfs), which equals approximately 27 TAF over 1.5 months or 18 TAF over 1 month. So the formulation varies by month:

For the months April–September, the formulation is:

(2a) Required_Exports = (Required_Exports_NowtoDec - 27)/(remain_months - 1.5)

For the month of October, the formulation is:

(2b) Required_Exports = (Required_Exports_NowtoDec - 18)/(remain_months - 1)

And for the months of November–December the formulation is:

(2c) Required_Exports = Required_Exports_NowtoDec/remain_months

Where

- remain_months is the number of months remaining in the calendar year starting from the beginning of this month of simulation to the end of December

At this point in the calculation, SWP exports could be prioritized up to Required_Exports such that Oroville releases would be made to support those exports. But that is not the modeling technique used in CalSim. As discussed, the balance of upstream storage and San Luis storage is guided with rulecurve; so to prioritize SWP exports up to Required_Exports, rulecurve must be appropriately set. Expected change in San Luis storage (Change_San_Luis_Storage (TAF)) if exports equal Required_Exports is now calculated. The formulation is:

(3) Change_San_Luis_Storage = Required_Exports – This_Month_Forecasted_Delivery – This_Month_Forecasted_Loss – This_Month_Forecasted_Evap

Where

- This_Month_Forecasted_Delivery is this month's estimated Table A deliveries (TAF)
- This_Month_Forecasted_Loss is this month's estimated California Aqueduct losses (TAF)
- This_Month_Forecasted_Evap is this month's estimated SWP San Luis evaporation (TAF)

Given the calculated Change_San_Luis_Storage, the rulecurve (SWP_Rulecurve (TAF)) that will encourage sufficient Oroville releases to support SWP exports at Required_Exports is determined as follows:

(4) SWP_Rulecurve = Beg_Month_SWP_San_Luis_Storage + Change_San_Luis_Storage

## NEGATIVE CARRIAGE OPERATIONS

Delta carriage is the additional Delta outflow above minimum required Delta outflow (MRDO) necessary to meet D-1641 salinity standards. When salinity is controlling, an increase in exports requires an increase in release from upstream reservoirs to the Delta that equals the export increase plus carriage. In other words, carriage is the water cost of Delta exports when salinity standards are controlling. While higher exports typically result in higher carriage, there are times of the year when Rock Slough and Emmaton salinity standards can be met with higher exports and negative carriage. Essentially, when a negative carriage salinity constraint is controlling, a unit increase in Delta exports is supplied partially by a decrease in carriage (decrease in Delta outflow) and the remainder by an increase in upstream reservoir release. While negative carriage might be counterintuitive, it is an actual phenomenon observed in Delta operations.

Negative carriage in CalSim presents problems of prioritization. In CalSim, Delta outflow above MRDO, whether the outflow is surplus or carriage, is given a highly negative weight (low priority). The intent is to discourage any Delta outflow in excess of MRDO. So when a negative carriage salinity constraint is controlling operations, CalSim will operate to minimize Delta outflow even though it might cause an imbalance between NOD and SOD storage. Delta outflow is reduced through increased exports, but some water still has to be released from upstream reservoirs to support part of the increased export. If NOD reservoirs are relatively full, this could be a desirable operation, but if NOD reservoirs are low and further exports are not needed to support this year's allocation, minimizing Delta outflow at the expense of upstream storage is an unwarranted operational decision. During the critical periods, CalSim makes several of these decisions that result in the transfer of NOD storage to San Luis when the water would be better kept NOD.

The implemented negative carriage operation fix in CalSim_27JAN2015_Revised is to remove the model flexibility to make an unwarranted decision. In CalSim, SWP and CVP export estimates are made to guide operations when salinity standards are controlling (C400_MIF logic). This is used to ensure that needed exports are made even if positive carriage must be paid. In CalSim_27JAN2015_Revised, similar export estimates are now used to limit how much carriage can be reduced through increases in exports under a negative carriage constraint. Essentially, under an Emmaton or Rock Slough negative carriage constraint, the carriage is held at the level to support the estimated export – no more and no less. CalSim does not get an objective function benefit of releasing more water from upstream storage for a fractional reduction in Delta outflow.

## Comparison of CalSim_27JAN2015 and CalSim_27JAN2015_Revised Results

The revisions in CalSim_27JAN2015_Revised change the storage balance between Oroville and SWP San Luis. Figure 13 and Figure 14 relate SWP San Luis low point storage to Oroville carryover in each year of the CalSim_27JAN2015 simulation. The only difference between the two figures is that data in Figure 13 is labeled by year and data in Figure 14 is labeled by Table A allocation. Note the years that SWP San Luis low point is at dead pool. This occurs over a wide spectrum of Oroville carryover and Table A allocations. Also note the four data points highlighted in red—1925, 1932, 1949, and 1955 with Table A allocations of 37%, 28%, 29%, and 38%, respectively. Ideally, higher allocations would have been made in these years, reducing San Luis low point storage. Figure 15 and Figure 16 relate SWP San Luis low point storage to Oroville carryover storage in each year of the CalSim_27JAN2015_Revised simulation. Compare Figure 15 and Figure 16 to Figure 13 and Figure 14, respectively to see the effect of the model edits (export forecast, rulecurve, and negative carriage) on the overall San Luis-Oroville storage balance. Note that the San Luis low point has been largely lifted above dead pool in CalSim_27JAN2015_Revised. Also note the red highlighted data points in Figure 15 and Figure 16, which correspond to the same years highlighted in red in Figure 13 and Figure 14. The combined effect of the model edits creates a more ideal balance between Oroville storage, SWP San Luis storage, and Table A allocations.

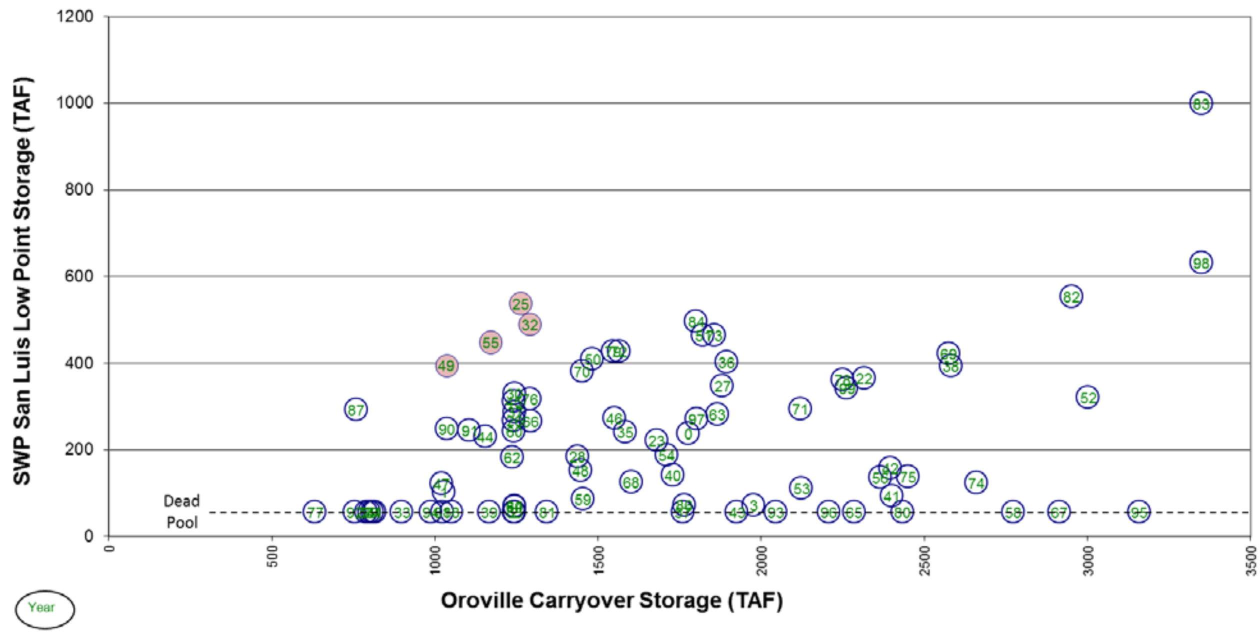


**Figure 13. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015 with contract year data label**

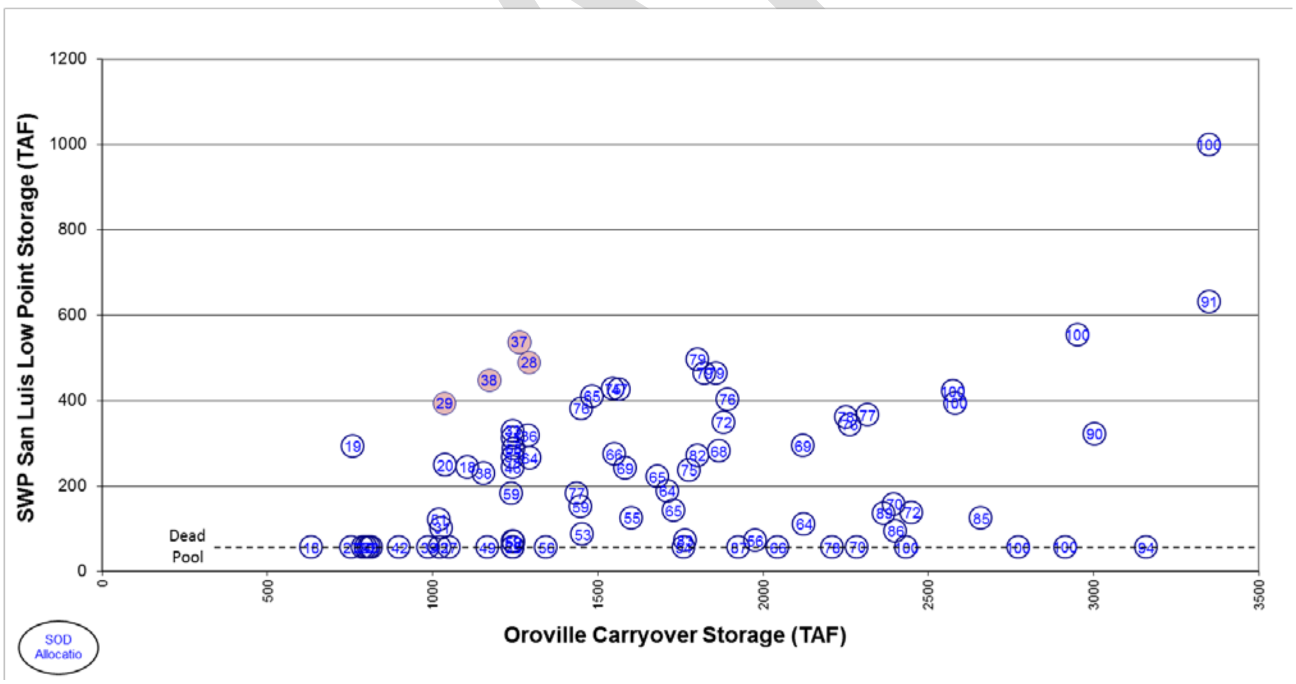


**Figure 14. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015 with Table A allocation data label**

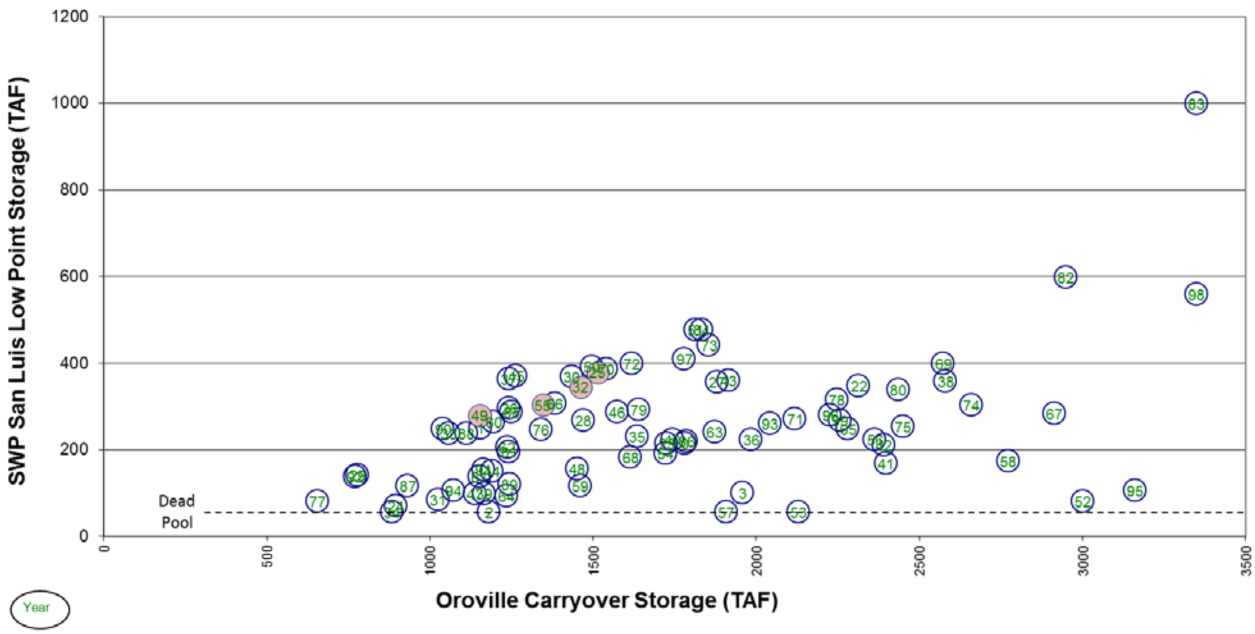


**Figure 15. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015_Refined with contract year data label**

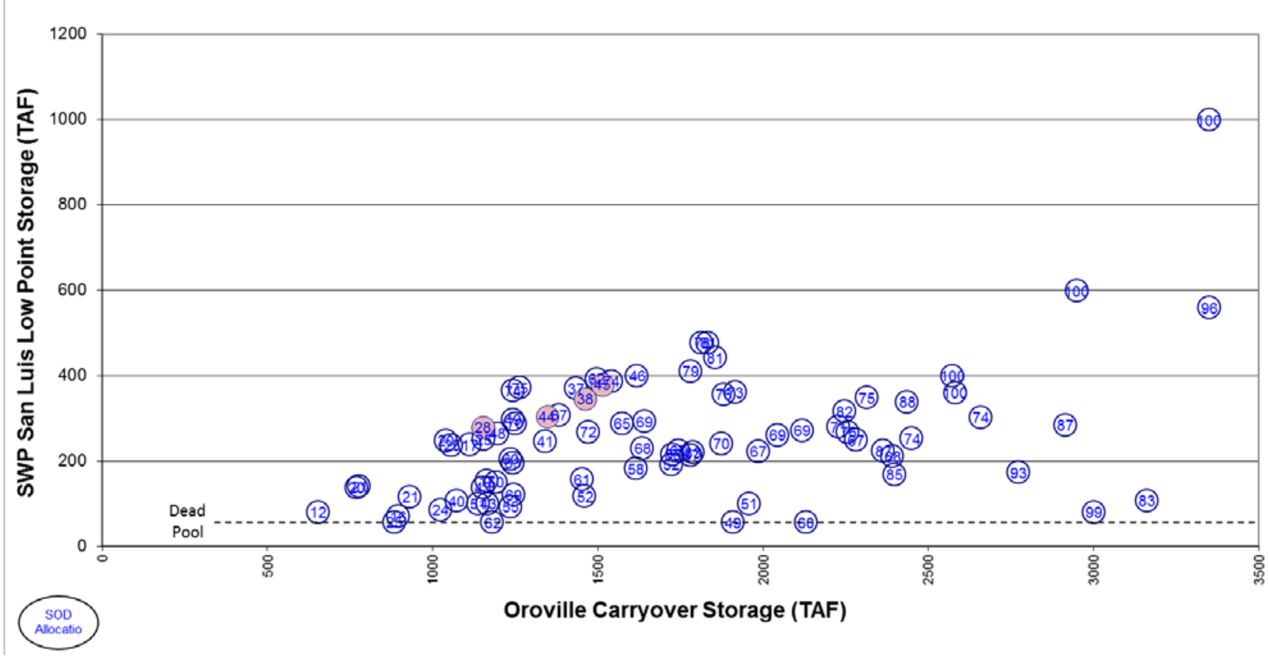


**Figure 16. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015_Revised with Table A allocation data label**

CVP San Luis storage often hits its annual low point in August. Figure 17 compares CVP San Luis end of August storage probability of exceedance curves for CalSim_27JAN2015 and CalSim_27JAN2015_Revised. In CalSim_27JAN2015, there is an almost 20% chance that end of August CVP San Luis storage is at dead pool; there is only slightly more than a 1% chance in

CalSim_27JAN2015_Revised. Also, in CalSim_27JAN2015_Revised, CVP San Luis is consistently drawn down to the 90 TAF low point target used in the CVP SOD export forecast allocation logic, whereas CalSim_27JAN2015 tends to diverge from this target.

SWP San Luis storage often hits its annual low point in October. Figure 18 compares SWP San Luis end-of-October storage probability of exceedance curves for CalSim_27JAN2015 and CalSim_27JAN2015_Revised. In CalSim_27JAN2015, there is a greater than 16% chance that end-of-October SWP San Luis storage is at dead pool; there is only a 3% chance in CalSim_27JAN2015_Revised. The low point target used in SWP export forecast allocation logic is 110 TAF. There is no obvious drawdown to this target in Figure 18 because of Article 56 carryover. CalSim_27JAN2015_Revised does a better job of preserving Article 56 requested by contractors. This is more evident when comparing CalSim_27JAN2015_Revised and CalSim_27JAN2015 Article 56 deliveries.

Model revisions also affect NOD carryover storage (end of September). Figure 19 through Figure 22 show the CalSim_27JAN2015 and CalSim_27JAN2015_Revised carryover storage probability exceedance curves for Trinity, Shasta, Folsom, and Oroville reservoirs, respectively. As shown, the model revisions had a largely positive effect on upstream carryover storage.

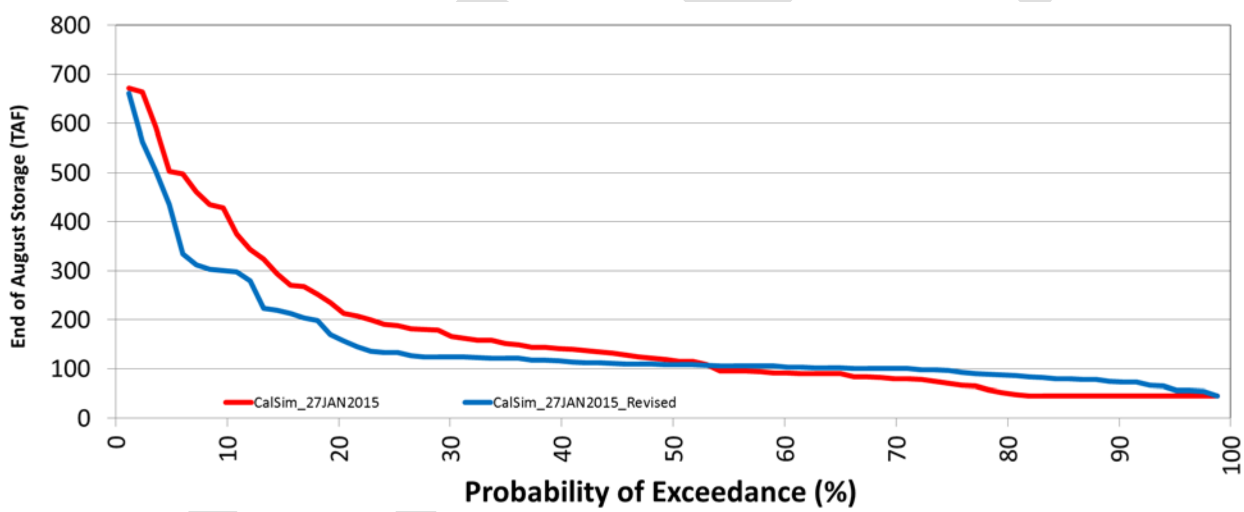


**Figure 17. CVP San Luis end of August storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

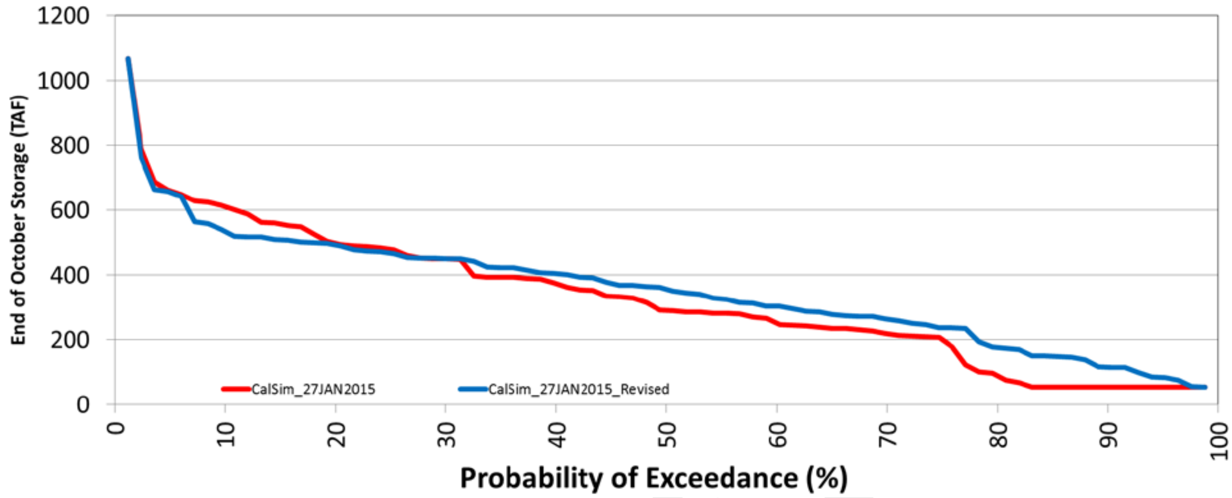


**Figure 18. SWP San Luis end of October storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

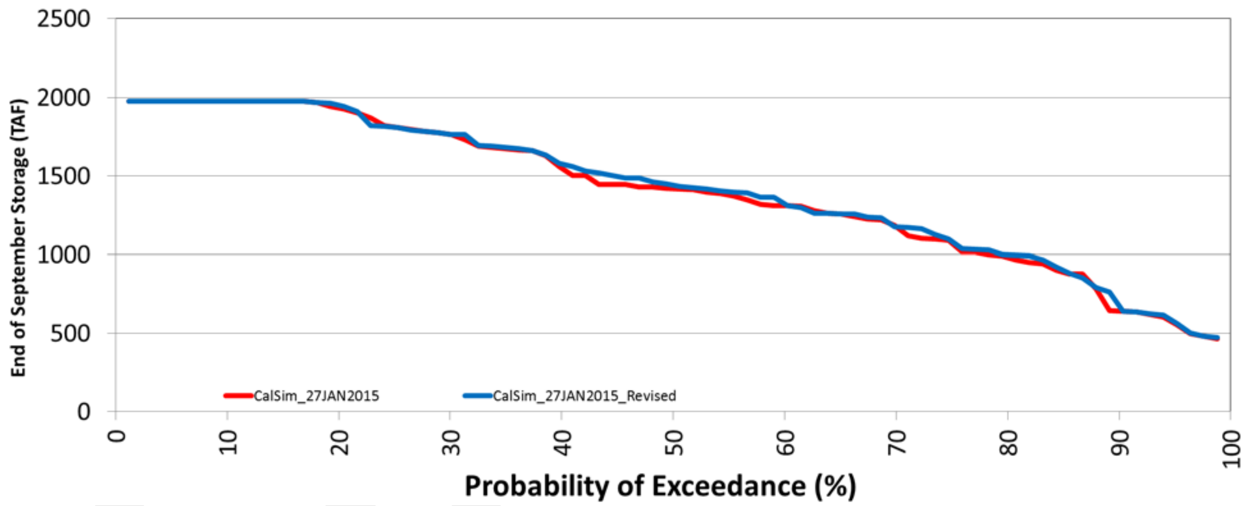


**Figure 19. Trinity carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

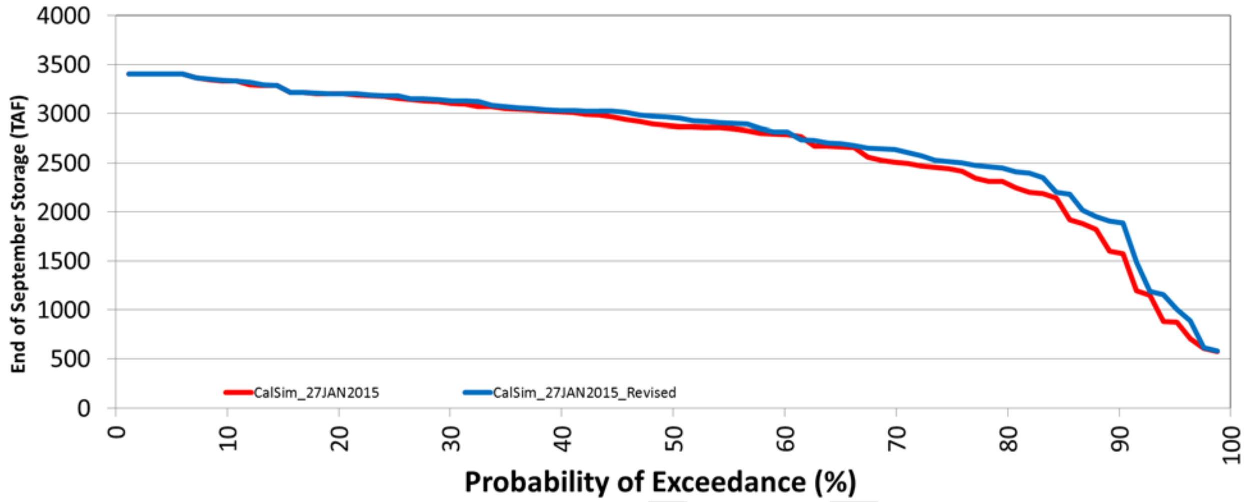


**Figure 20. Shasta carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

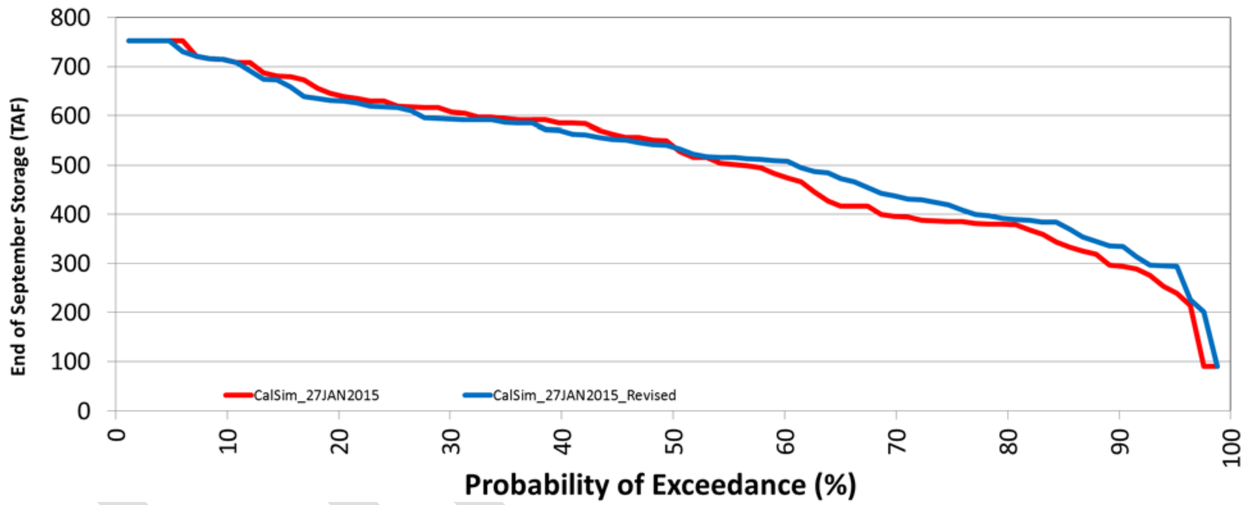


**Figure 21. Folsom carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

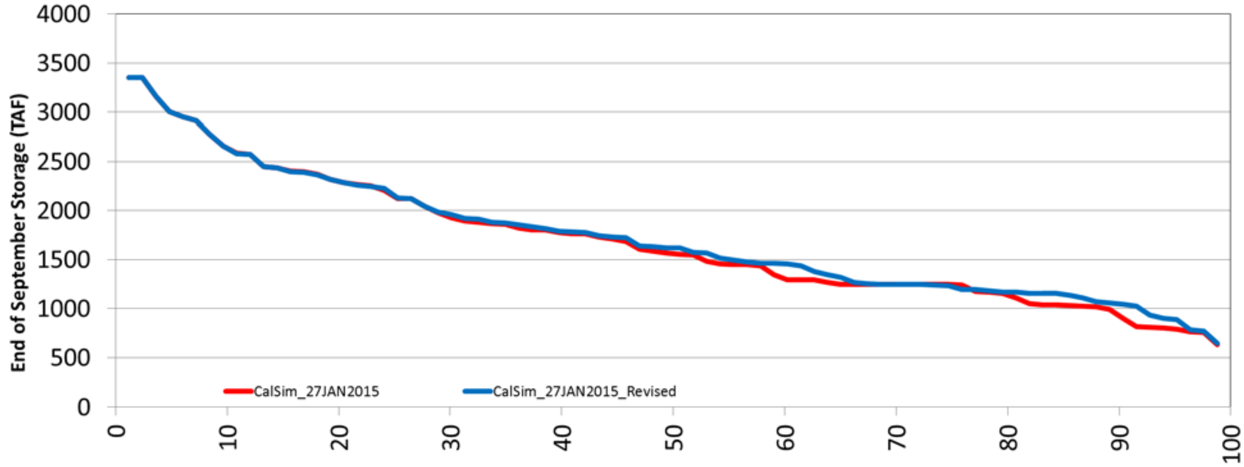


**Figure 22. Oroville carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

Significant changes in project reservoir operations necessarily affect project deliveries. Table 5 and Table 6 quantify the difference in CVP NOD and SOD project deliveries by month and water year type. Overall, CVP NOD project deliveries increased by 13 TAF, whereas CVP SOD project deliveries decreased by 25 TAF.

**Table 5. Change in total CVP NOD project deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| AN | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 8 |
| BN | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 7 | 8 | 7 | 3 | 34 |
| D | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 4 | 3 | 1 | 16 |
| C | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 10 |
| All | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 1 | 13 |

**Table 6. Change in total CVP SOD project deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | -2 | -1 | -2 | -3 | -4 | 2 | -3 | -3 | -5 | -6 | 11 | -2 | -18 |
| AN | -3 | -2 | -3 | -5 | -5 | 4 | -4 | -5 | -8 | -10 | 3 | -2 | -41 |
| BN | 0 | 0 | 0 | -1 | -1 | 9 | 8 | 9 | 14 | 18 | 13 | 4 | 73 |
| D | 0 | 0 | 0 | 0 | 0 | 1 | -6 | -8 | -13 | -16 | -9 | -4 | -57 |
| C | -1 | -1 | -1 | -2 | -2 | -4 | -7 | -12 | -17 | -22 | -13 | -6 | -89 |
| All | -1 | -1 | -1 | -2 | -2 | 2 | -2 | -4 | -6 | -7 | 2 | -2 | -25 |

Table 7 through Table 9 quantify the difference in SWP Table A, Article 56, and Article 21 project deliveries by month and water year type. Overall, Table A deliveries decreased 44 TAF, Article 56 deliveries increased 7 TAF, and Article 21 deliveries decreased 11 TAF. It is expected that reduced Table A allocations would result in fewer Article 56 requests. The reason for higher Article 56 deliveries is that the improved San Luis operation results in fewer Article 56 shortages.

**Table 7. Change in SWP Table A deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | -2 | 6 | -2 | 1 | -3 | 11 | -10 | -11 | -11 | -8 | -7 | -6 | -41 |
| AN | 21 | -10 | -25 | 1 | 0 | 1 | -12 | -13 | -15 | -16 | -16 | -12 | -97 |
| BN | 0 | -3 | -14 | 8 | -6 | -6 | -4 | -3 | -1 | 0 | 0 | 0 | -30 |
| D | -9 | -6 | -40 | 1 | 1 | 2 | 15 | 9 | 7 | 6 | 14 | 14 | 13 |
| C | 10 | 7 | -6 | 0 | 0 | -1 | -1 | -18 | -30 | -39 | -38 | 17 | -97 |
| All | 2 | 0 | -16 | 2 | -2 | 3 | -3 | -6 | -9 | -9 | -7 | 2 | -44 |

**Table 8. Change in SWP Article 56 deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 0 | 0 | 0 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| AN | 0 | 0 | 0 | -4 | -2 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | -7 |
| BN | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| D | 0 | 0 | 0 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| C | 0 | 0 | 0 | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| All | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |

**Table 9. Change in SWP Article 21 deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 0 | 0 | 0 | -7 | -6 | 7 | -2 | 0 | 0 | 0 | 1 | 0 | -7 |
| AN | 0 | 0 | -1 | -2 | -1 | -1 | 0 | 0 | 0 | 0 | 1 | 0 | -4 |
| BN | 0 | 0 | 0 | 0 | -1 | -25 | 0 | 0 | 0 | 0 | 0 | 0 | -25 |
| D | 0 | 0 | 0 | 0 | -4 | -2 | 0 | 0 | 0 | 0 | 1 | 0 | -6 |
| C | 0 | 0 | 0 | 0 | -14 | -7 | 0 | 0 | 0 | 0 | 0 | 0 | -20 |
| All | 0 | 0 | 0 | -2 | -5 | -4 | -1 | 0 | 0 | 0 | 1 | 0 | -11 |

Table 10 quantifies the difference in Feather River Settlement Contractor fall rice decomposition deliveries by month and water year type. The annual average difference between the CalSim_27JAN2015_Revised and CalSim_27JAN2015 is 8 TAF. CalSim meets less than the rice decomposition demand when Oroville storage drops below 1.2 MAF. Since CalSim_27JAN2015_Revised maintains higher Oroville storage than CalSim_27JAN2015, the revised study is able to meet more of the rice decomposition demand annually.

**Table 10. Change in Feather River Settlement Contractor rice decomposition deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| AN | -2 | -2 | -1 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -6 |
| BN | 4 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| D | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| C | 4 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| All | 2 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |

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# Attachment A

## CalSim II Assumptions for Future No Action Conditions

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| | Period of Simulation: 82 years (1922-2003) |
|---|---|
| | **Future Level Study** |
| **HYDROLOGY** | |
| **Level of Development** | 2020 Level, *DWR Bulletin 160-98*[1] |
| Sacramento River Region Demands | |
| CVP | Land use based, limited by full contract |
| SWP (FRSA) | Land use based, limited by full contract |
| Non-Project | Land use based |
| Woodland-Davis Clean Water Agency | Included |
| Antioch | Pre-1914 water right |
| CVP Refuges | Firm Level 2 water needs |
| American River Basin Demands | |
| Water rights | 2020 Level |
| CVP | 2020 Level, full contracts including Freeport Regional Water Project and Sacramento River Water Reliability Project |
| San Joaquin River Basin Demands | |
| Friant Unit | Limited by contract amounts, based on current allocation policy |
| Lower Basin | Land use based with district level operations and constraints |
| Stanislaus River Basin[2] | Land use based, with New Melones Interim Operations Plan and NMFS biological opinion (June 2009), Actions 3.1.2 and 3.1.3[5] |
| South of Delta Demands | |
| CVP | Full contract |
| Contra Costa Water District | 195 taf/yr |
| SWP (with North Bay Aqueduct) | 4.1 maf/yr |
| SWP Article 21 Demand | Metropolitan Water District of Southern California up to 200 taf/month (Dec-Mar), KCWA demand up to 180 taf/month and others up to 34 taf/month |
| **FACILITIES** | |
| Red Bluff Diversion Dam | Fish Passage Improvement Project in place with 2,500 cfs capacity |
| Freeport Regional Water Project | Included with diversions to EBMUD |
| Banks Pumping Capacity | Physical capacity is 10,300 cfs, 6,680 cfs permitted capacity up to 8,500 cfs (Dec 15th–Mar 15th) depending on Vernalis flow conditions[3] additional capacity of 500 cfs (up to 7,180 cfs) allowed for Jul–Sep for reducing impact of NMFS biological opinion on SWP (Jun 2009), Action 4.2.1[5] |
| Jones Pumping Capacity | Exports up to 4,600 cfs permit capacity in all months |
| Delta-Mendota Canal-California Aqueduct Intertie | Included with 400 cfs capacity |
| Los Vaqueros Reservoir Capacity | 160 taf |
| South Bay Aqueduct | South Bay Aqueduct Enlargement to 430 cfs |
| **REGULATORY STANDARDS** | |
| Trinity River | |
| Minimum Flow below Lewiston Dam | Trinity EIS Preferred Alternative (369-815 taf/yr) |
| Trinity Reservoir End-of-September Minimum Storage | Trinity EIS Preferred Alternative (600 taf as able) |

| | Period of Simulation: 82 years (1922-2003) |
|---|---|
| | **Future Level Study** |
| **Clear Creek** | |
| Minimum Flow below Whiskeytown Dam | Downstream water rights, 1963 Reclamation Proposal to USFWS and NPS, predetermined Central Valley Project Improvement Act 3406(b)(2) flows and NMFS biological opinion (June 2009) Action I.1.1[5] |
| **Upper Sacramento River** | |
| Shasta Lake End-of-September Minimum Storage | NMFS 2004 Winter-run biological opinion (1900 taf), predetermined Central Valley Project Improvement Act 3406(b)(2) flows, and NMFS biological opinion (Jun 2009) Action I.2.1[5] |
| Minimum Flow below Keswick Dam | Flows for SWRCB Water Rights Order 90-5 and 1993 Winter-run biological opinion temperature control, predetermined Central Valley Project Improvement Act 3406(b)(2) flows, and NMFS biological opinion (Jun 2009), Action I.2.2[5] |
| **Feather River** | |
| Minimum Flow below Thermalito Diversion Dam | 2006 Settlement Agreement (700/800 cfs) |
| Minimum Flow below Thermalito Afterbay outlet | 1983 DWR, DFG Agreement (750-1700 cfs) |
| **Yuba River** | |
| Minimum flow below Daguerre Point Dam | D-1644 Operations (Lower Yuba River Accord)[4] |
| **American River** | |
| Minimum Flow below Nimbus Dam | American River Flow Management as required by NMFS biological opinion (Jun 2009), Action 2.1[5] |
| Minimum Flow at H Street Bridge | SWRCB D-893 |
| **Lower Sacramento River** | |
| Minimum Flow near Rio Vista | SWRCB D-1641 |
| **Mokelumne River** | |
| Minimum Flow below Camanche Dam | Federal Energy Regulatory Commission 2916-029, 1996 Joint Settlement Agreement (100 – 325 cfs) |
| Minimum Flow below Woodbridge Diversion Dam | Federal Energy Regulatory Commission 2916-029, 1996 Joint Settlement Agreement (25 – 300 cfs) |
| **Stanislaus River** | |
| Minimum Flow below Goodwin Dam | 1987 Reclamation, DFG agreement, and flows required for NMFS biological opinion (Jun 2009) Actions III.1.2 and III.1.3[5] |
| Minimum Dissolved Oxygen | SWRCB D-1422 |
| **REGULATORY STANDARDS** | |
| **Merced River** | |
| Minimum Flow below Crocker-Huffman Diversion Dam | Davis-Grunsky (180 – 220 cfs, Nov – Mar) and Cowell Agreement |
| Minimum Flow at Shaffer Bridge | Federal Energy Regulatory Commission 2179 (25-100 cfs) |
| **Tuolumne River** | |
| Minimum Flow at Lagrange Bridge | Federal Energy Regulatory Commission 2299-024, 1995 Settlement Agreement (94-301 taf/yr) |
| **San Joaquin River** | |
| San Joaquin River Restoration | Full flows |
| Maximum Salinity near Vernalis | SWRCB D-1641 |
| Minimum Flow near Vernalis | SWRCB D-1641, NMFS biological opinion (Jun 2009), Action 4.2.1[5] |

| | Period of Simulation: 82 years (1922-2003) |
|---|---|
| | **Future Level Study** |
| Sacramento River-San Joaquin River Delta | |
| Delta Outflow Index (Flow and Salinity) | SWRCB D-1641, USFWS biological opinion (Dec 2008), Action 4[5] |
| Delta Cross Channel Gates | SWRCB D-1641, NMFS biological opinion (Jun 2009) Action 4.1.2[5] |
| Delta Exports | SWRCB D-1641, NMFS biological opinion (Jun 2009) Action 4.2.1[5] |
| Combined Flow in Old and Middle River | USFWS biological opinion (Dec 2008), Actions 1–3 and NMFS biological opinion (Jun 2009), Action 4.2.3[5] |
| **OPERATIONS CRITERIA** | |
| **Subsystem** | |
| Upper Sacramento River | |
| Flow Objective for Navigation (Wilkins Slough) | NMFS biological opinion (Jun 2009) Action I.4[5]; 3,250 – 5,000 cfs based on CVP water supply condition |
| American River | |
| Folsom Dam Flood Control | Variable 400/670 without outlet modifications |
| Feather River | |
| Flow at Mouth | Maintain DFG/DWR flow target above Verona or 2800 cfs Apr-Sep, dependent on Oroville inflow and FRSA allocation |
| **System-wide** | |
| CVP Water Allocation | |
| CVP Settlement and Exchange | 100% (75% in Shasta Critical years) |
| CVP Refuges | 100% (75% in Shasta Critical years) |
| CVP Agriculture | 100% - 0% based on supply; additionally limited due to D-1641, USFWS biological opinion (Dec 2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| CVP Municipal & Industrial | 100% - 0% based on supply; additionally limited due to D-1641, USFWS biological opinion (Dec 2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| **OPERATIONS CRITERIA** | |
| **SWP Water Allocation** | |
| North of Delta (FRSA) | Contract specific |
| South of Delta | Based on supply, Monterey Agreement; allocations limited due to D-1641, USFWS biological opinion (Dec2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| CVP/SWP Coordinated Operations | |
| Sharing of Responsibility for In Basin Use | 1986 Coordinated Operations Agreement |
| Sharing of Surplus Flows | 1986 Coordinated Operations Agreement |
| Sharing of Restricted Export Capacity | Equal sharing of export capacity under SWRCB D-1641, USFWS biological opinion (Dec 2008) and NMFS biological opinion (Jun 2009) export restrictions[5] |
| Transfers | |
| Lower Yuba River Accord[6] | Yuba River acquisitions for reducing impact of NMFS biological opinion export restrictions on SWP |

[1] The Sacramento Valley hydrology used in the Future Conditions CalSim II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of future-level projected land-use assumptions are being coordinated with the California Water Plan Update for future models.

[2] The CalSim II model representation for the Stanislaus River does not necessarily represent Reclamation's current or future operational policies. A suitable plan for supporting flows has not been developed for NMFS biological opinion (Jun 2009), Action 3.1.3.

[3] Current US Army Corps of Engineers permit for Harvey O. Banks Pumping Plant allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during Dec 15th–Mar 15th up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.

[4] D-1644 and the Lower Yuba River Accord are assumed to be implemented for Future Conditions. The Yuba River is not dynamically modeled in CalSim II. Yuba River hydrology and availability of water acquisitions under the Lower Yuba River Accord are based on modeling performed and provided by the Lower Yuba River Accord EIS/EIR study team.

[5] In cooperation with USBR, NMFS, USFWS, and DGF, the DWR has developed assumptions for implementation of the USFWS biological opinion (December 15, 2008) and NMFS biological opinion (June 4, 2009) in CalSim II.

[6] Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks Pumping Plant during Jul–Sep, are assumed to be used to reduce as much of the effect of the April–May Delta export actions on SWP contractors as possible.

# San Luis Low Point Improvement Project Environmental Impact Statement / Environmental Impact Report

## Appendix B: Attachment B, Comparison of Future No Action Conditions and Project Alternatives at Future LOD

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**Figure 1: Comparison of Trinity Storage for Lower San Felipe Intake Alternative**

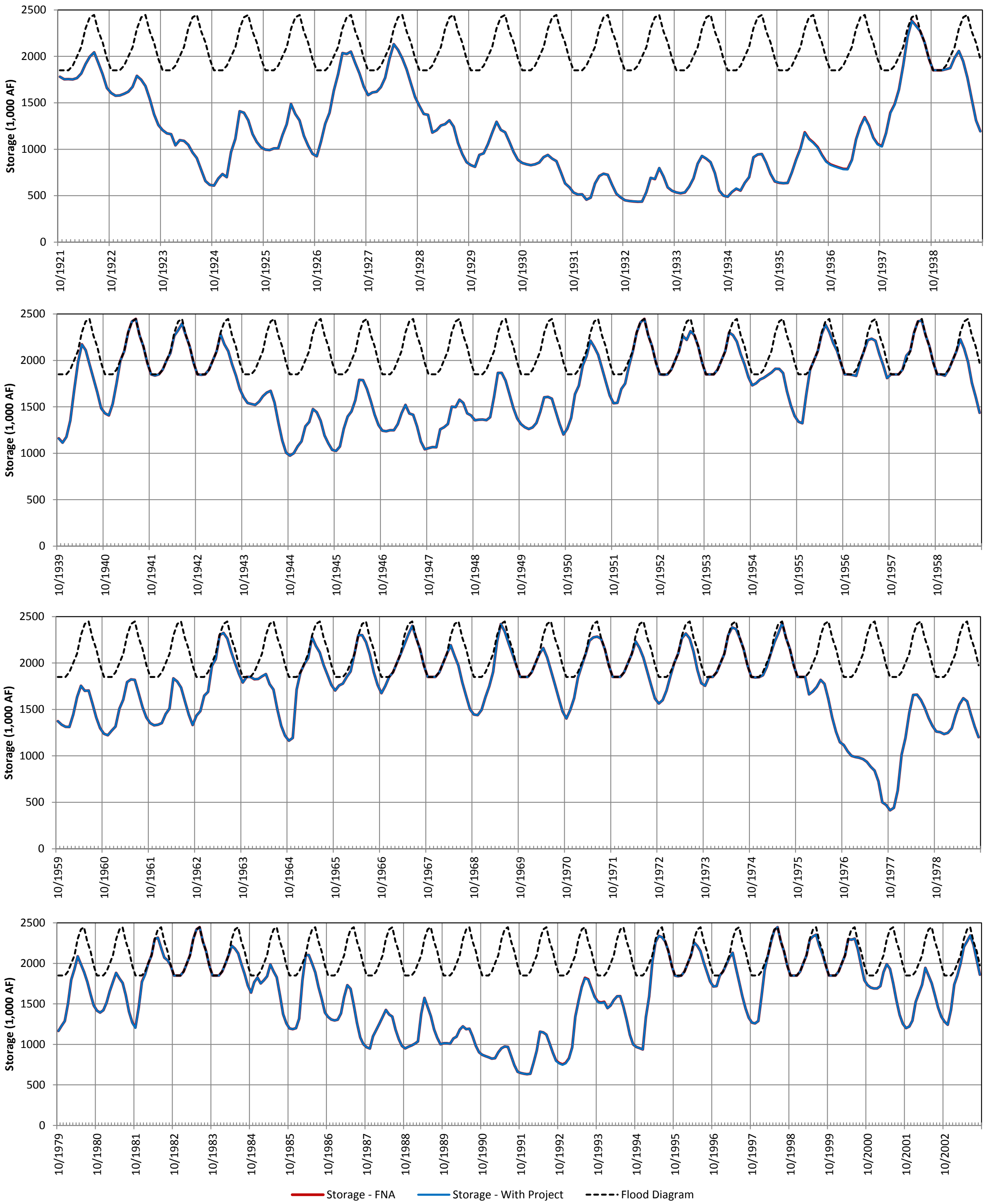


**Figure 2: Comparison of Shasta Storage for Lower San Felipe Intake Alternative**

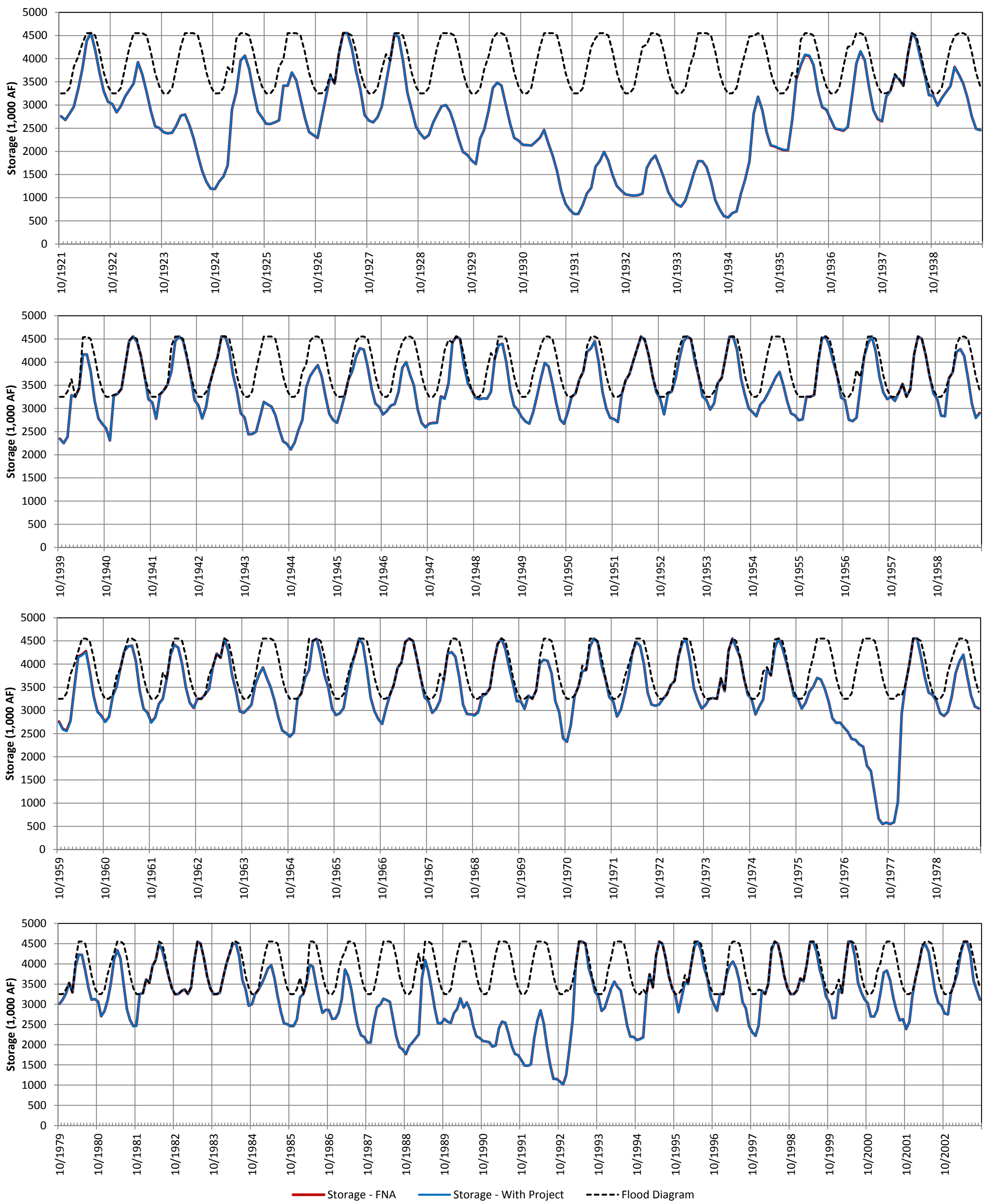


**Figure 3: Comparison of Folsom Storage for Lower San Felipe Intake Alternative**

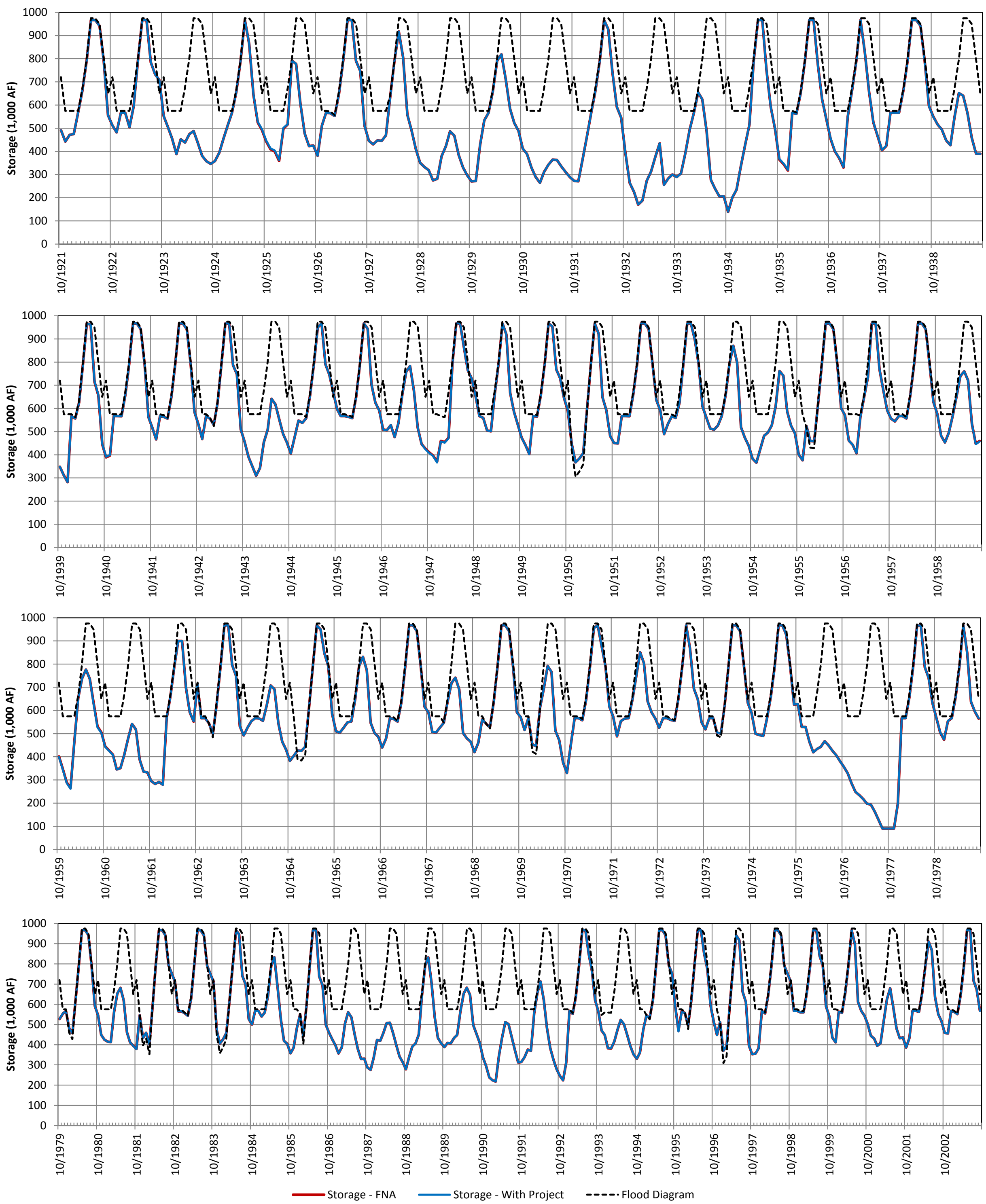


**Figure 4: Comparison of Oroville Storage for Lower San Felipe Intake Alternative**

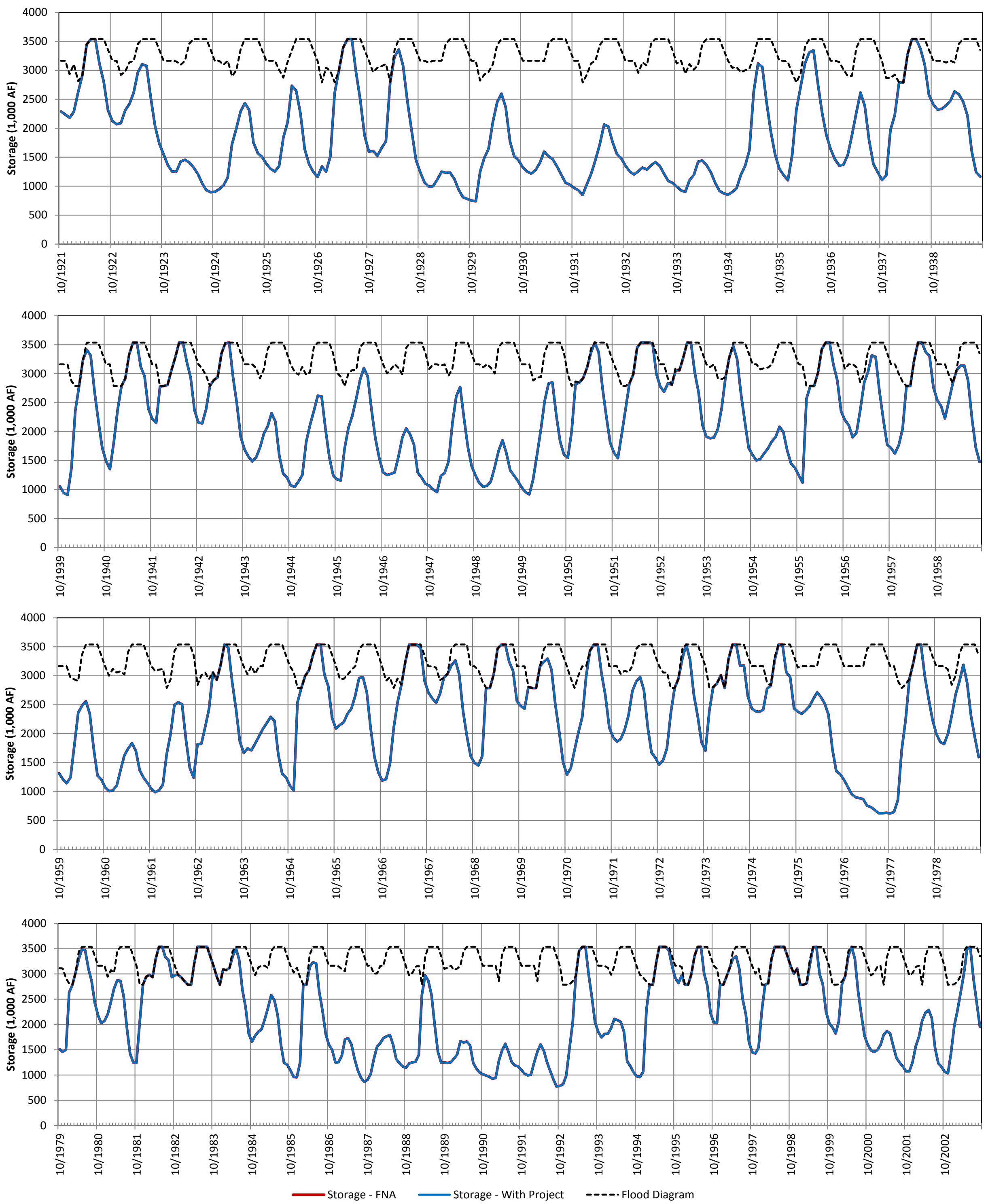


**Figure 5: Comparison of Sacramento River below Keswick Flow for Lower San Felipe Intake Alternative**

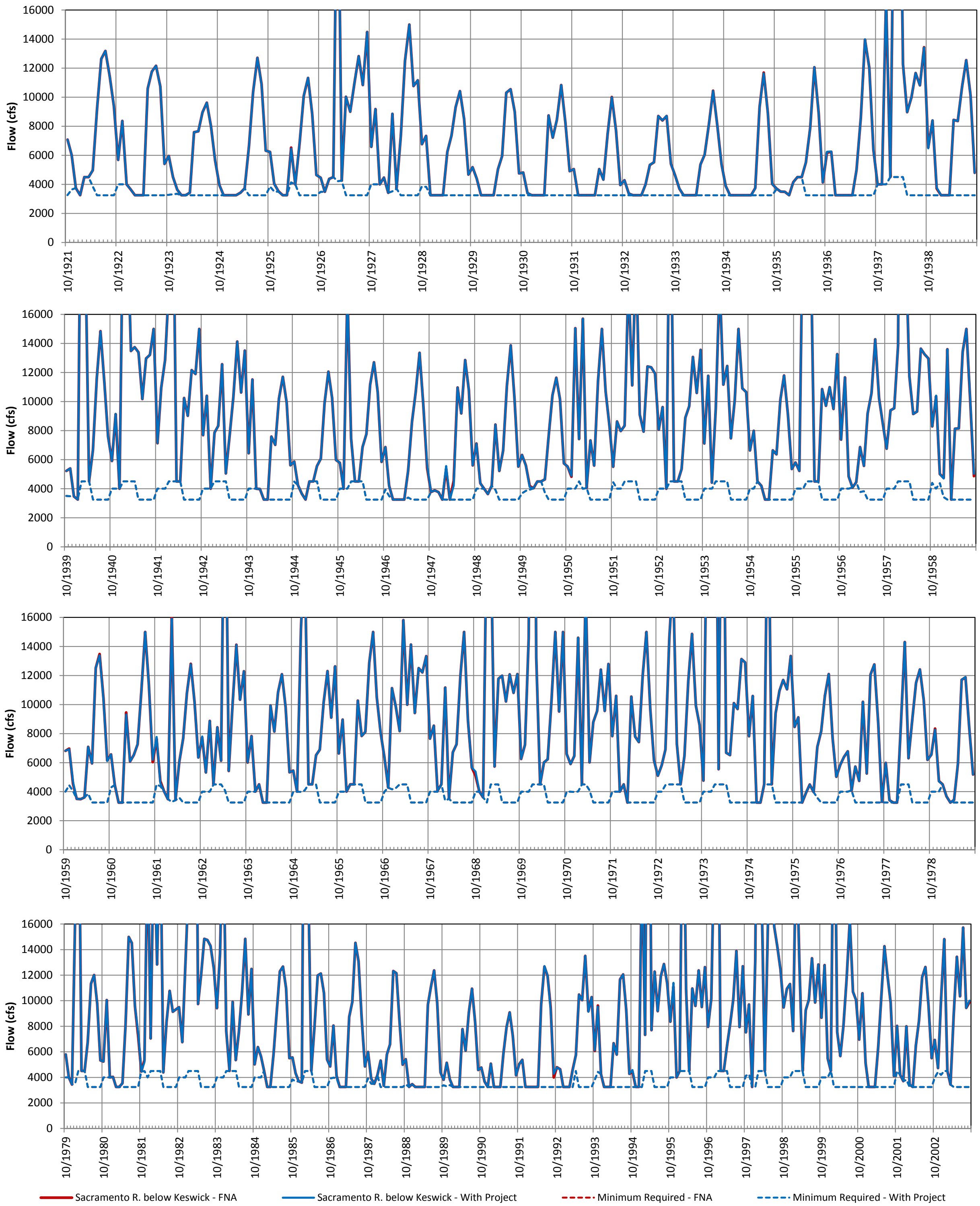


**Figure 6: Comparison of Sacramento River at Wilkins Slough Flow for Lower San Felipe Intake Alternative**

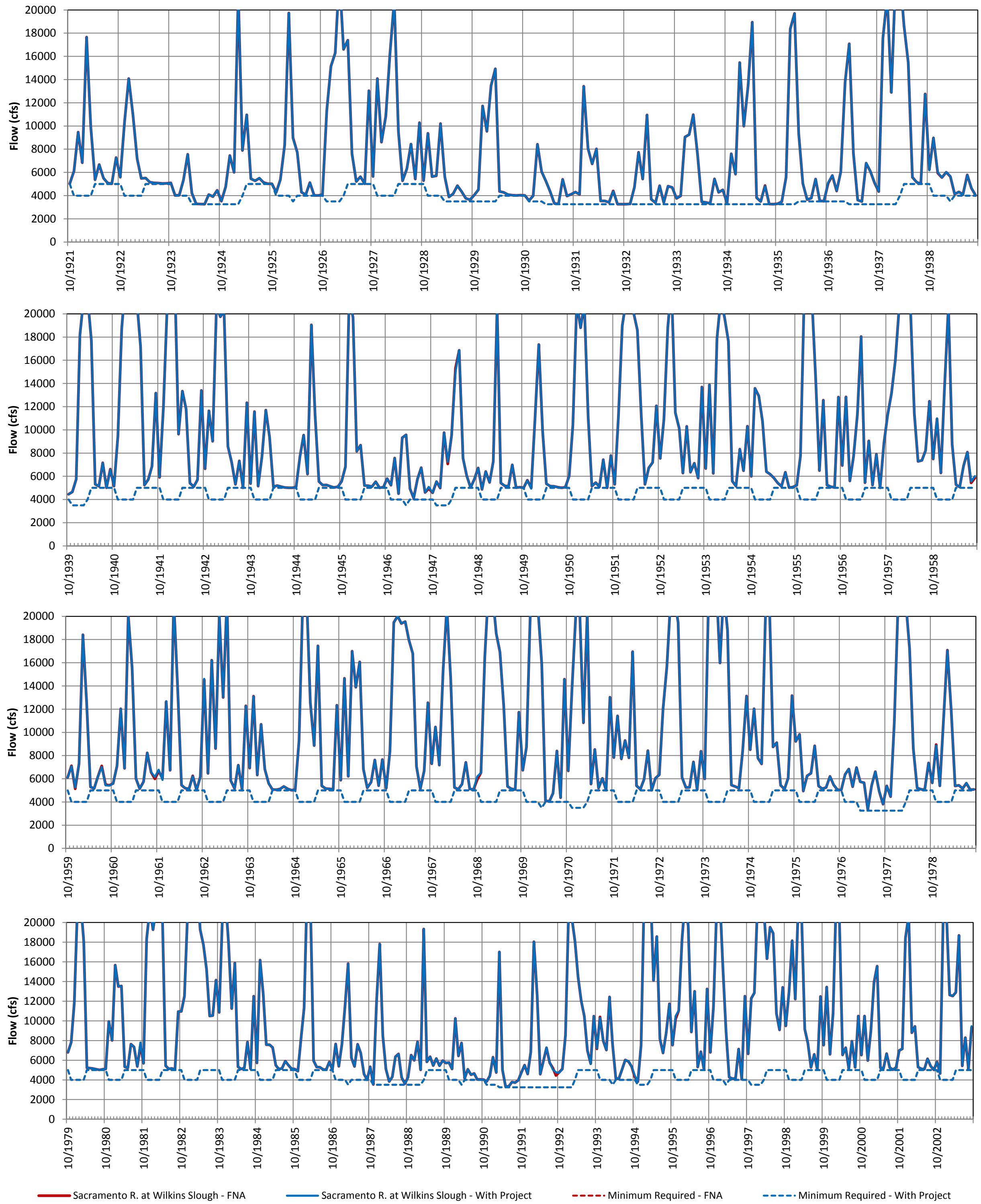


**Figure 7: Comparison of American River below Nimbus Flow for Lower San Felipe Intake Alternative**

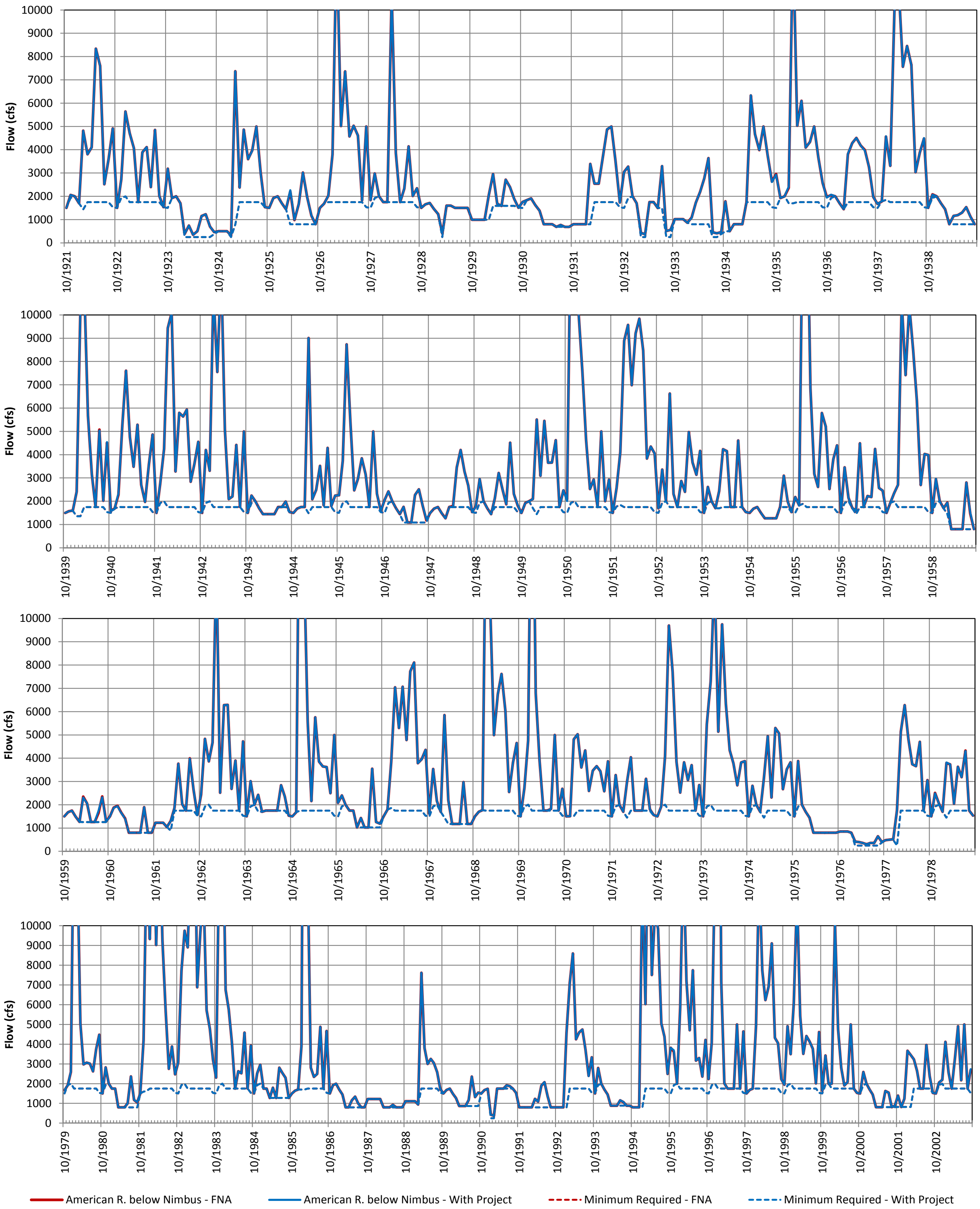


**Figure 8: Comparison of Lower Feather River Flow for Lower San Felipe Intake Alternative**

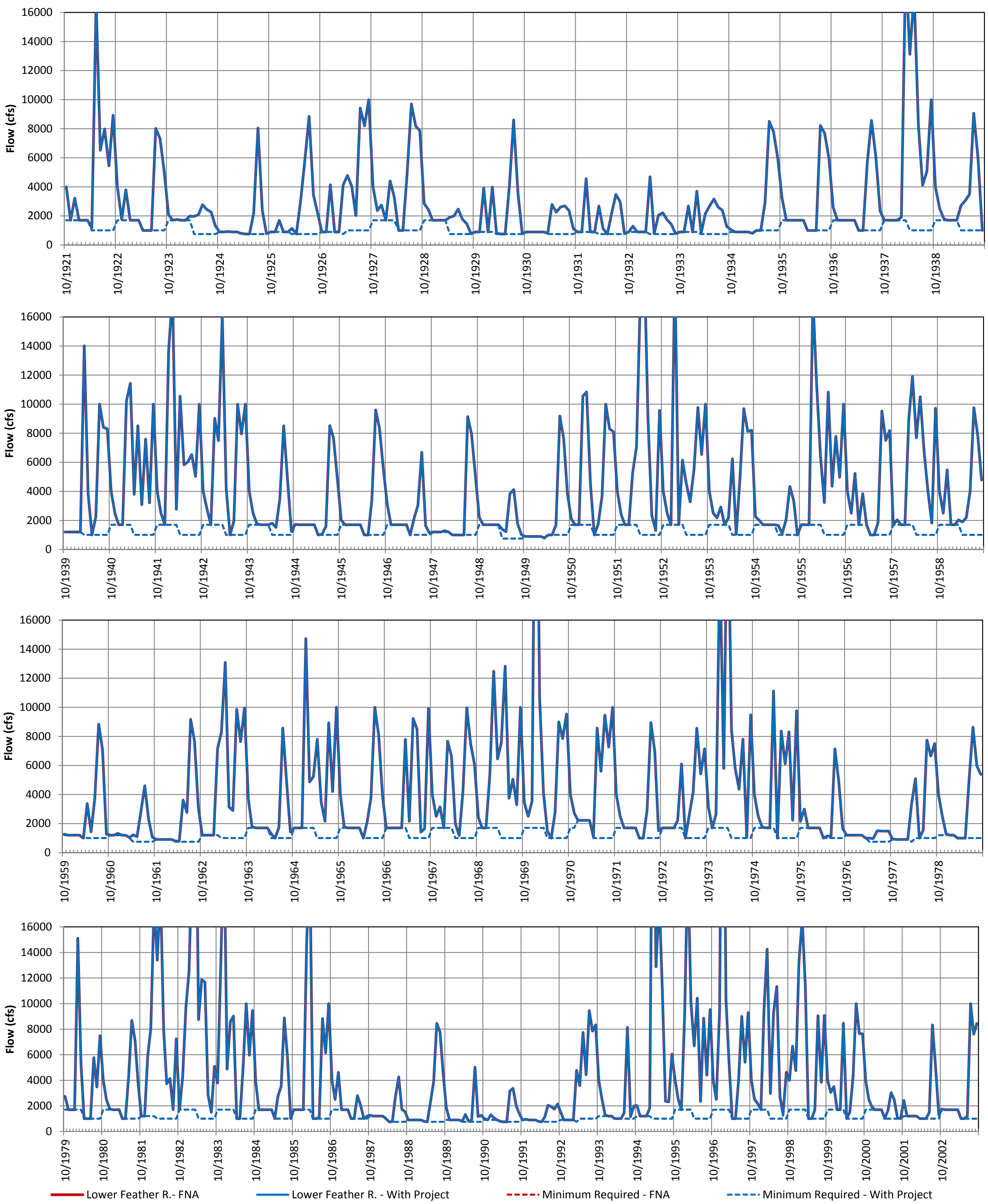


**Figure 9: Comparison of Delta Inflow for Lower San Felipe Intake Alternative**

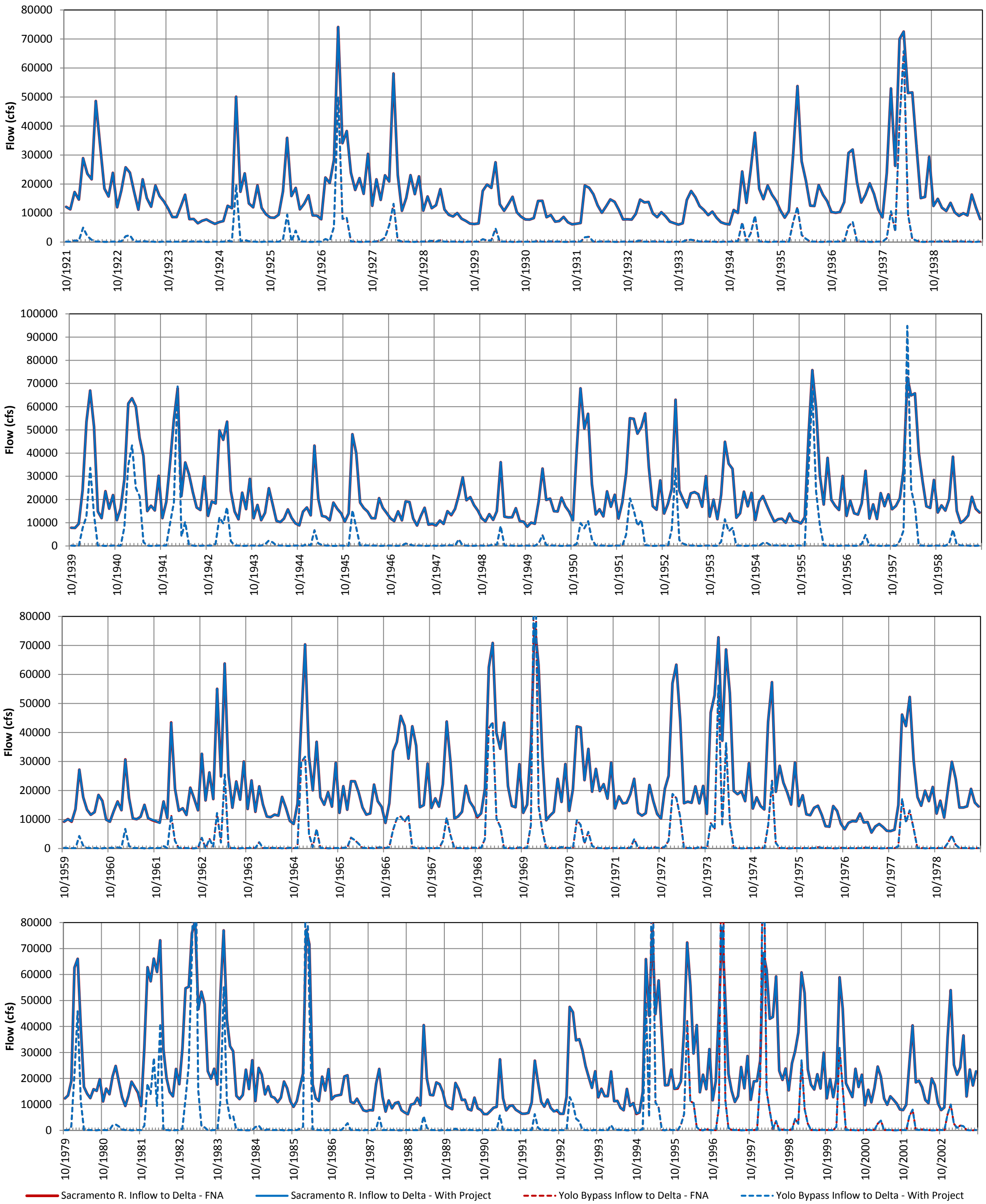


**Figure 10: Comparison of Delta Outflow for Lower San Felipe Intake Alternative**

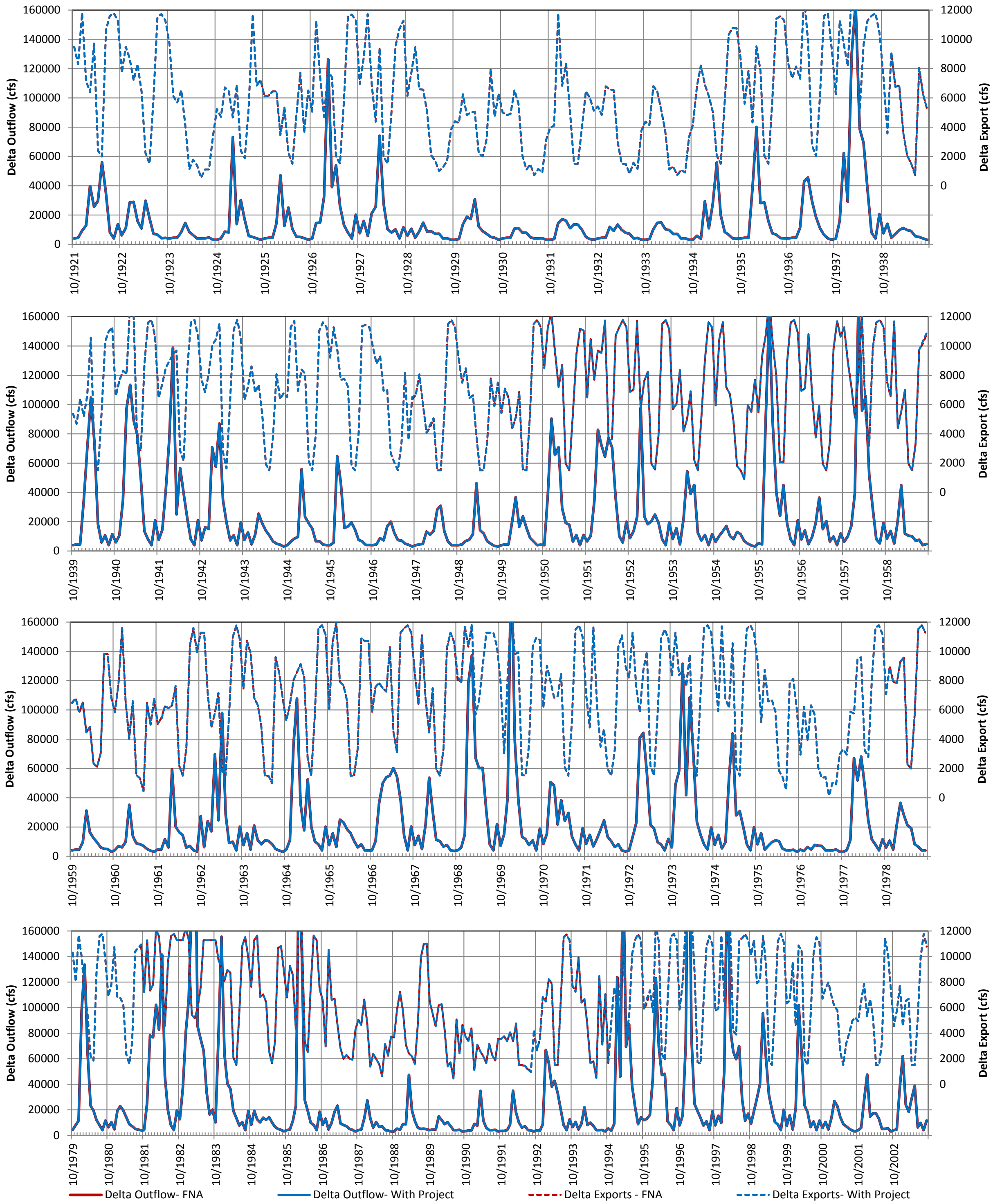


**Figure 11: Comparison of San Luis Reservoir Storage for Lower San Felipe Intake Alternative**

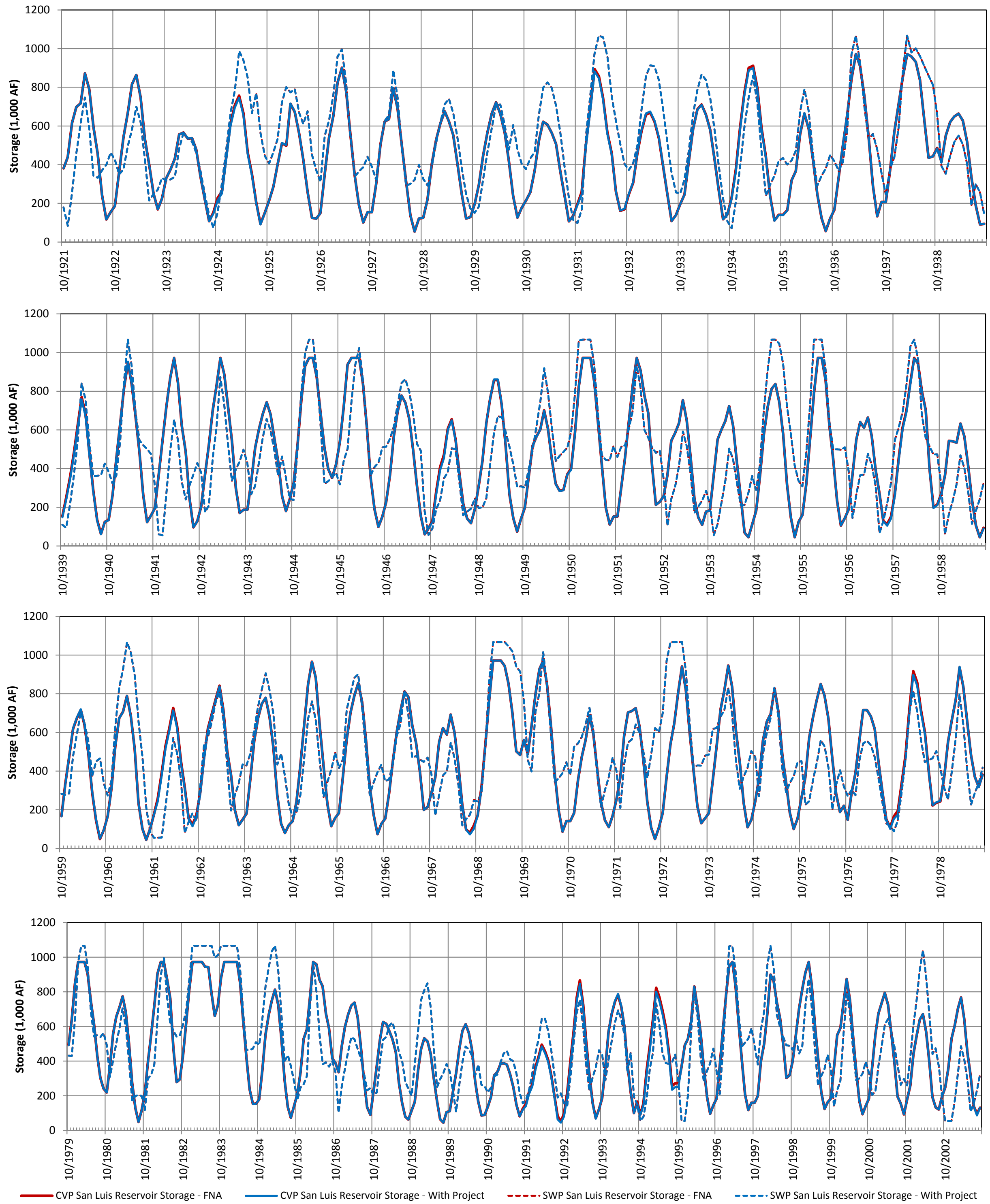


**Figure 12: Comparison of Trinity Storage for San Luis Reservoir Expansion Alternative**

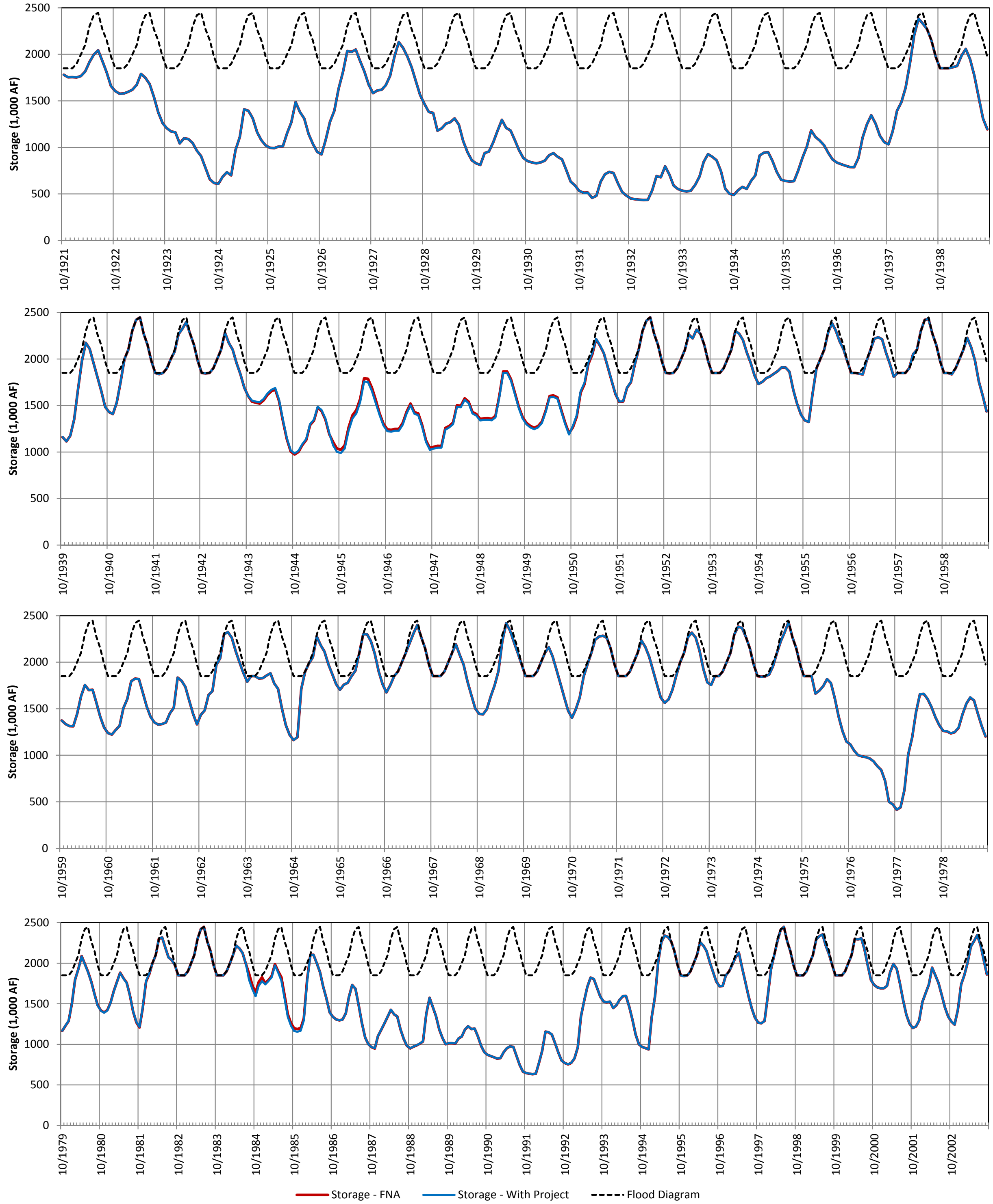


**Figure 13: Comparison of Shasta Storage for San Luis Reservoir Expansion Alternative**

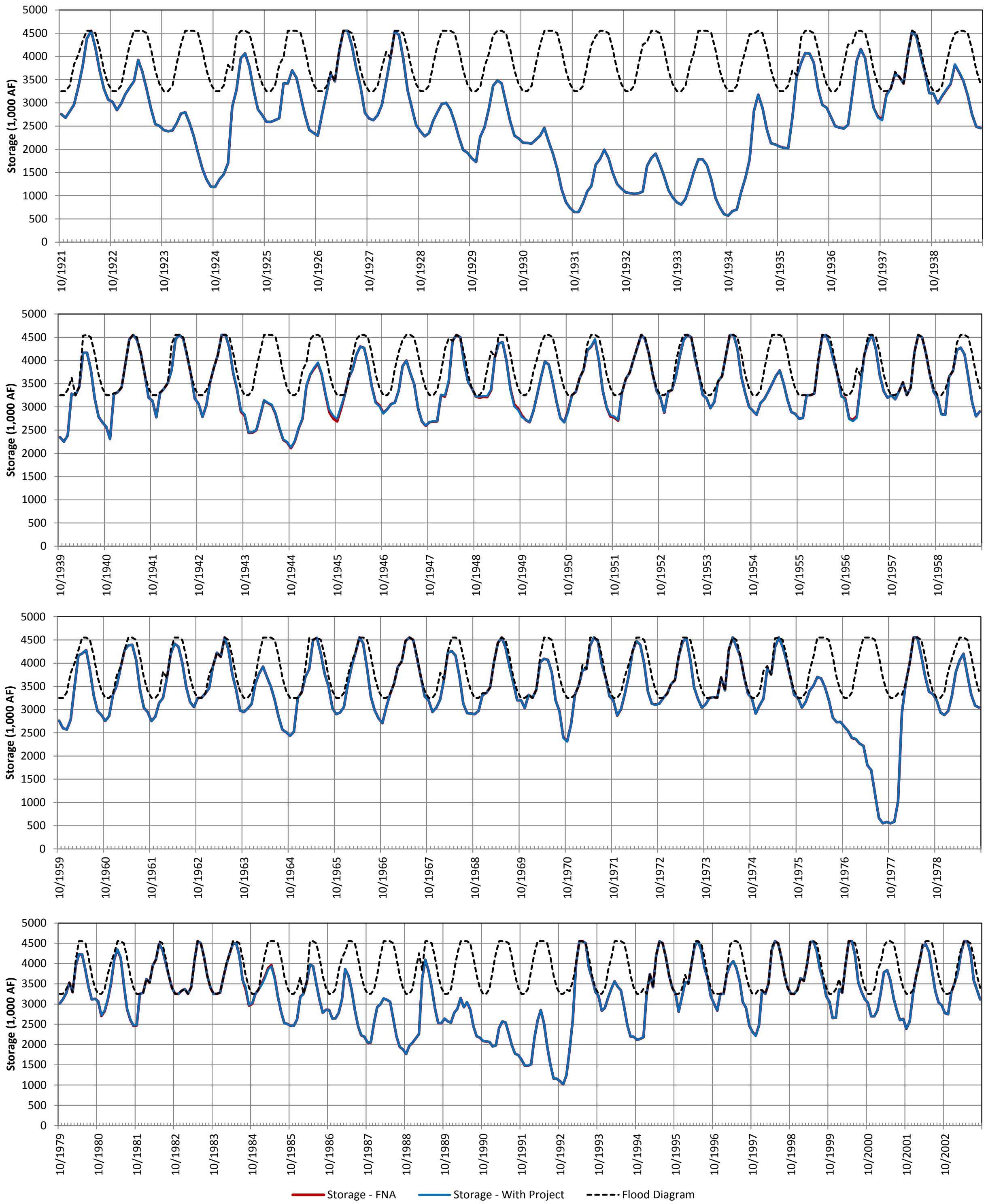


**Figure 14: Comparison of Folsom Storage for San Luis Reservoir Expansion Alternative**

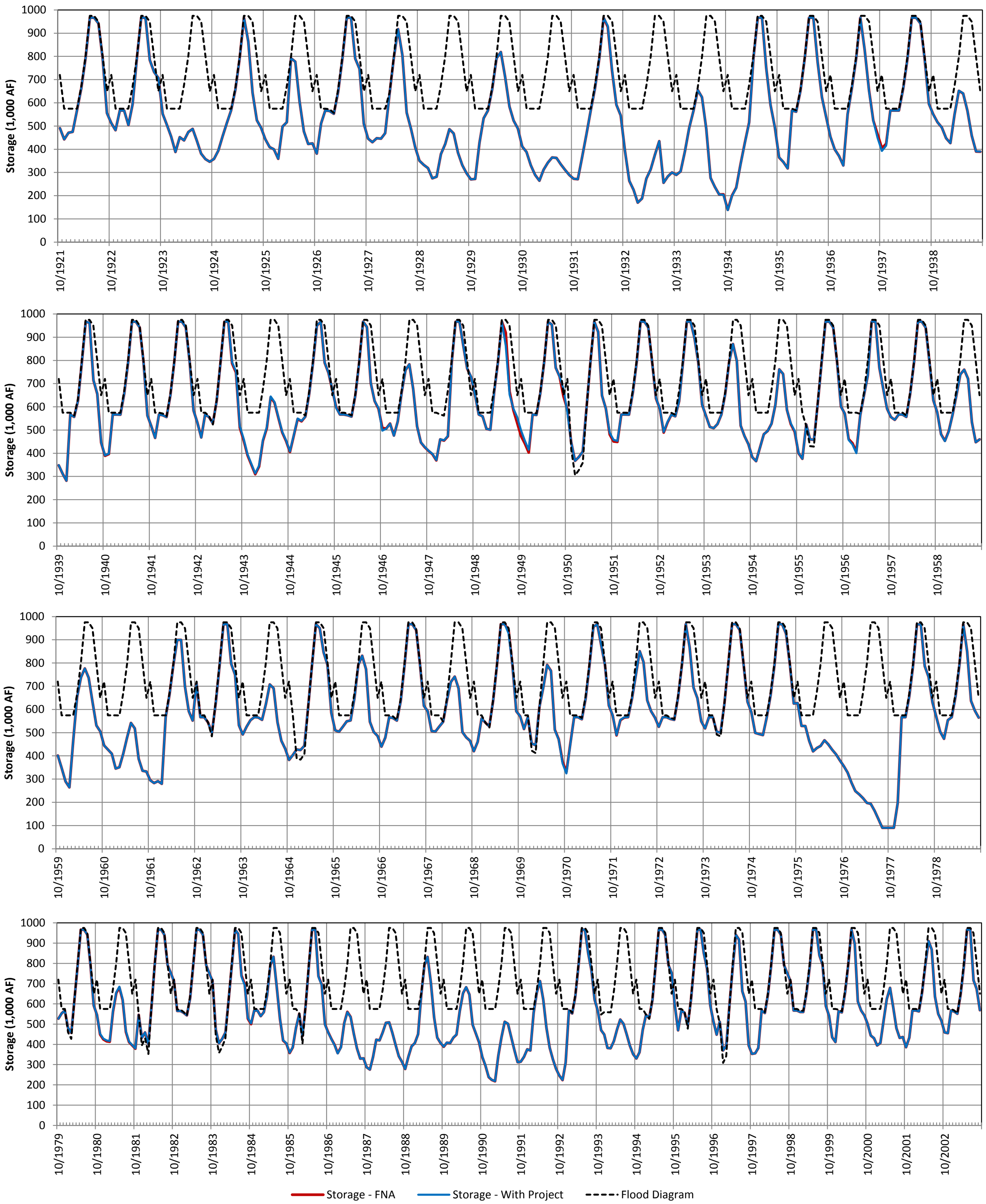


**Figure 15: Comparison of Oroville Storage for San Luis Reservoir Expansion Alternative**

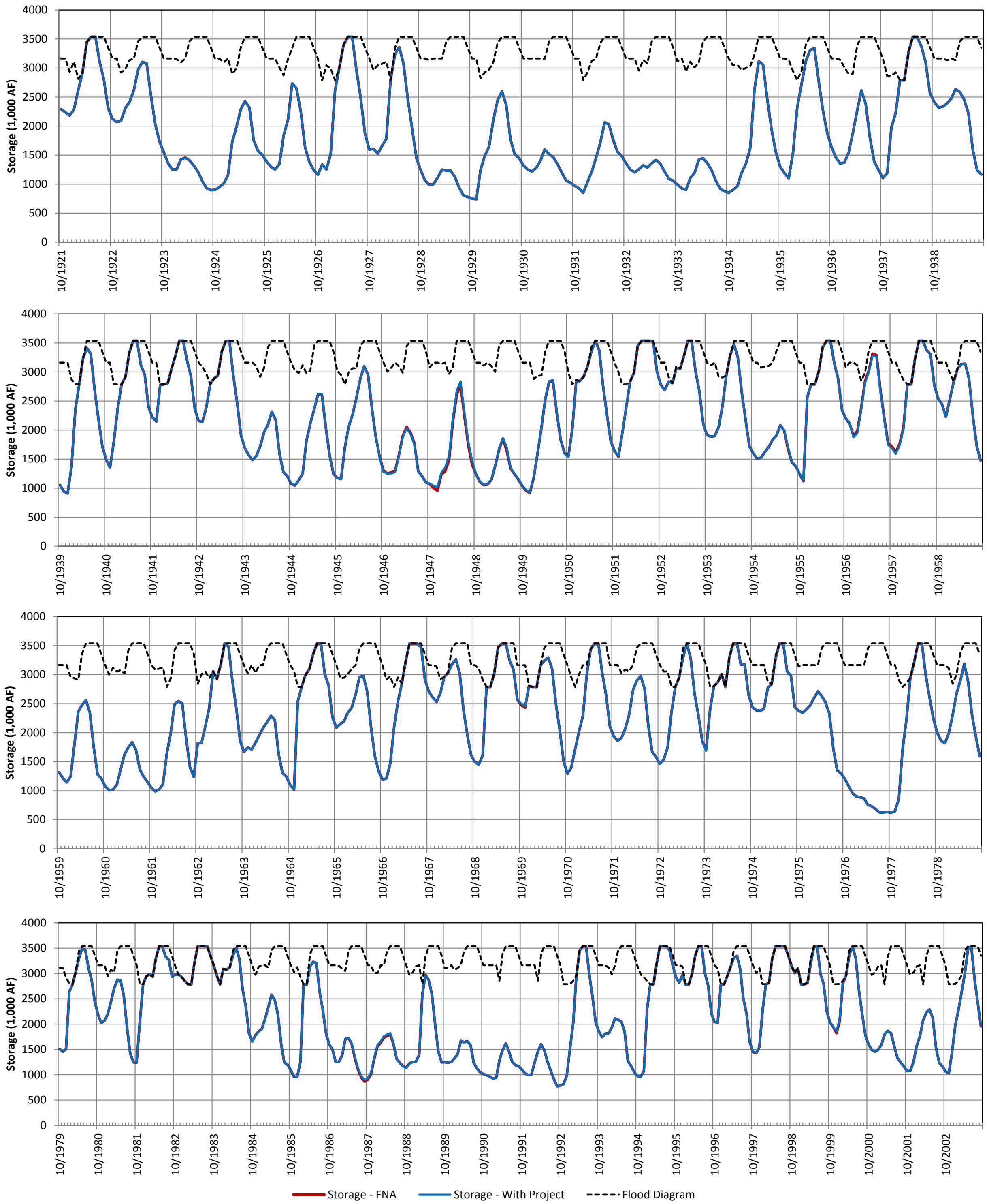


**Figure 16: Comparison of Sacramento River below Keswick Flow for San Luis Reservoir Expansion Alternative**

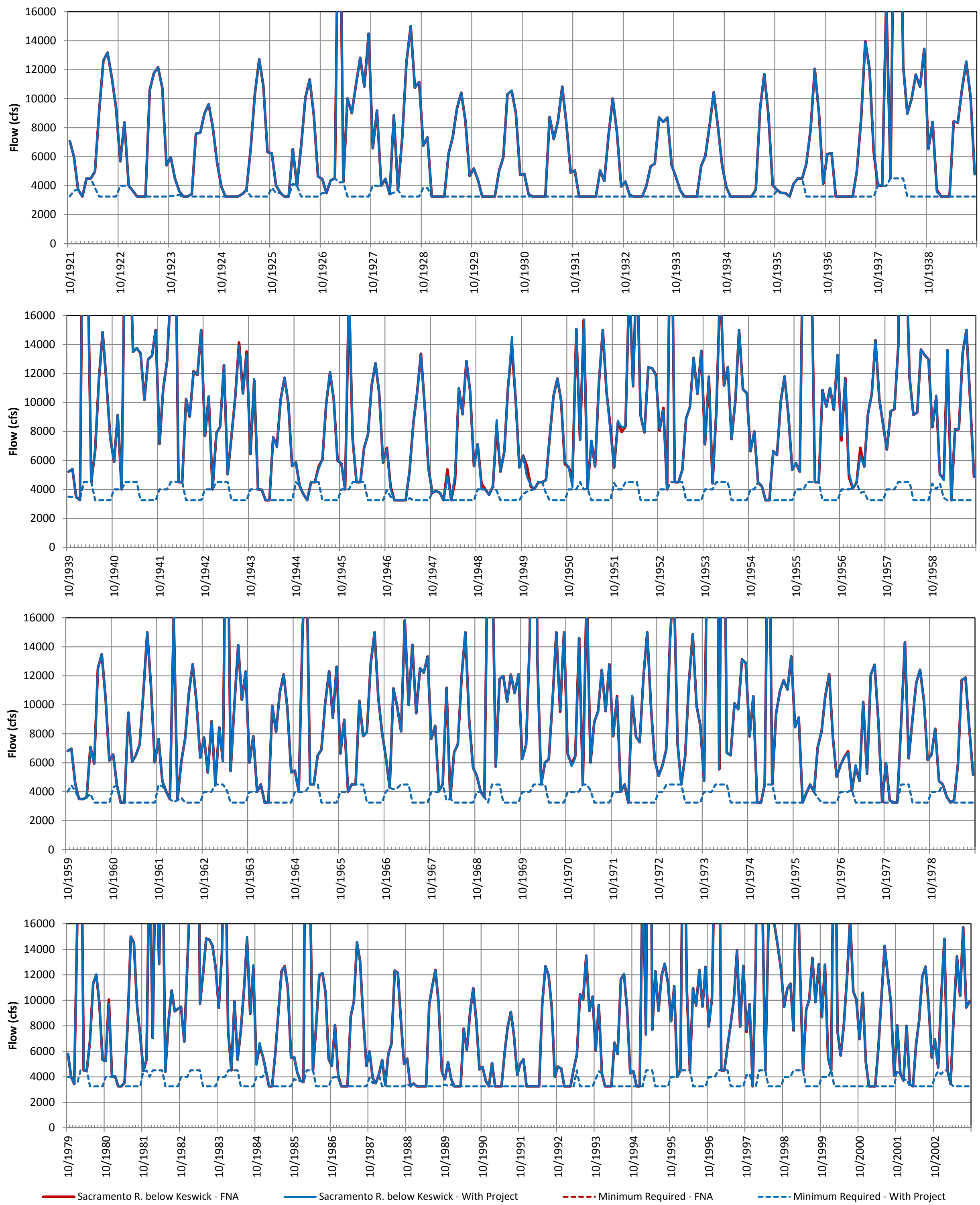


**Figure 17: Comparison of Sacramento River at Wilkins Slough Flow for San Luis Reservoir Expansion Alternative**

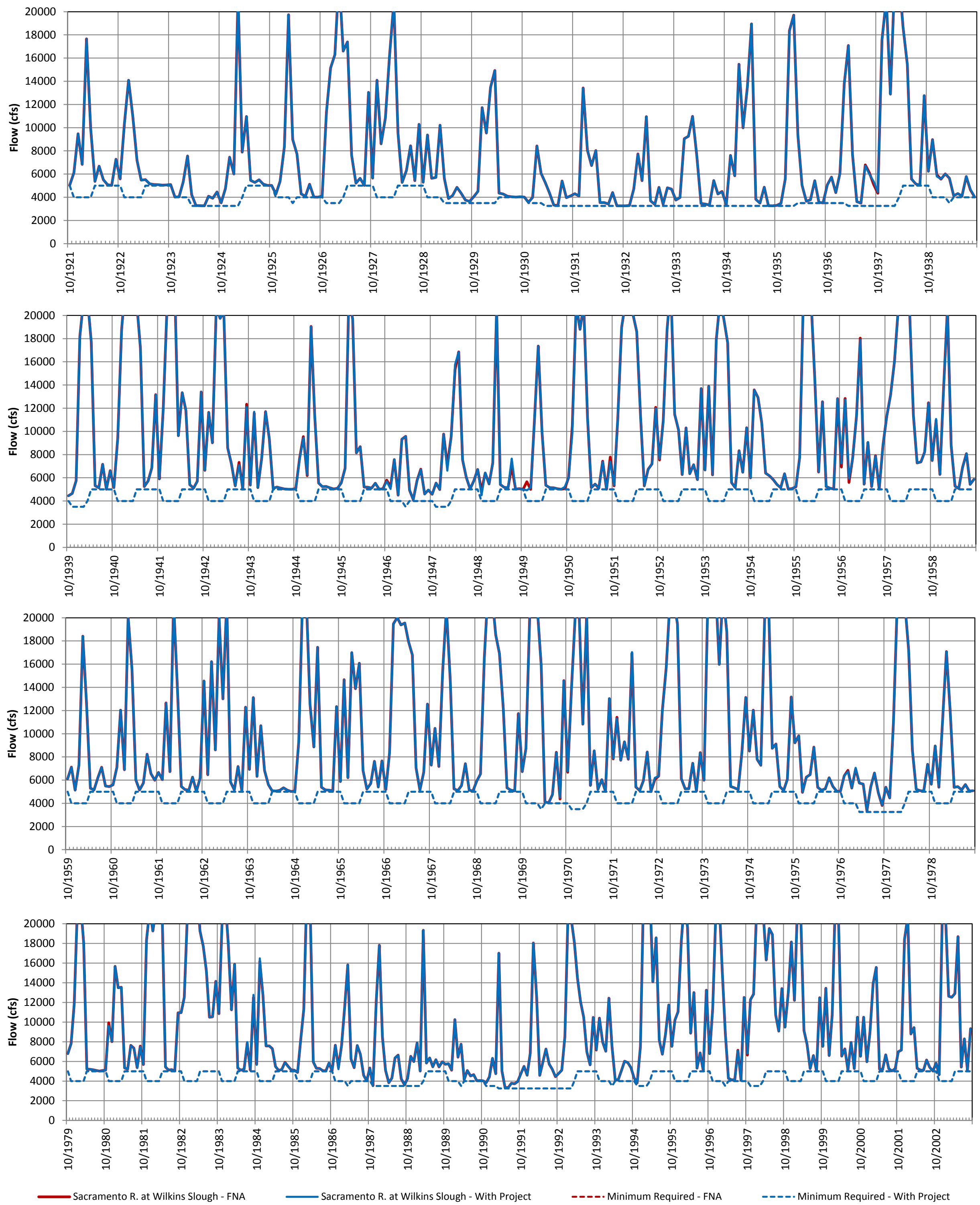


**Figure 18: Comparison of American River below Nimbus Flow for San Luis Reservoir Expansion Alternative**

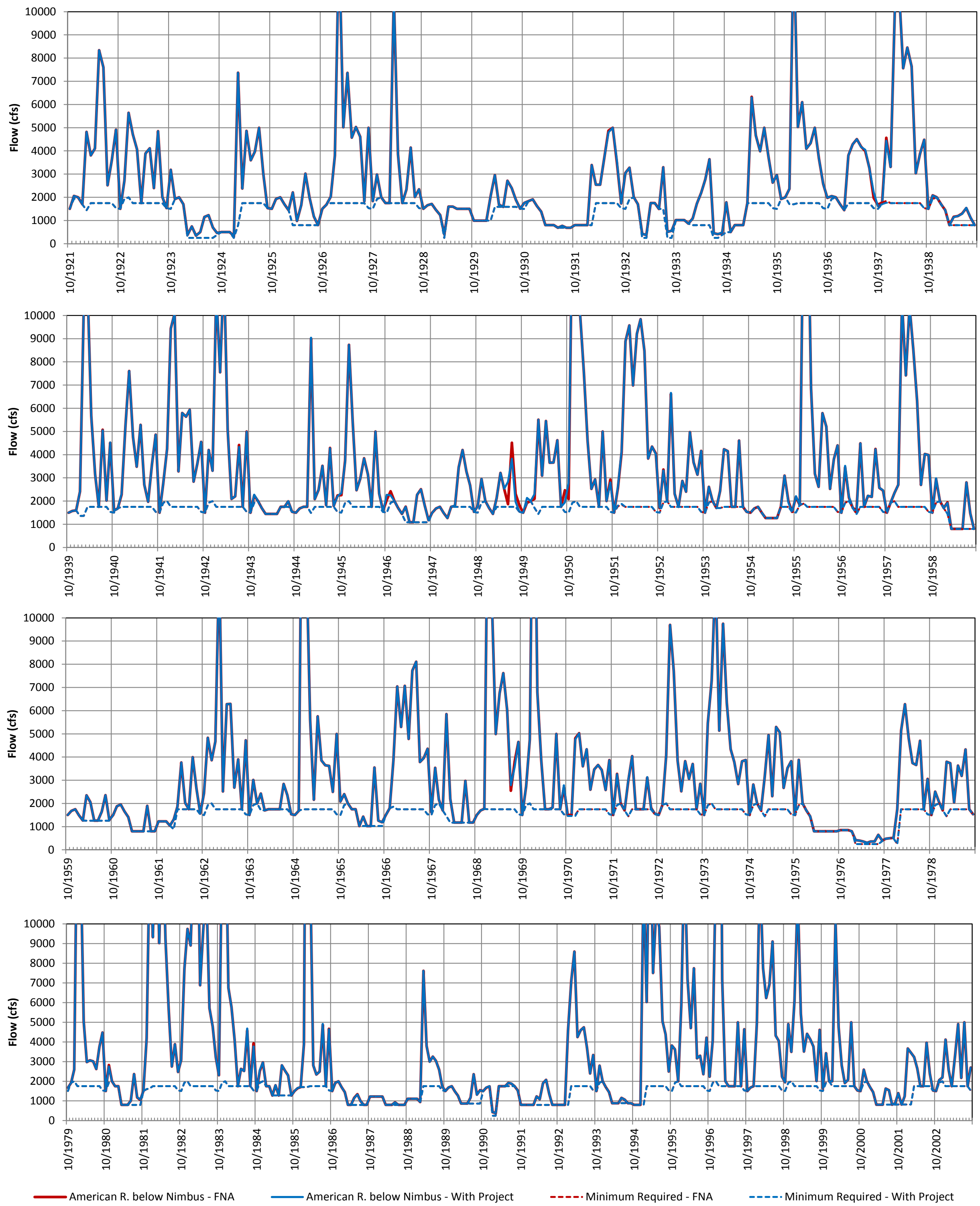


**Figure 19: Comparison of Lower Feather River Flow for San Luis Reservoir Expansion Alternative**

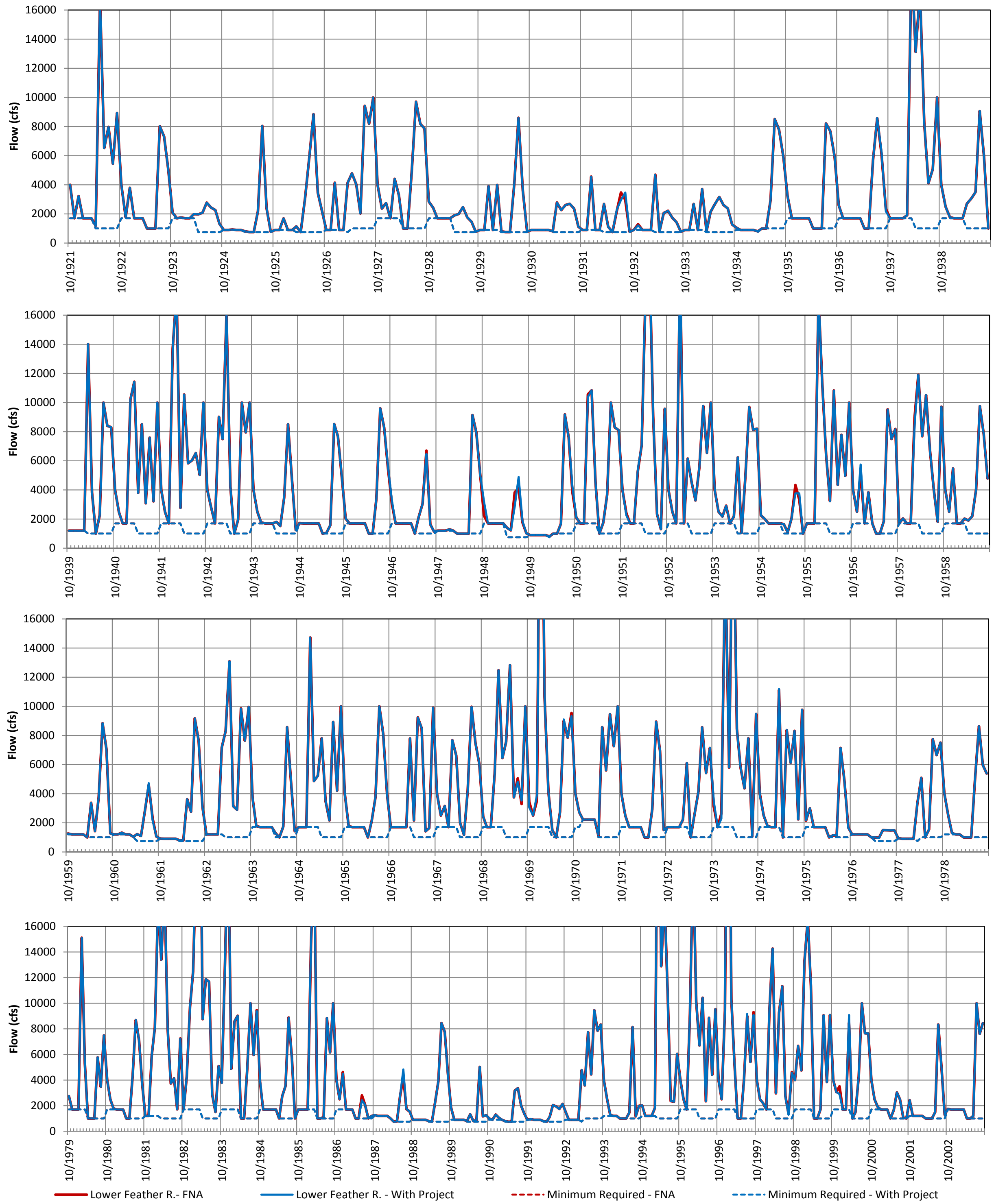


**Figure 20: Comparison of Delta Inflow for San Luis Reservoir Expansion Alternative**

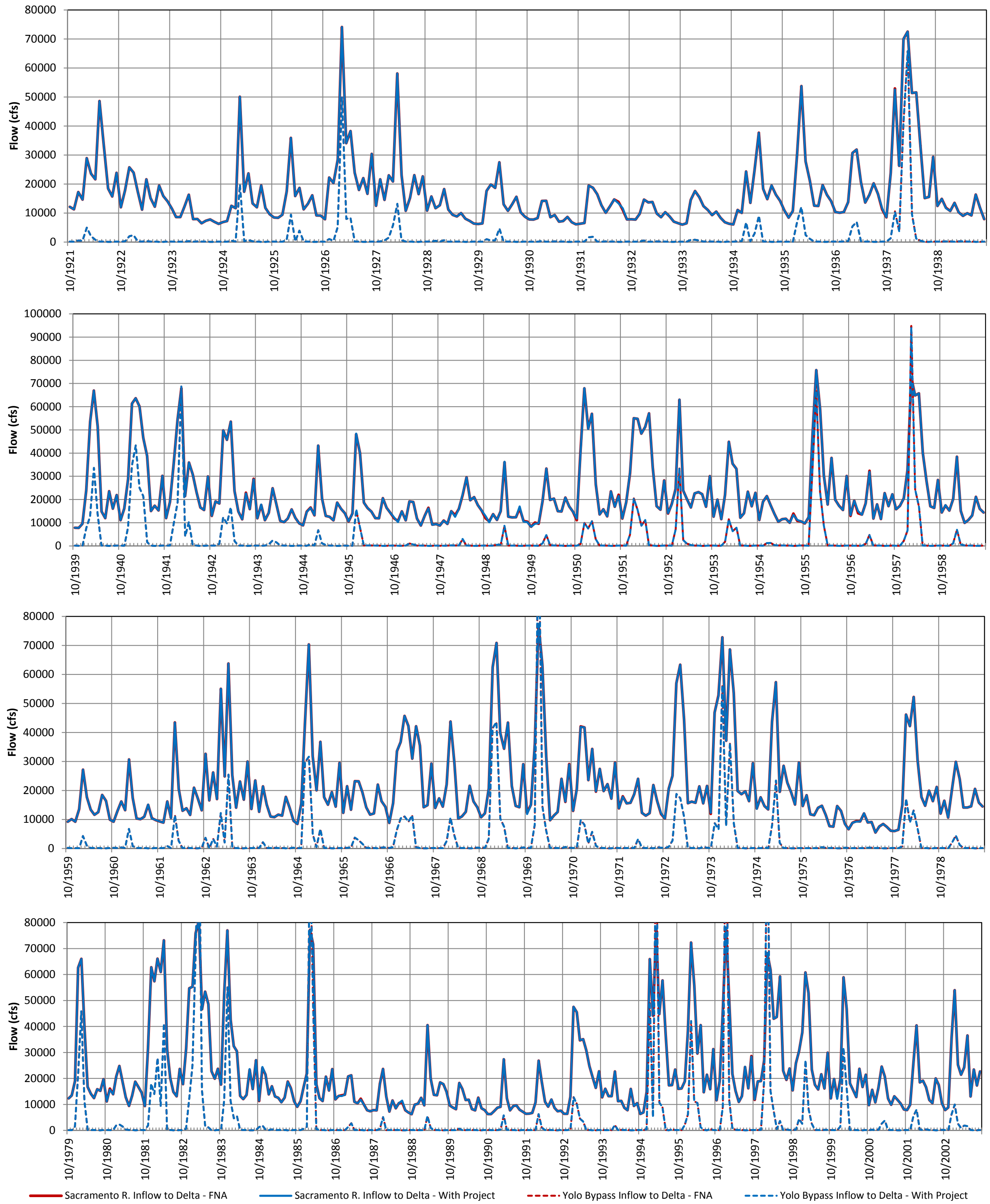


**Figure 21: Comparison of Delta Outflow for San Luis Reservoir Expansion Alternative**

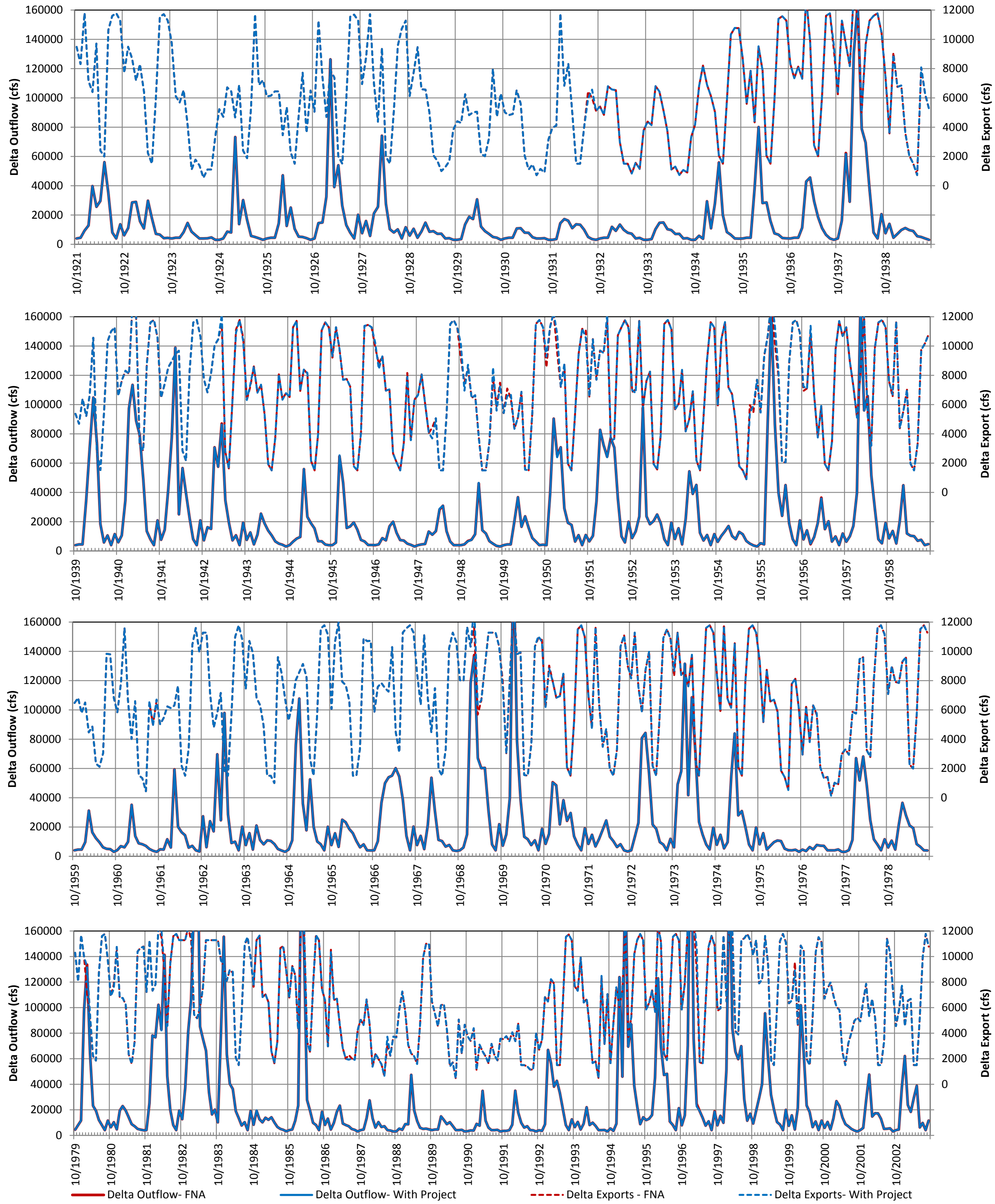


**Figure 22: Comparison of San Luis Reservoir Storage for San Luis Reservoir Expansion Alternative**

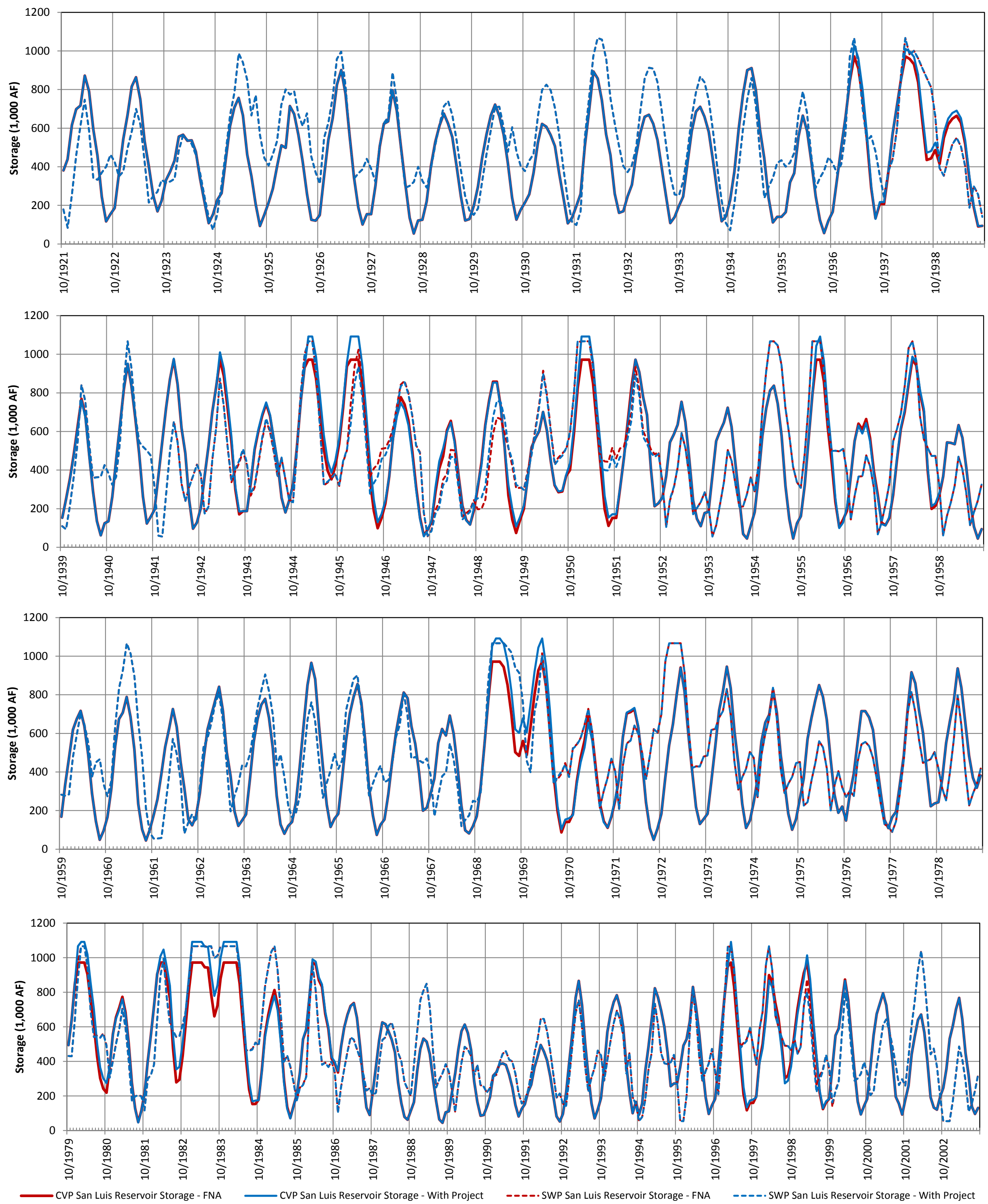


**Figure 23: Comparison of Trinity Storage for Pacheco Reservoir Expansion Alternative**

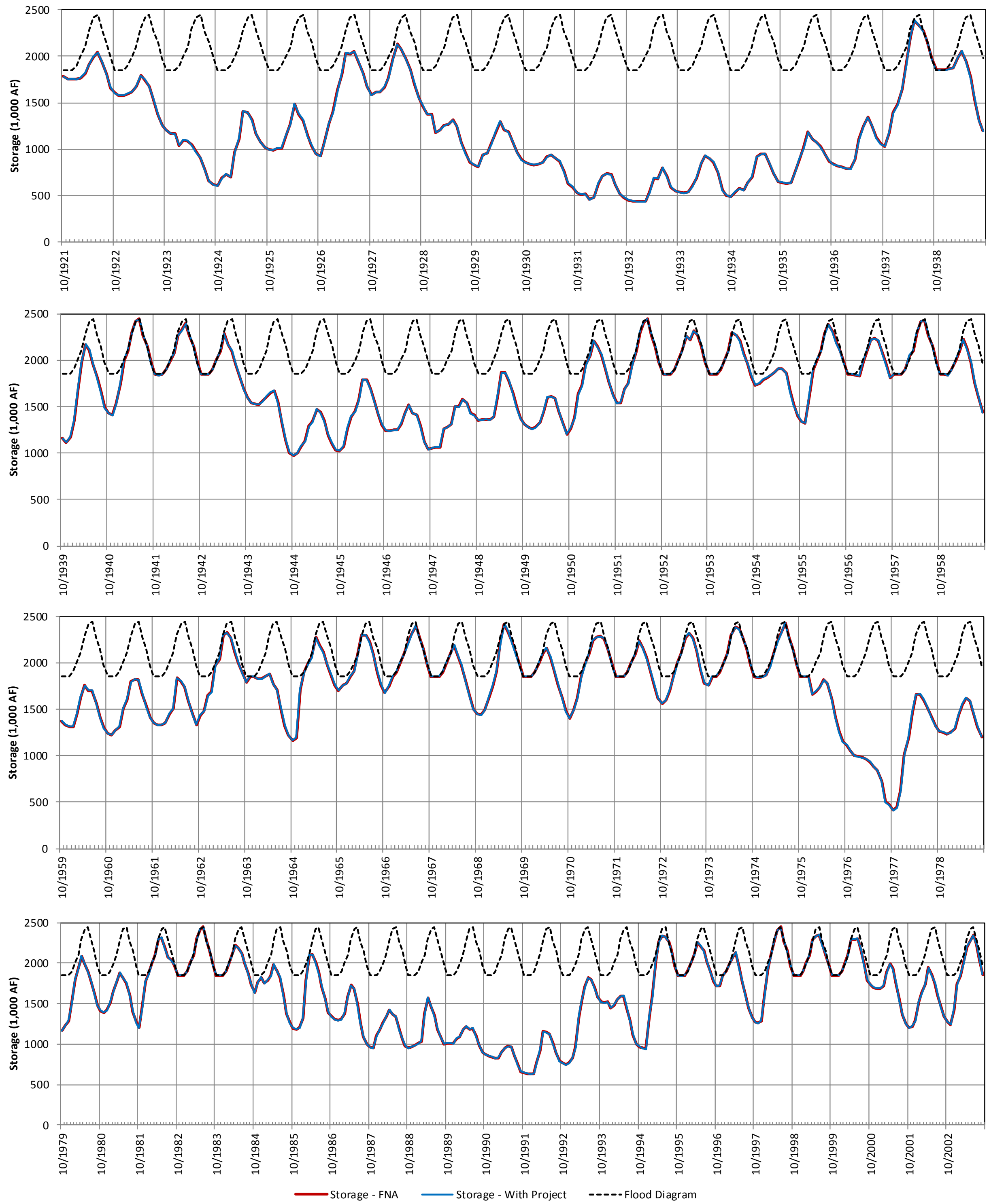


**Figure 24: Comparison of Shasta Storage for Pacheco Reservoir Expansion Alternative**

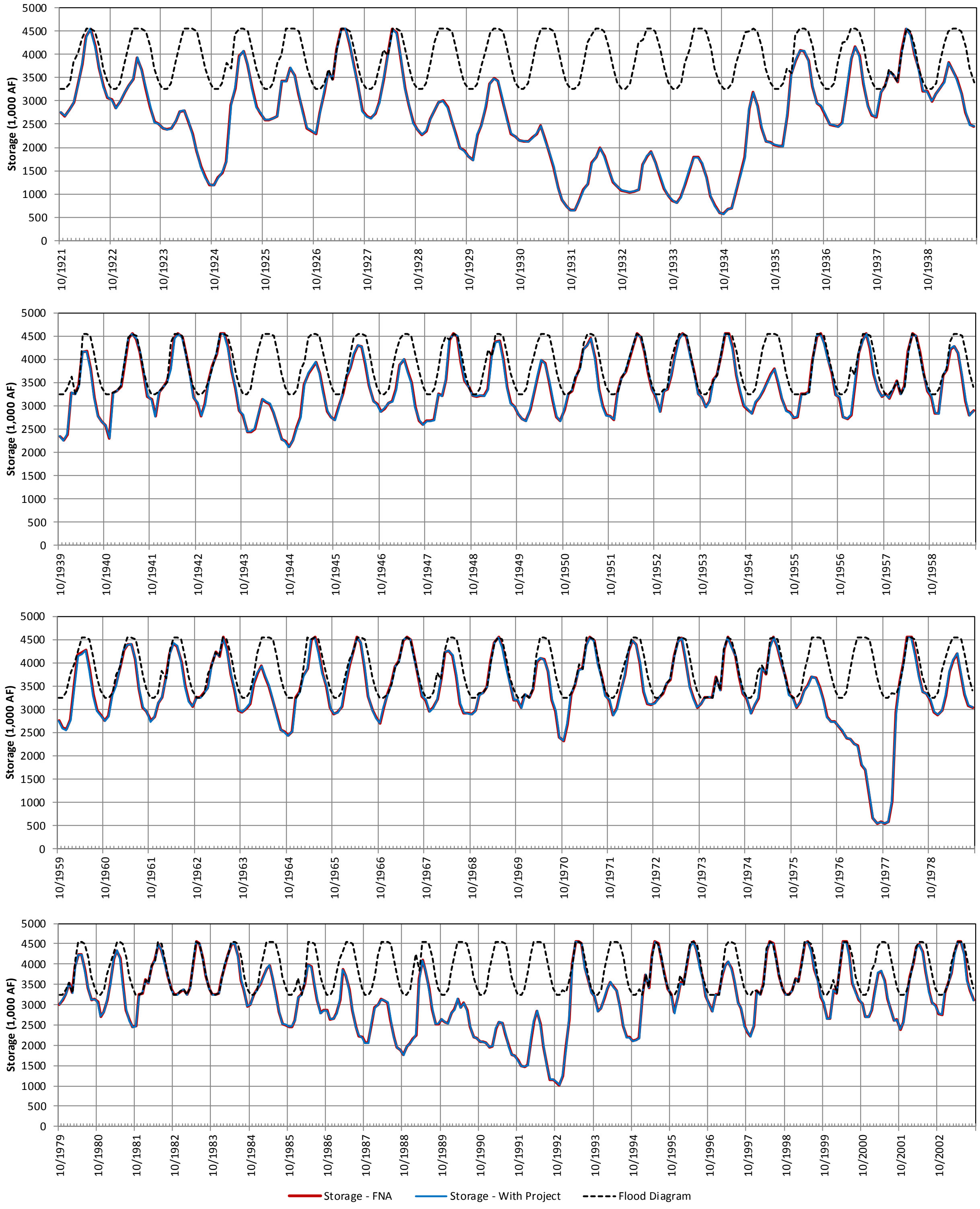


**Figure 25: Comparison of Folsom Storage for Pacheco Reservoir Expansion Alternative**

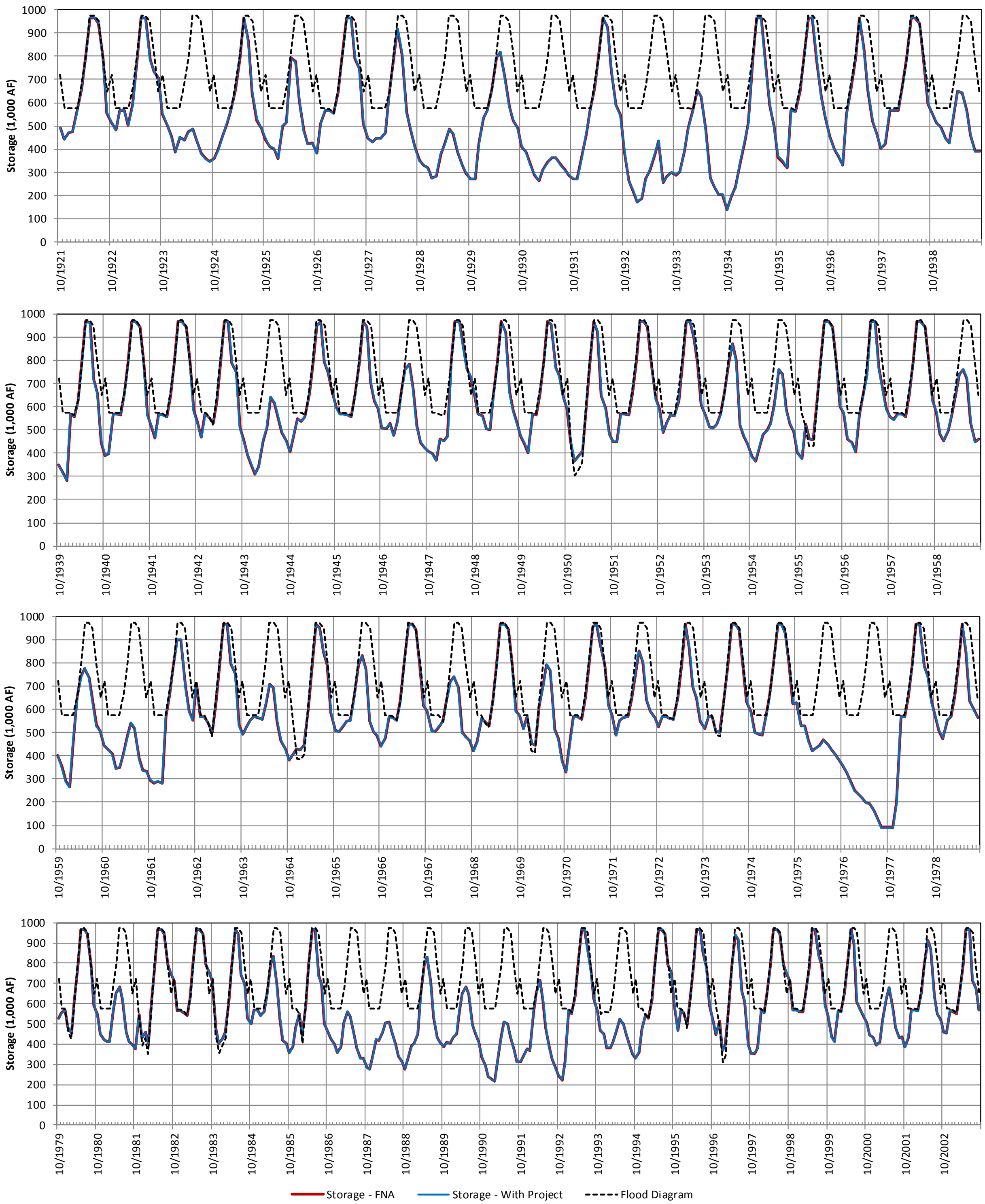


**Figure 26: Comparison of Oroville Storage for Pacheco Reservoir Expansion Alternative**

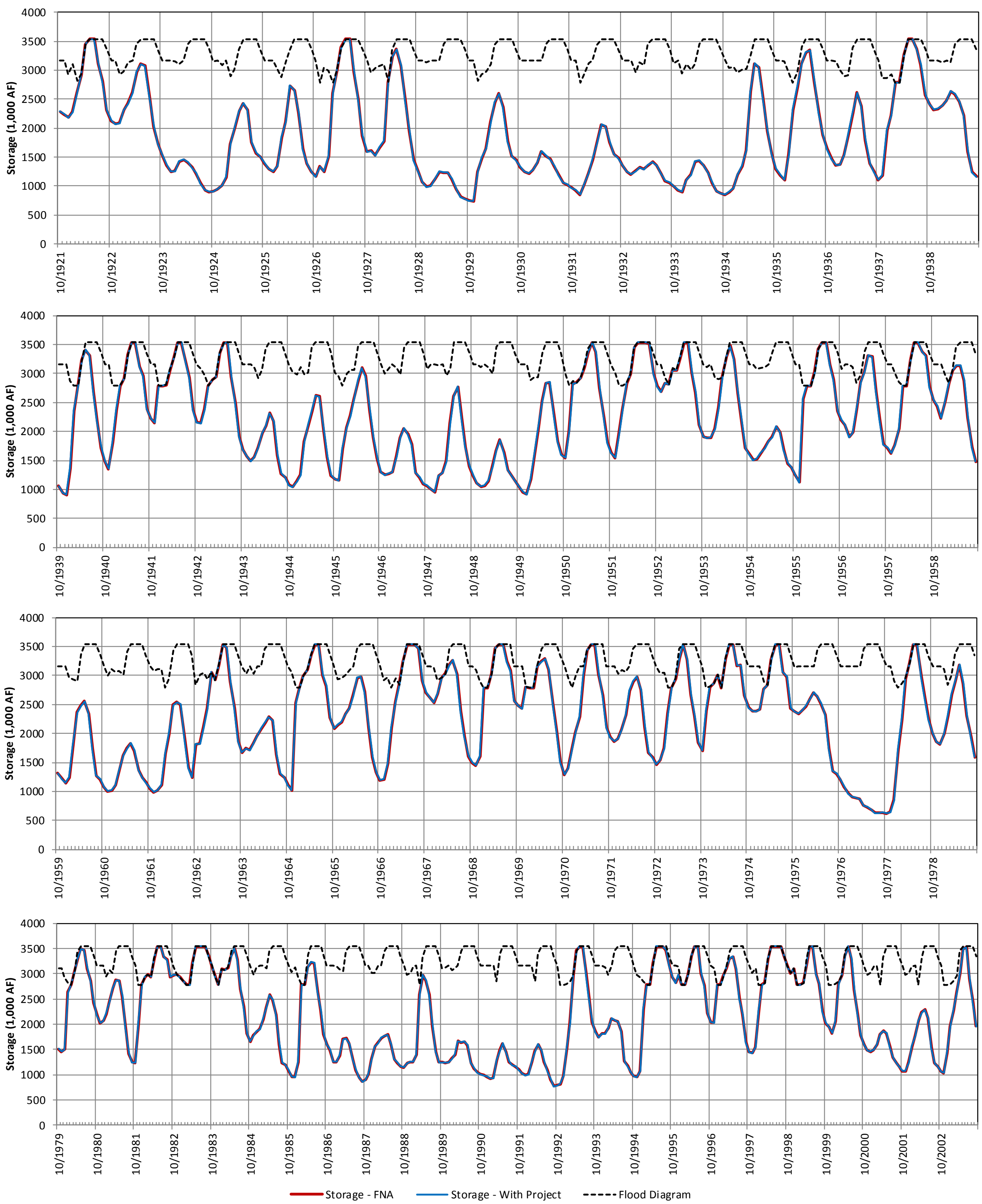


**Figure 27: Comparison of Sacramento River below Keswick Flow for Pacheco Reservoir Expansion Alternative**

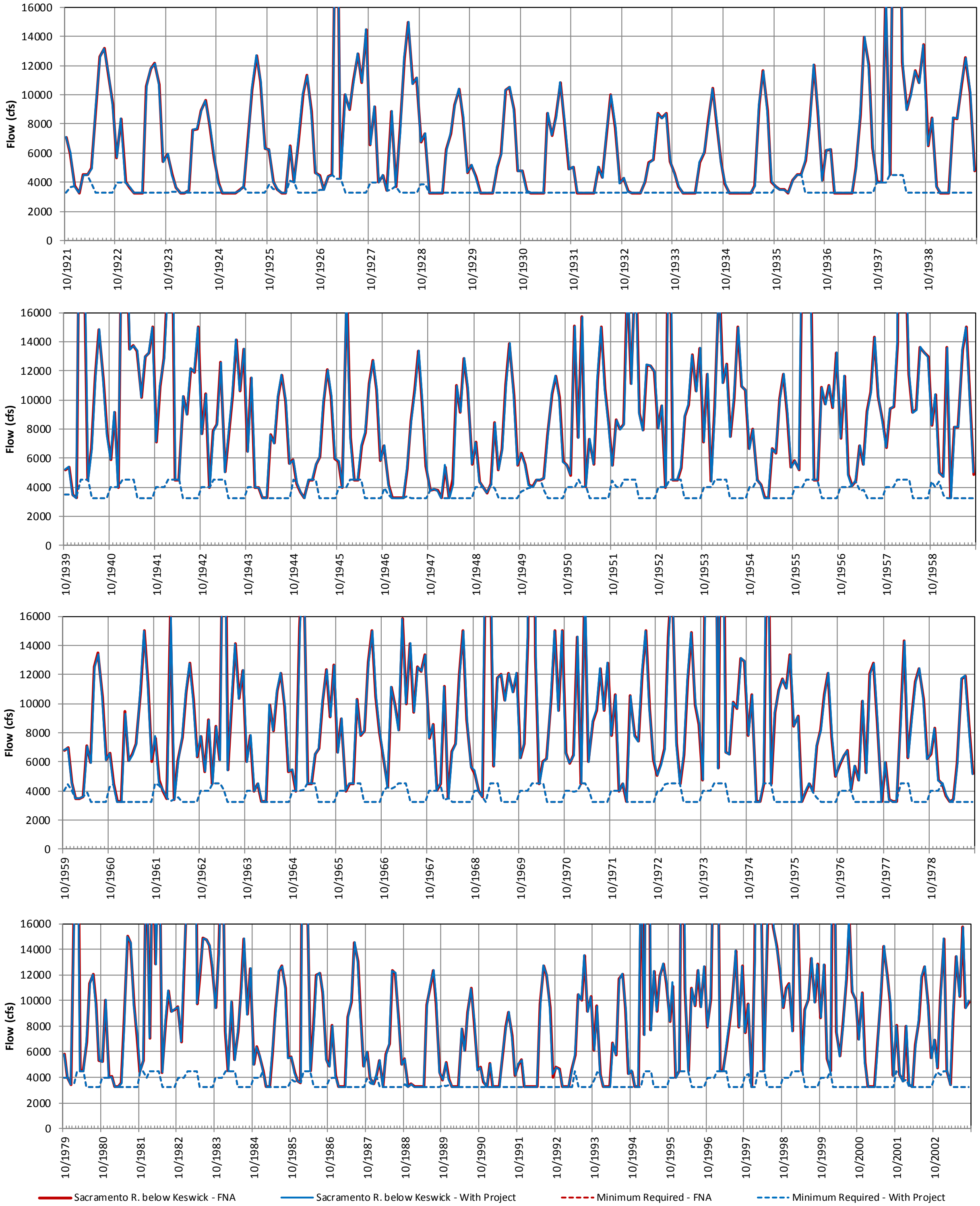


**Figure 28: Comparison of Sacramento River at Wilkins Slough Flow for Pacheco Reservoir Expansion Alternative**

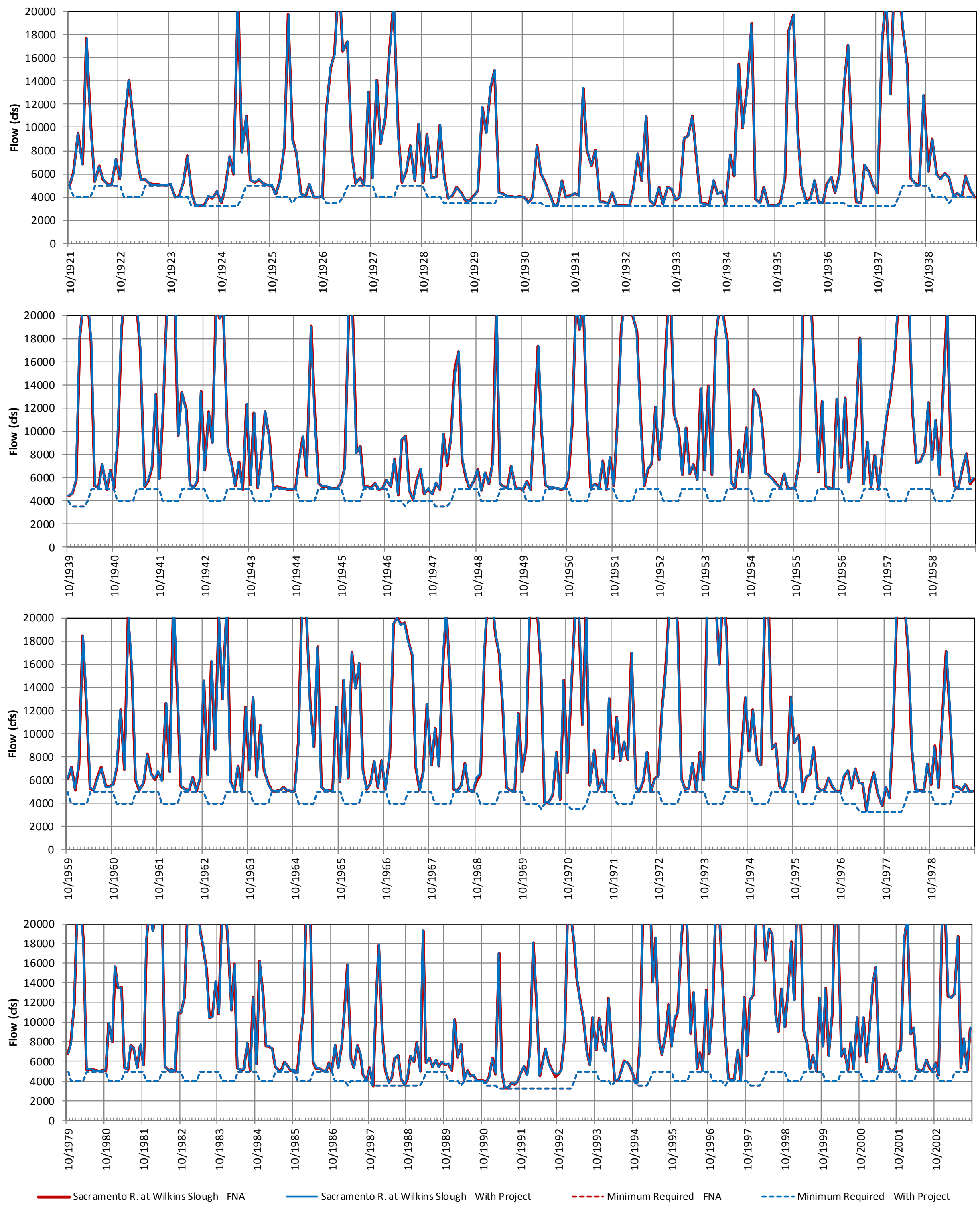


**Figure 29: Comparison of American River below Nimbus Flow for Pacheco Reservoir Expansion Alternative**

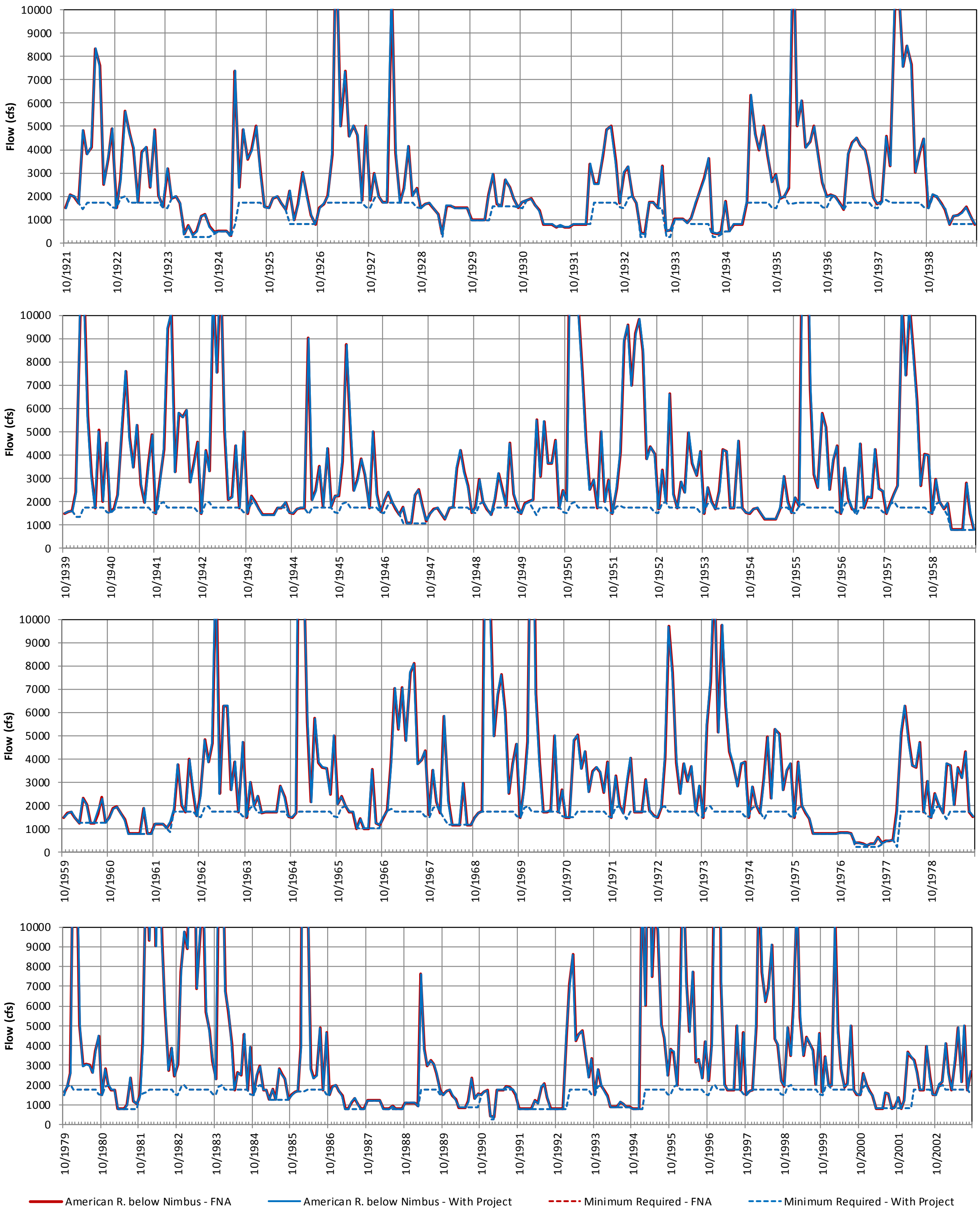


**Figure 30: Comparison of Lower Feather River Flow for Pacheco Reservoir Expansion Alternative**

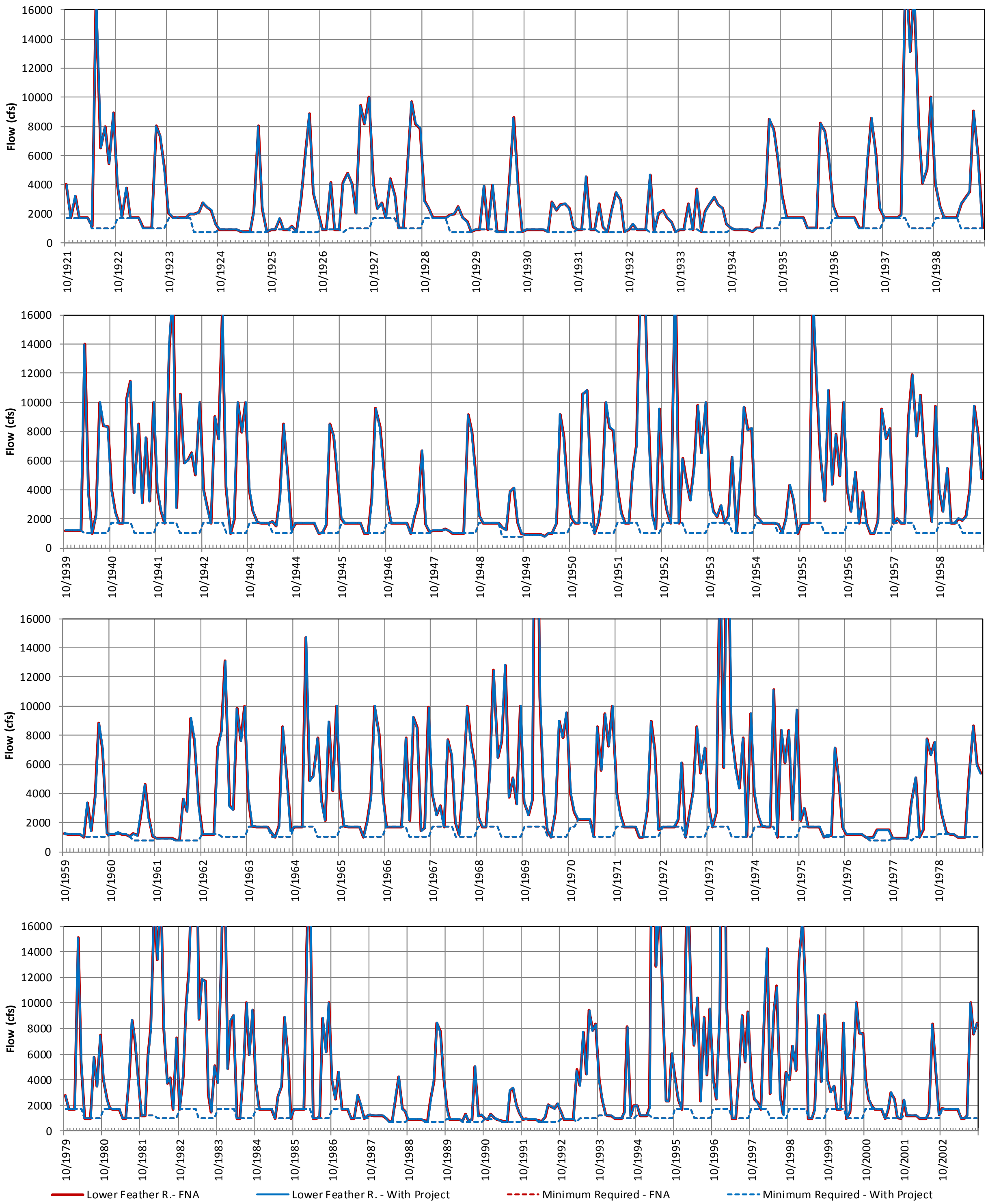


**Figure 31: Comparison of Delta Inflow for Pacheco Reservoir Expansion Alternative**

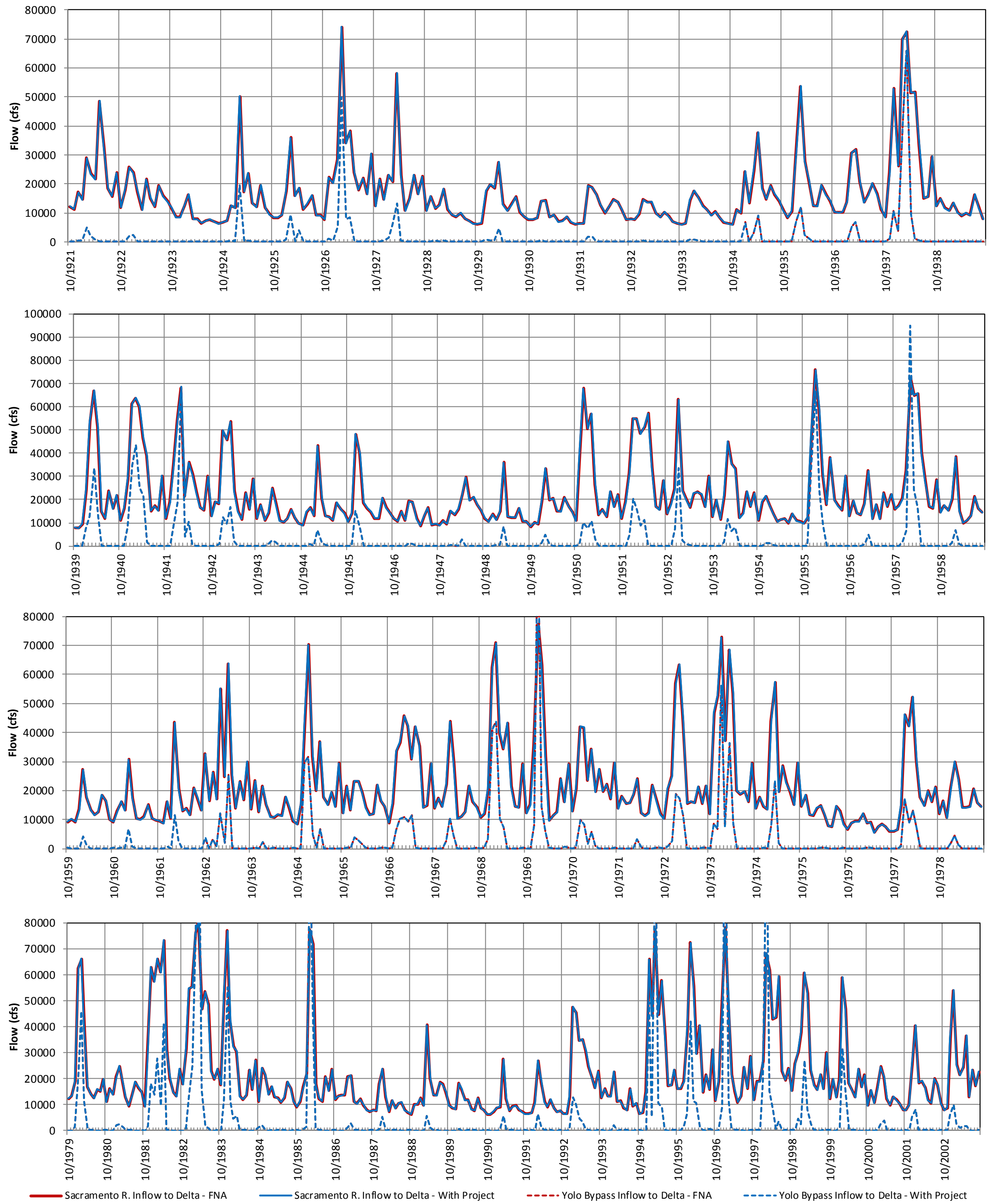


**Figure 32: Comparison of Delta Outflow for Pacheco Reservoir Expansion Alternative**

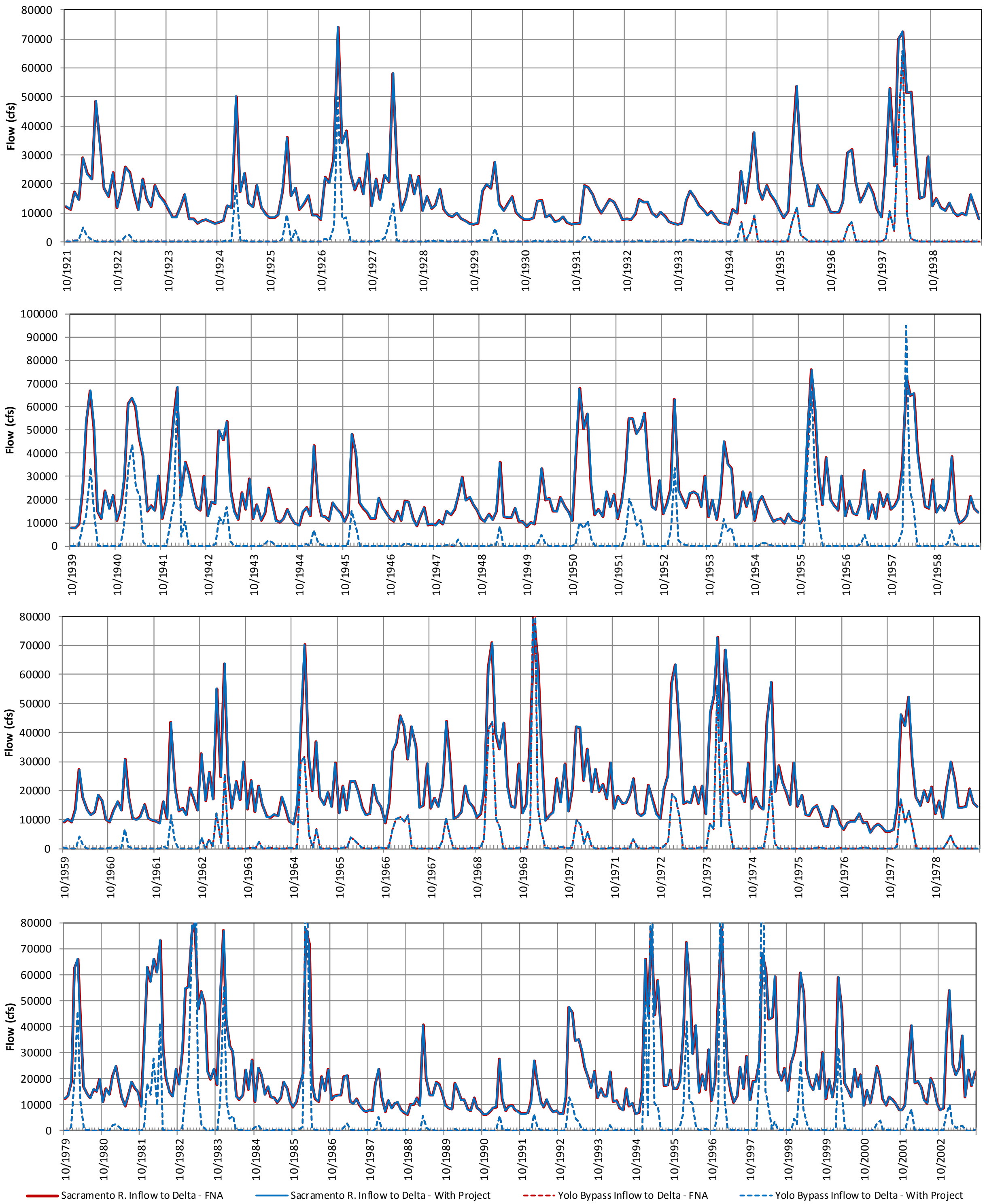
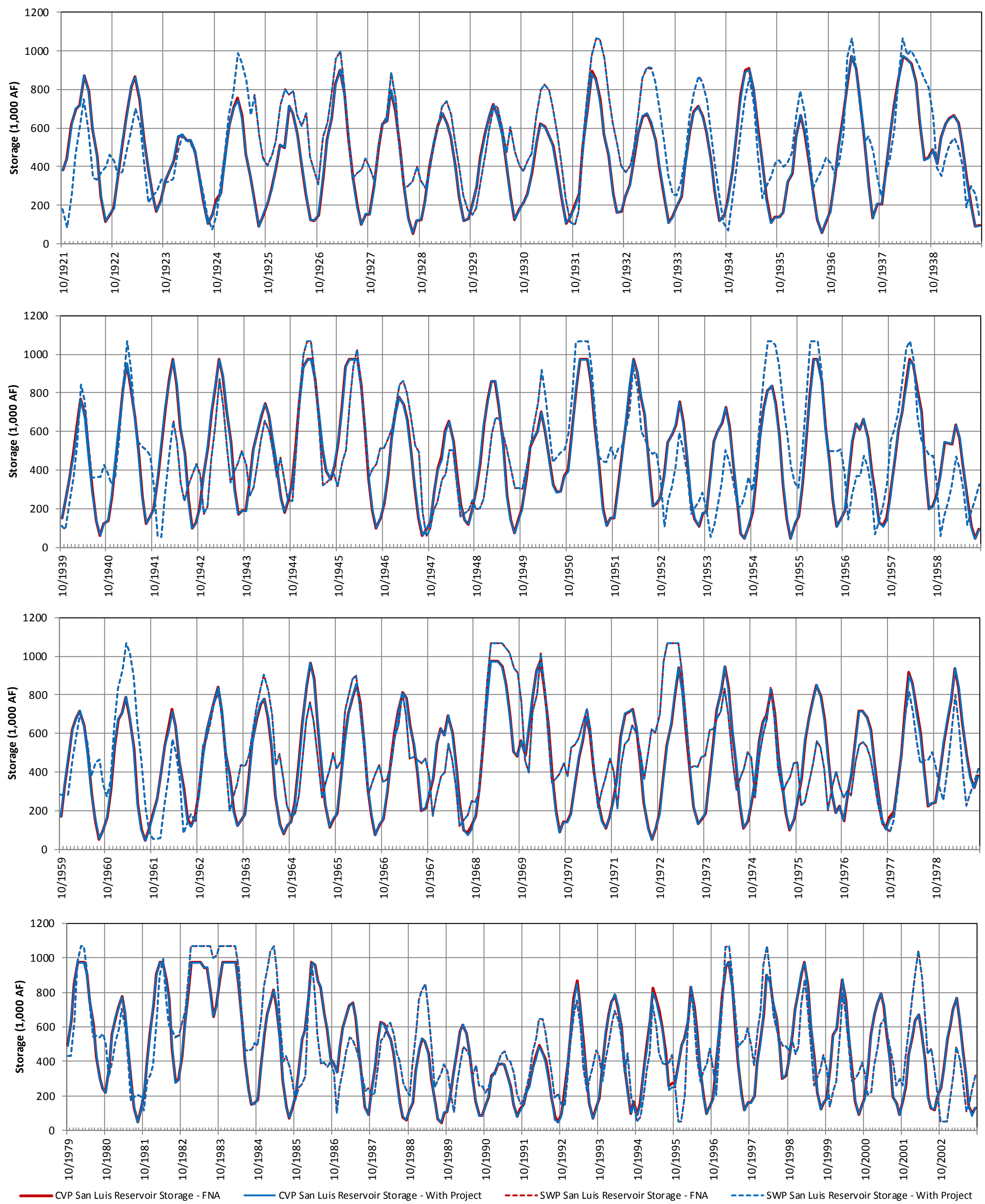


**Figure 33: Comparison of San Luis Reservoir Storage for Pacheco Reservoir Expansion Alternative**



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# Attachment C
## Improvements to CalSim San Luis Operations Technical Memorandum

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Water Resources ◆ Flood Control ◆ Water Rights

# TECHNICAL MEMORANDUM

**DATE:** July 16, 2015

**SUBJECT:** Improvements to CalSim San Luis Operations

**PREPARED BY:** Dan Easton

**REVIEWED BY:** Walter Bourez and Jennifer Wilson

MBK Engineers was tasked with improving San Luis operations in CalSim. At the December 2014 scoping meeting with CalSim modelers and Central Valley Project (CVP) and State Water Project (SWP) operators, issues with CalSim San Luis operations were outlined, and it was decided that there was not sufficient budget to resolve all issues under this task order. As such, the three key items listed below were selected for MBK to address and determine whether significant improvements could be made.

1. Reduce frequency of drawing San Luis to dead pool and shorting South-of-Delta (SOD) contract deliveries by improving the export forecasts used in SWP and CVP allocations.
2. Reduce excessive carryover in CVP San Luis during the critical period (particularly the 1930's) through reasonable increases in service contractor allocations.
3. Refine rulecurve formulations used to balance storage between North-of-Delta (NOD) project reservoirs and San Luis Reservoir.

While the problems outlined at the meeting have been present in CalSim for years, MBK used Reclamation's latest CalSim baseline generated on January 27, 2015 as a starting point. For the rest of this document, this baseline will be referred to as CalSim_27JAN2015, and the model edited to address the above three issues will be referred to as CalSim_27JAN2015_Revised. Any reference to CalSim in general includes CalSim_27JAN2015 and preceding versions.

## Refinement of CVP and SWP export forecasts used in CalSim allocation logic to reduce SOD contract delivery shortages

Since implementation of the smelt and salmon biological opinions, CalSim tended to over-allocate water to SOD CVP and SWP contractors in many years of the simulation. Although this does not occur in every year, it happens enough to skew results in water supply planning analysis. Over-allocation can result in breaking San Luis (drawing San Luis down to dead pool) and shorting project contractors. Figure 1 and Figure 2 relate annual SOD contractor shortages and San Luis low point for both the CVP and SWP, respectively, as simulated by CalSim_27JAN2015. CVP San Luis storage is drawn to dead pool (dashed line) in 15 years of the 82-year simulation; SWP San Luis storage is drawn to dead pool in 21 years of the simulation. Annual shortages to CVP contractors range as high as 100 thousand acre-feet (TAF). Running debt to SWP contractors reaches higher than 400 TAF in year 1995 of the simulation and greater than 100 TAF in several other years.

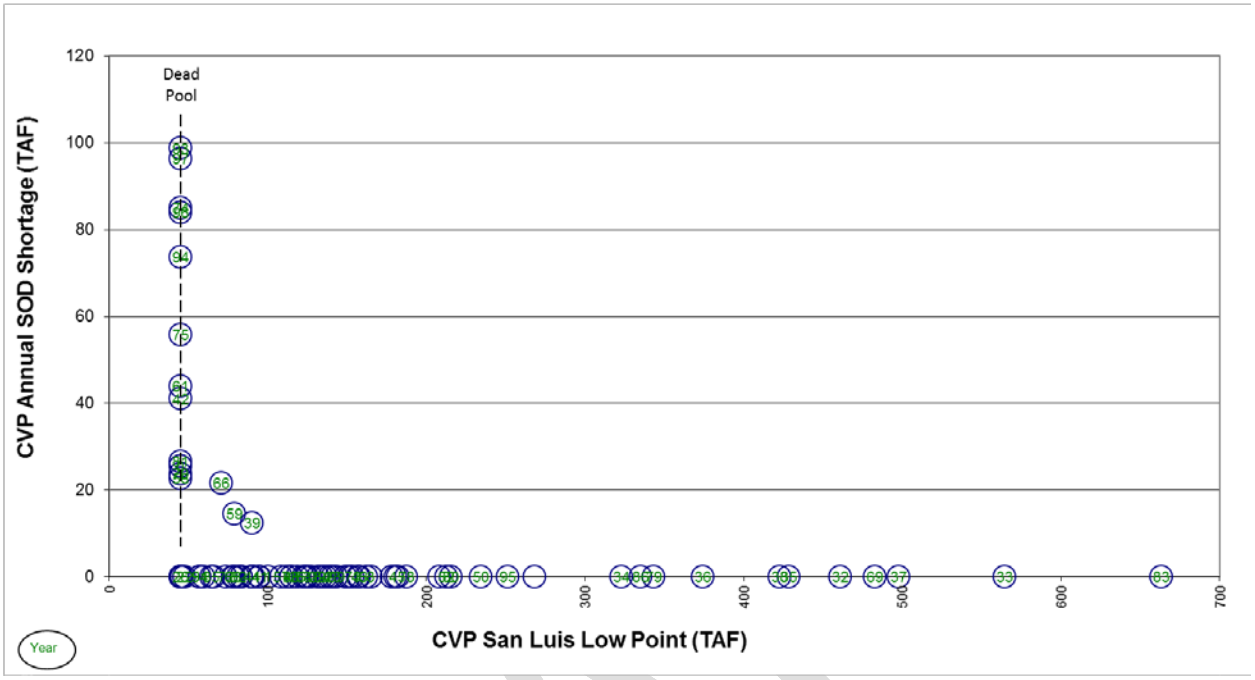


**Figure 1. CVP annual SOD shortage versus CVP San Luis storage low point as simulated in CalSim_27JAN2015**

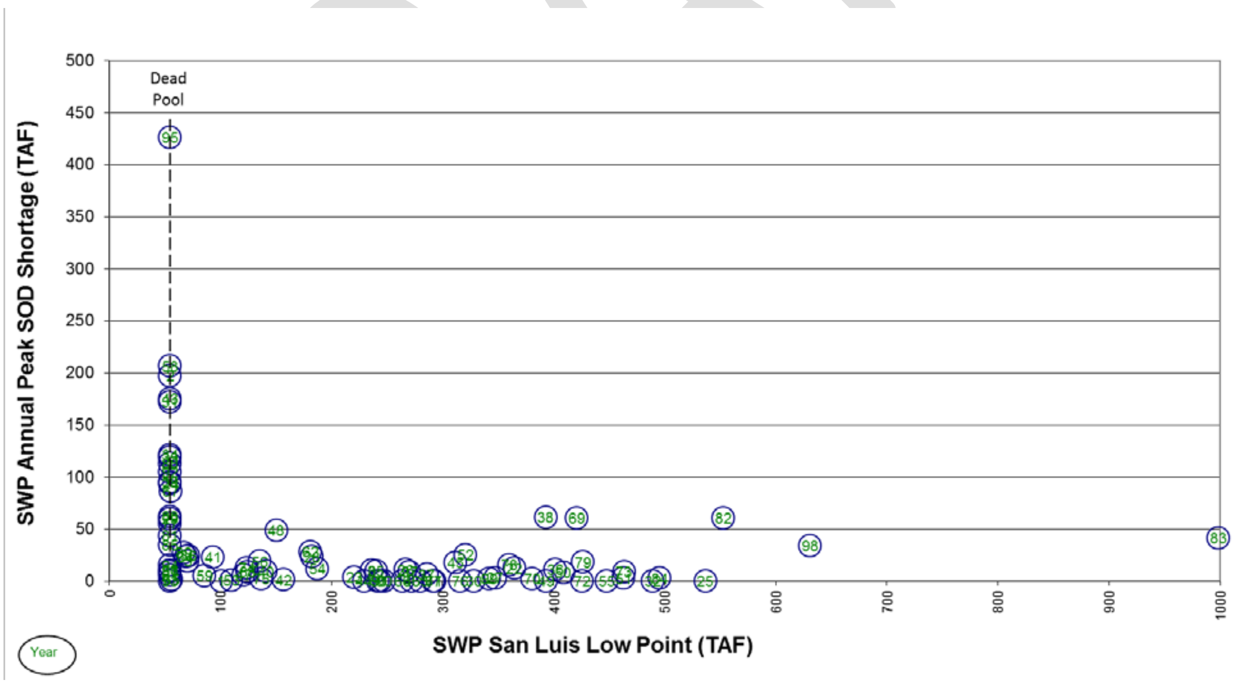


**Figure 2. SWP annual maximum SOD shortage versus SWP San Luis storage low point as simulated in CalSim_27JAN2015**

Over-allocation in CalSim can be traced back to the model methodology used for both the SWP Table A allocations and CVP SOD Agriculture (Ag) and Municipal and Industrial (M&I) allocations.

The CalSim allocation methodology (used for both the CVP and SWP) combines the Water Supply Index – Delivery Index (WSI-DI)–based allocation with an export forecast–based allocation. The minimum of the two is the final allocation for each project in each contract year. (Note that the CalSim model allocation methodology bears minimal resemblance to the methodology used in real-time allocations.)

The WSI-DI–based allocation assesses aggregate supply (forecasted inflow plus storage), but it does not adequately address limitations of available export capacity necessary to move the NOD supply to SOD contractors. Conversely, the export forecast–based allocation is intended to address export capacity limitations, but the current implementation has limited accuracy. Also, the export forecast–based allocation does not consider demand for export capacity. In other words, the export estimate does not consider whether or not the projects would release stored water from upstream reservoirs to make use of the available export capacity. If NOD storage is low, the projects will not want to release stored water to support exports. This should be explicitly incorporated into the allocation decisions, and it currently is not in CalSim.

The purpose of combining the WSI-DI allocation with an export forecast–based allocation was to have each allocation method cover the weaknesses of the other. However, as seen in current CalSim results (Figure 1 and Figure 2), this has not been accomplished. Ideally, the allocation methodology used in CalSim should better reflect real-time operations methodologies where consideration of supply, demand, conveyance capacity, and carryover in upstream reservoirs are physically integrated. This has been attempted by the Department of Water Resources (DWR) in the form of its Forecast Allocation Model (FAM), but it is beyond the scope of this contract.

The objective is to improve allocation decisions with the current methodology thereby preventing drawing San Luis to dead pool and shorting contractors. The most appropriate improvement is to create a more accurate export forecast—one that takes into account both the availability of and the demand for export capacity. However, before potential improvements are discussed, it is important to examine the CVP and SWP export forecast currently used in CalSim.

During the CVP allocation season (March–May), the current version of CalSim has only two possible export forecasts: one when it is a wet year as classified by the San Joaquin River (SJR) 60-20-20 index; and another when it is critical, dry, below normal, or above normal year classification. Table 1 shows the export estimates for each month from March to August. The export forecast–based allocation sums the export estimates from the current month through August.

In Table 1, only April, May, and June are conditioned on the SJR 60-20-20 index because those are the months where exports are most likely controlled by either the SJR inflow-export (IE) ratio or Old and Middle River (OMR) flow requirements. The sum total of the export estimates from April to June in a wet year is 516 TAF (2,000 cubic feet per second [cfs], 2,000 cfs, and 4,600 cfs); in a non-wet year the sum total is 240 TAF (1,000 cfs, 1,000 cfs, and 2,000 cfs). Such a coarse export estimate does not adequately account for the variability in SJR hydrology or in the conditionality of the SJR IE ratio or OMR flow regulations. It also does not reflect the information that operators have at hand to refine their forecasts, which include current SJR flows at Vernalis, forecasted operations on the SJR and its tributaries, and ongoing discussions with the U.S. Fish and Wildlife Service (FWS) about fish take, trawl data and expected OMR flow requirements.

**Table 1. Monthly CVP export estimates found in the CalSim_27JAN2015 lookup table ExportEstimate_CVP**

| CalSim Baseline CVP Export Forecast for SOD Ag and M&I Allocation | | | |
|---|---|---|---|
| Month | Export Estimate (cfs) | Wet SJR Export Estimate (cfs) | Delivery Pattern Fraction |
| MAR | 2500 | 0 | 0.68 |
| APR | 1000 | 2000 | 0.622 |
| MAY | 1000 | 2000 | 0.553 |
| JUN | 2000 | 4600 | 0 |
| JUL | 4600 | 0 | 0 |
| AUG | 4600 | 0 | 0 |

The July and August export estimates for the CVP are listed in Table 1 at 4,600 cfs, which is Jones Pumping Plant's full capacity. Obviously this will never be an underestimate of simulated Jones pumping in July and August, but it is often an overestimate. Even though 4,600 cfs capacity is available, the CVP does not always want to release water from upstream reservoirs to fill that capacity. CalSim overestimates exports in these months with the expectation that the WSI-DI–based allocation will prevent an over-allocation. The WSI-DI does serve as a backstop in many years, but there are many years when it does not limit the export estimate based on available supply.

Figure 3 compares annual CVP SOD delivery shortage with the error in the CVP export forecast used in the export forecast–based allocation. The CVP export forecast error is calculated as the April–August CVP export forecast minus the modeled total April–August CVP Jones Pumping Plant exports. As shown in Figure 3, the error is both negative and positive but skews positive. There are no shortages when the export forecast is an underestimate of exports (negative error). There are 15 years with shortages when the forecast is an overestimate. However, the shortages in three of those years — 1939, 1959, and 1966, the three lowest shortages not equal to zero — have nothing to do with over-allocation but a quirk in the SJR model formulation. The remaining 12 are all due to over-allocation, both from the WSI-DI–based approach and the export forecast approach.

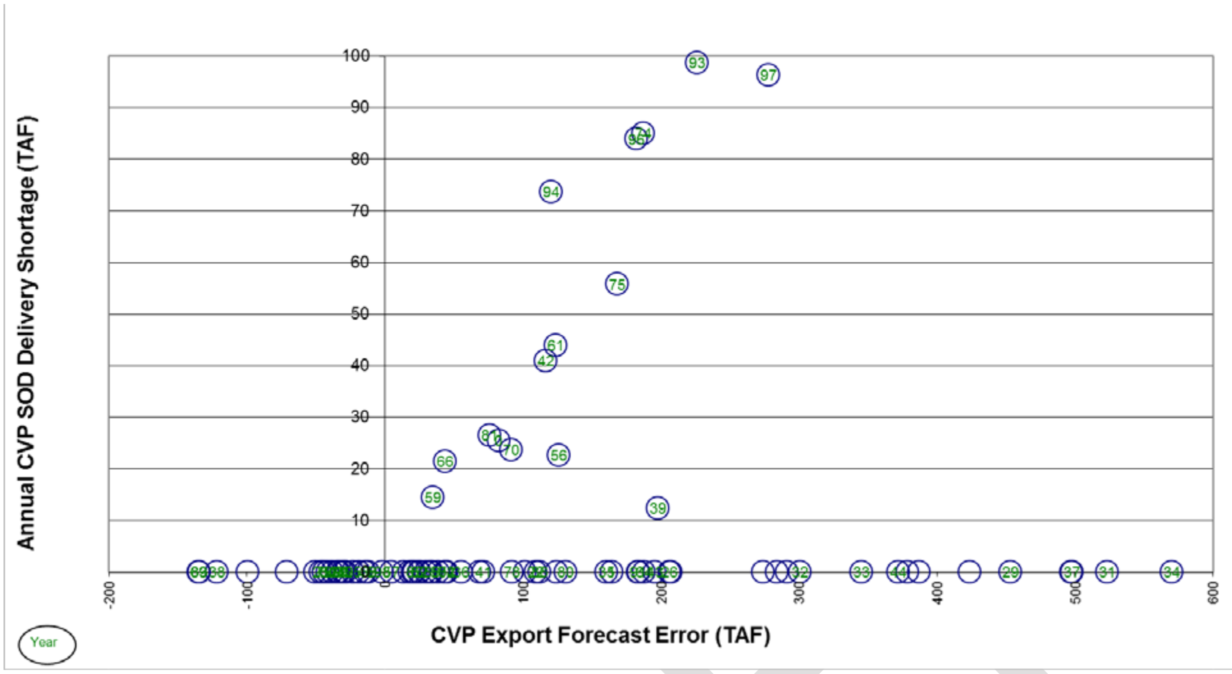


**Figure 3. Annual CVP SOD delivery shortage versus CVP export forecast error in CalSim_27JAN2015**

Problems with the SWP export forecast are similar to those explained above for the CVP. Table 2 lists the monthly SWP export estimates from January to August. Whereas the CVP contract year begins in March, the SWP contract year begins in January along with SWP allocations. Like the CVP, export estimates are conditioned on the SJR 60-20-20 index in April, May, and June. Unlike the CVP, the SWP export forecast logic adds a flood condition on the SJR in April and May. The flood condition is triggered when flow at Vernalis exceeds 16,000 cfs in March, April, or May. However, even with this added nuance, this is still a very coarse export forecast that does not capture the refinement inherent in real-time operations or what is needed in the model.

**Table 2. Monthly SWP export estimates found in the CalSim_27JAN2015 lookup table ExportEstimate_SWP**

| **CalSim Baseline SWP Export Forecast for Table A Allocation** | | | | |
|---|---|---|---|---|
| Month | Export Estimate (cfs) | Wet SJR Export Estimate (cfs) | Flood SJR Export Estimate (cfs) | Delivery Pattern Fraction |
| JAN | 3750 | 0 | 0 | 0.737 |
| FEB | 4250 | 0 | 0 | 0.721 |
| MAR | 4250 | 0 | 0 | 0.695 |
| APR | 1000 | 2000 | 6000 | 0.657 |
| MAY | 1000 | 2000 | 6000 | 0.566 |
| JUN | 2500 | 6000 | 0 | 0 |
| JUL | 7000 | 0 | 0 | 0 |
| AUG | 7000 | 0 | 0 | 0 |

The SWP export forecast for July and August is 7,000 cfs as listed in Table 2. This exceeds permitted capacity of 6,680 cfs in these months, and simulated SWP exports in CalSim_27JAN2015 never exceed permitted capacity in July and August. In fact, simulated July and August SWP exports are often significantly below permitted capacity. The explanation for this is the same as it was for the CVP: just because capacity is available does not mean the SWP wants to use it; that depends on the storage condition of Oroville, and the export forecast in Table 2 does not consider such details.

Figure 4 compares SWP SOD shortage with export forecast error. Export forecast error was again calculated by subtracting April–August total SWP exports from the forecasted exports. Only 1979 had an underestimate of forecasted exports, and that underestimate was slight. In all other years the SWP export forecasts were overestimates with some errors greater than 1 million acre-feet (MAF). The greatest delivery shortage occurred in a wet year, 1995 (Figure 4). The delivery shortage was approximately 425 TAF; it was the result of a 500 TAF overestimate of exports. (Many of the shortages shown that are below 70 TAF in Figure 4 are not due to over-allocation and breaking San Luis; they are due to insufficient California Aqueduct capacity to meet the assumed demand pattern. These are of less concern than the shortages caused by breaking San Luis.)

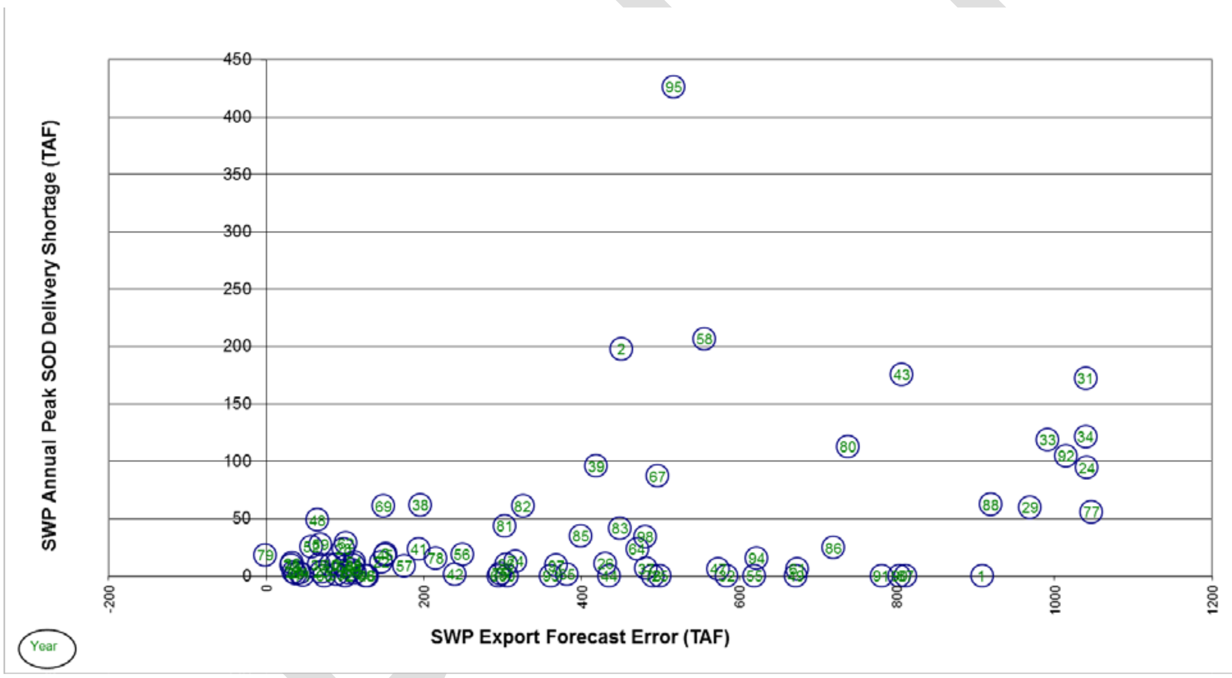


**Figure 4. SWP annual peak SOD delivery shortage versus SWP export forecast error in CalSim_27JAN2015**

To improve on the export forecasts, it is recognized that more detail is necessary. The two CVP and three SWP export forecast possibilities currently provided in CalSim do not adequately cover the different circumstances found from one year to the next. What follows is a proposal for deriving export forecasts that vary by year and month that will take into account hydrologic, regulatory, and operational variability. The methodology is similar to the WSI-DI procedure in that it requires infrequent iterations of CalSim, and it is best described as a series of steps.

### Step 1

Set the CVP and SWP export forecasts equivalent to Health and Safety (H&S) minimum export levels (800 cfs for the CVP and 300 cfs for the SWP). As such, the respective April to August export forecasts are approximately 240 TAF for the CVP and 90 TAF for the SWP. Run CalSim with this initial export forecast.

### Step 2

Use the CalSim CVP and SWP export results (D418 and D419_SWP, respectively) from Step 1 as new export estimates and re-run CalSim. Repeat until the maximum difference between aggregate export estimates and cumulative simulated exports is less than 100 TAF. Many previous trials indicate this will likely take three iterations. The first iteration (Step 1) uses the H&S export estimate, and the second and third use the CalSim-generated export estimates. A spreadsheet has been set up to process CalSim output into export forecast input for the purpose of expediting this process.

### Step 3

Refine export estimates as necessary to achieve desired balance of contract deliveries and storage carryover. This refinement of export forecasts can be done by an automated procedure or manually. A combination of both was employed in this analysis.

Ideally, the procedure would stop at Step 2. Understanding why the procedure progresses to Step 3 requires an understanding of the logic of the first two steps. Starting with the H&S export forecast in Step 1 ensures very low allocations for both projects in all years of that simulation. As such, export of available Delta supplies without supplemental reservoir release – or export of incidental Delta inflow – are sufficient in almost every year to meet allocated deliveries and San Luis carryover targets. So the final result of that first iteration and the iterations that follow in Step 2 is a lower bound on the SWP and CVP export forecasts. In any year that moving additional water from NOD reservoirs is not desired, the final export forecast derived in Step 2 also represents an upper bound. But in those years where NOD stored water and SOD export capacity are available, the export forecast must be increased to drive higher allocations and movement of that additional water through rulecurve. (Rulecurve will be discussed later in this memo.) There are also very wet years such as 1983, when a full San Luis prevented additional exports during the iterative process. A boost in the export forecast increases allocations and deliveries, which allows for higher exports when San Luis is full. Given the reasons for refinement, the only changes to the export forecasts going from Step 2 to Step 3 were increases.

The final CVP and SWP export forecasts derived from the three-step methodology are listed in Table 3 and Table 4. While these forecasts extend through the period of record (1922–2003), the tables show a small sample (1922–1931) for the sake of brevity. Each export forecast provided by year and month represents cumulative exports from the given month through August. As such, the export forecast can easily be retrieved from a lookup table or DSS timeseries (either data retrieval mechanism will work) and directly input into the current SWP and CVP export-based allocation logic (some minor edits were made for the new format of the export forecasts). Note the variability of the SWP and CVP export forecasts from a wet year like 1922, to a below-normal year like 1928, and to a critical year like 1931 (all SJR 60-20-20 index–based classifications). This is a significant change from the rough forecasts found in CalSim_27JAN2015.

**Table 3. Sample CVP export forecast derived from the three-step process and used in CalSim_27JAN2015_Revised**

| Modified CVP Export Forecast for SOD Ag and M&I Allocation (cumulative from current simulation month to August) | | | |
|---|---|---|---|
| | Cumulative Export Estimate (TAF) | | |
| Year | MAR | APR | MAY |
| 1922 | 1255 | 972 | 901 |
| 1923 | 1083 | 883 | 817 |
| 1924 | 388 | 269 | 180 |
| 1925 | 1039 | 856 | 784 |
| 1926 | 622 | 339 | 271 |
| 1927 | 1062 | 835 | 775 |
| 1928 | 935 | 652 | 592 |
| 1929 | 501 | 338 | 269 |
| 1930 | 551 | 395 | 329 |
| 1931 | 325 | 261 | 189 |

**Table 4. Sample SWP export forecast derived from the three-step process and used in CalSim_27JAN2015_Revised**

| Modified SWP Export Forecast for Table A Allocation (cumulative from current simulation month to August) | | | | | |
|---|---|---|---|---|---|
| | Cumulative Export Estimate (TAF) | | | | |
| Year | JAN | FEB | MAR | APR | MAY |
| 1922 | 2025 | 1805 | 1729 | 1409 | 1325 |
| 1923 | 1634 | 1413 | 1318 | 1117 | 1038 |
| 1924 | 412 | 232 | 111 | 93 | 75 |
| 1925 | 1227 | 1029 | 1049 | 800 | 709 |
| 1926 | 1179 | 981 | 1015 | 990 | 905 |
| 1927 | 1687 | 1542 | 1425 | 1192 | 1119 |
| 1928 | 1695 | 1482 | 1432 | 1132 | 1062 |
| 1929 | 684 | 482 | 299 | 136 | 67 |
| 1930 | 1209 | 1061 | 922 | 767 | 704 |
| 1931 | 508 | 308 | 152 | 88 | 71 |

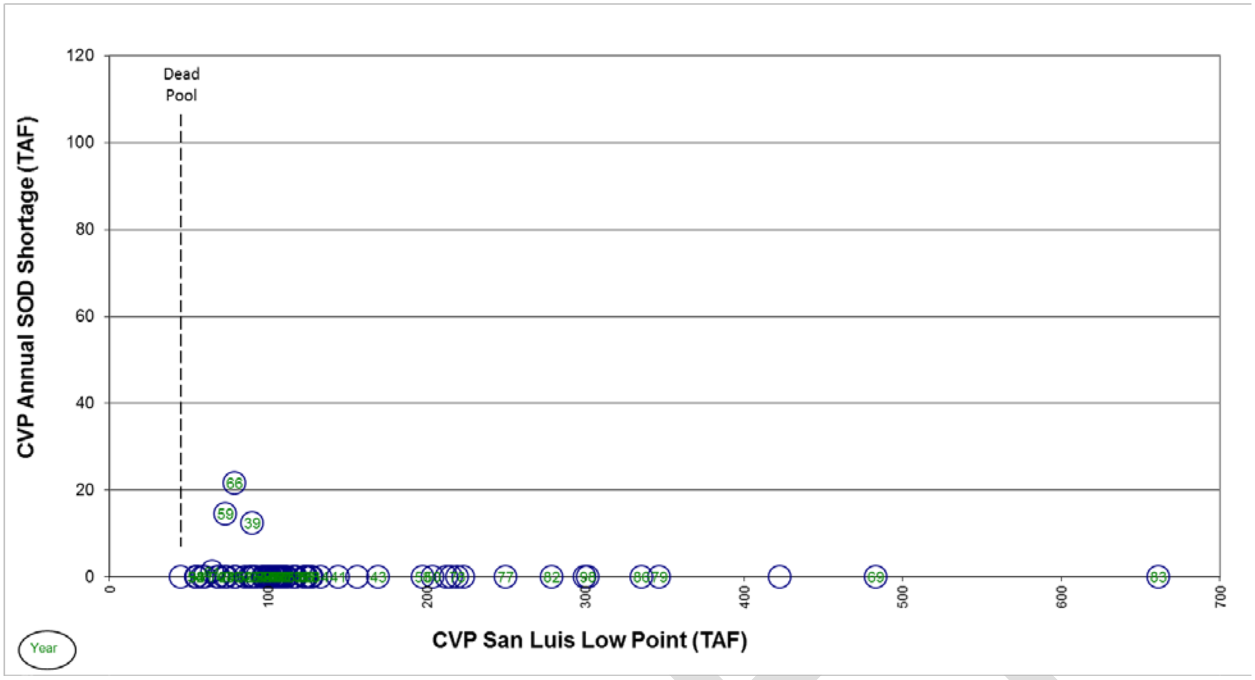


**Figure 5. CVP annual SOD shortage versus CVP San Luis storage low point as simulated in CalSim_27JAN2015_Revised**

Figure 5 and Figure 6 compare annual shortage and San Luis low point as simulated in CalSim_27JAN2015_Revised with the updated export forecasts listed above. CVP San Luis is drawn to dead pool only once and no shortage occurs in that year. The only years with CVP SOD shortages are 1939, 1959, and 1966; as discussed previously, the shortages are not caused by over-allocation but a quirk in the SJR model formulation. The SWP is drawn to dead pool in four years, but there are shortages in only two of them. (The two dead pool data points where the shortage is zero overlap.) All SWP shortages shown are reasonably small and are almost entirely caused by insufficient California Aqueduct capacity to meet the simulated delivery pattern. This type of shortage is of less concern than those caused by breaking San Luis. To gage the improvement in San Luis operations and reductions in project SOD delivery shortages due to the updated export forecasts, compare Figure 5 to Figure 1 and Figure 6 to Figure 2.

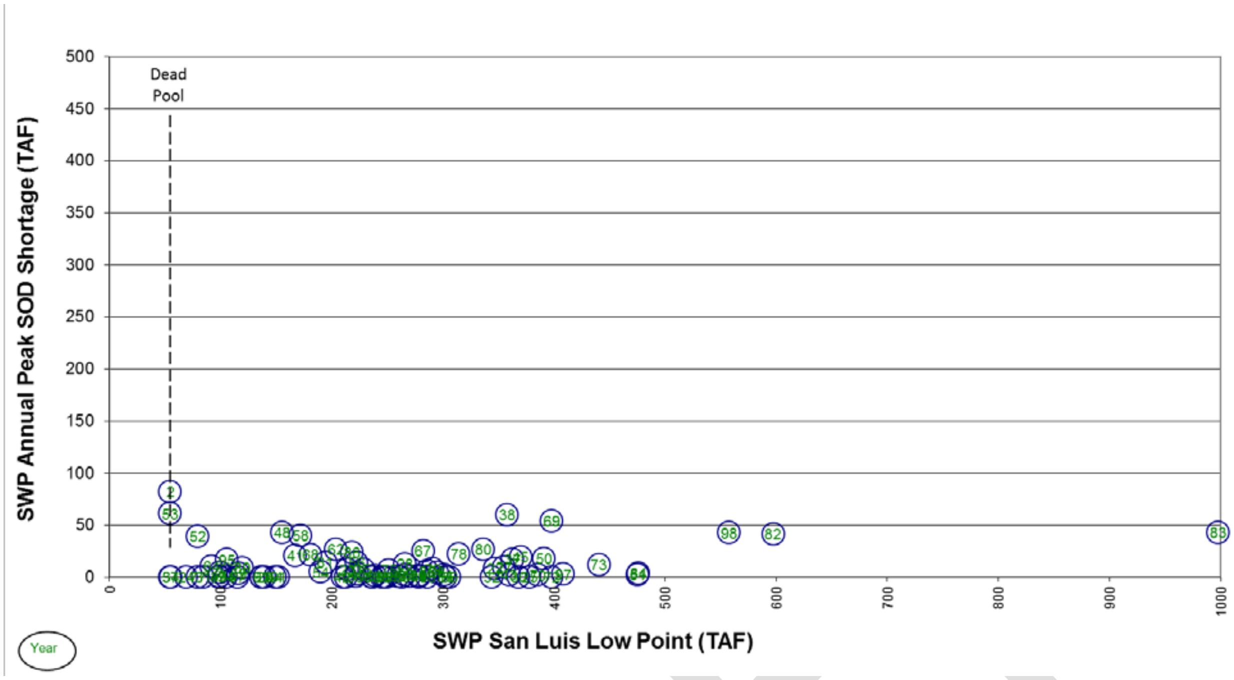


**Figure 6. SWP annual maximum SOD shortage versus SWP San Luis storage low point as simulated in CalSim_27JAN2015_Revised**

Export forecast error was shown to be large for both the CVP (Figure 3) and SWP (Figure 4) in CalSim_27JAN2015. Reducing export forecast error was essential to the prevention of breaking San Luis and shorting SOD contractors. Figure 7 relates CVP SOD delivery shortage to CVP export forecast error in CalSim_27JAN2015_Revised. As shown, most of the CVP export forecast errors fall under 100 TAF. Those errors above 100 TAF were edited in Step 3 of the proposed export forecast methodology to refine the balance between deliveries and carryover. Figure 8 relates SWP SOD delivery shortage to SWP export forecast error in CalSim_27JAN2015_Revised. The forecast error in three years is above 200 TAF: 1952, 1982, and 1983. It was recognized that in all three of these years there was sufficient water and export capacity to meet a 100% Table A allocation. The export forecast in each was set sufficiently high so that it would not prevent a full allocation. The rest of the SWP export forecast errors were less than 200 TAF. The refinements in Step 3 were responsible for pushing the errors above 100 TAF.

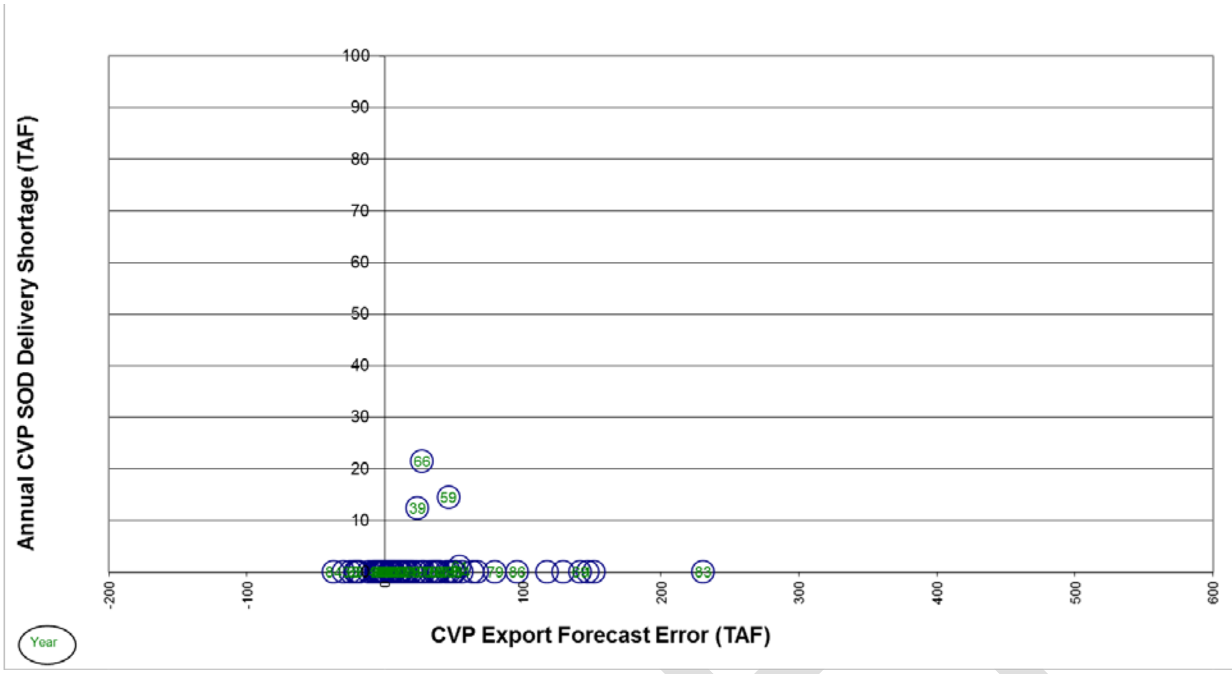


Figure 7. Annual CVP SOD delivery shortage versus CVP export forecast error in CalSim_27JAN2015_Revised

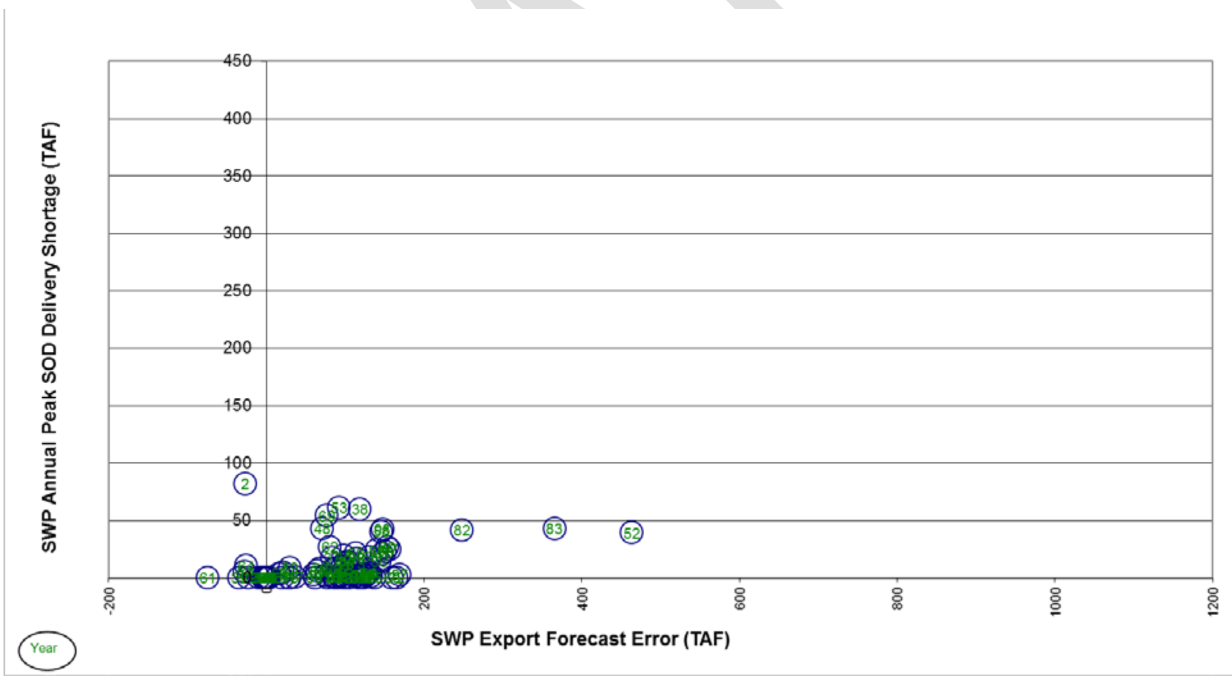


Figure 8. SWP annual peak SOD delivery shortage versus SWP export forecast error in CalSim_27JAN2015_Revised

## CalSim CVP Allocation Logic Refinement

Other adjustments were made to CalSim_27JAN2015_Revised in addition to the update of the export forecasts used in CVP and SWP allocations. One was a refinement to the CVP allocation procedure to reduce instances where there are low CVP SOD service contract allocations in years that end in excessively high San Luis carryover. Figure 9 links CVP San Luis low point with combined Shasta and Folsom carryover as simulated in CalSim_27JAN2015. Six of the annual data points are highlighted in red due the relatively high San Luis low point and low CVP SOD Ag Service allocation (see Figure 10 for the allocation associated with each data point). The highlighted years are 1932–1937, and the SOD Ag Service allocations in these years range from 4% in 1932 to 43% in 1936. The San Luis low point is above 300 TAF throughout this period and reaches almost 600 TAF in 1932. San Luis also fills during critical periods, thereby constraining CVP export of valuable winter surplus. Clearly, higher deliveries could be made SOD without impacting upstream storage; so it is advantageous to determine why the current model does not perform this operation, and what change can be made to more efficiently use available water.

The problem within the model is caused by dry conditions north of the American River and wetter conditions from the American River south. Such a hydrologic imbalance leaves Shasta and Trinity storage low but keeps San Luis storage high through export of surplus originating on the American and San Joaquin Rivers. Low Shasta and Trinity storage results in a low WSI-DI–based allocation. A low WSI-DI allocation supersedes a higher export-based allocation (recall that the model uses the minimum), and SOD service contractor allocations end up being governed by the dry conditions to the north even though there is sufficient water SOD to meet higher demand.

In the end, this is entirely the result of a modeling artifact. It is standard policy within the CVP that NOD service contractor allocations will be equal to or greater than SOD service contractor allocations. The issue lies with how this policy is applied in the model. NOD service contractor allocations are calculated using the WSI-DI method; SOD service contractor allocations are calculated as the minimum of the WSI-DI–based allocation and the export forecast–based allocation. This, at times, artificially constrains system-wide allocations based solely on low conditions at Shasta and Trinity.

In other words, the model ignores the details that operators would consider in developing a real-time service contractor allocation. Note that NOD Ag Service contracts along the Sacramento River total 377 TAF. As such, a NOD Ag Service allocation increase of 1 percent would expose Shasta and Trinity to a combined 4 TAF of additional drawdown. Also consider that SOD Ag Service contracts total 1,987 TAF. Therefore a 1 percent increase in SOD Ag Service allocations would require 20 TAF of combined drawdown in San Luis and/or increased exports. If in actual operations the CVP operators see the potential to boost SOD Ag Service allocations by 100 TAF due to high San Luis storage levels—an allocation increase of approximately 5 percentage points. There may be concern about boosting NOD Ag Service allocations by an equal percentage, but the operators would understand that such an increase would only result in an additional 20 TAF of load on Shasta and Trinity. There are certainly cases where such a tradeoff would be made, and years 1932–1937 as simulated in CalSim_27JAN2015 appear to be such cases.

The modification applied in CalSim_27JAN2015_Revised was to conditionally reformulate CVP Ag Service allocations in contract years 1932–1937. In these years, allocations for both NOD and SOD service contractors are allowed to be driven by the export-based methodology when appropriate. This does not circumvent the standard policy of maintaining NOD service contractor allocations at or above SOD allocations; this policy is maintained. The result of this change in allocation formulation is shown in Figure 11 and Figure 12. The data points highlighted in red correspond to the same annual data points highlighted in Figure 9 and Figure 10. The San Luis low point in these years has been significantly reduced in CalSim_27JAN2015_Revised as compared to CalSim_27JAN2015 and the impact to upstream carryover is acceptable.

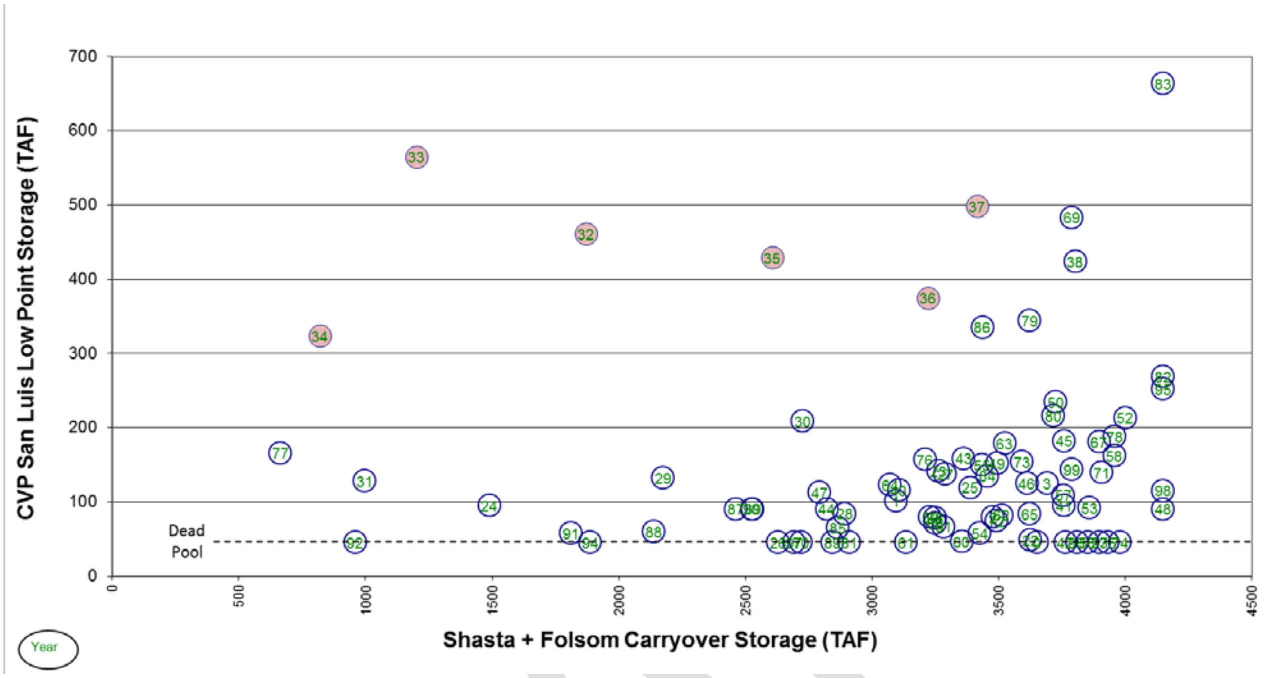


**Figure 9. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015 with contract year data label**

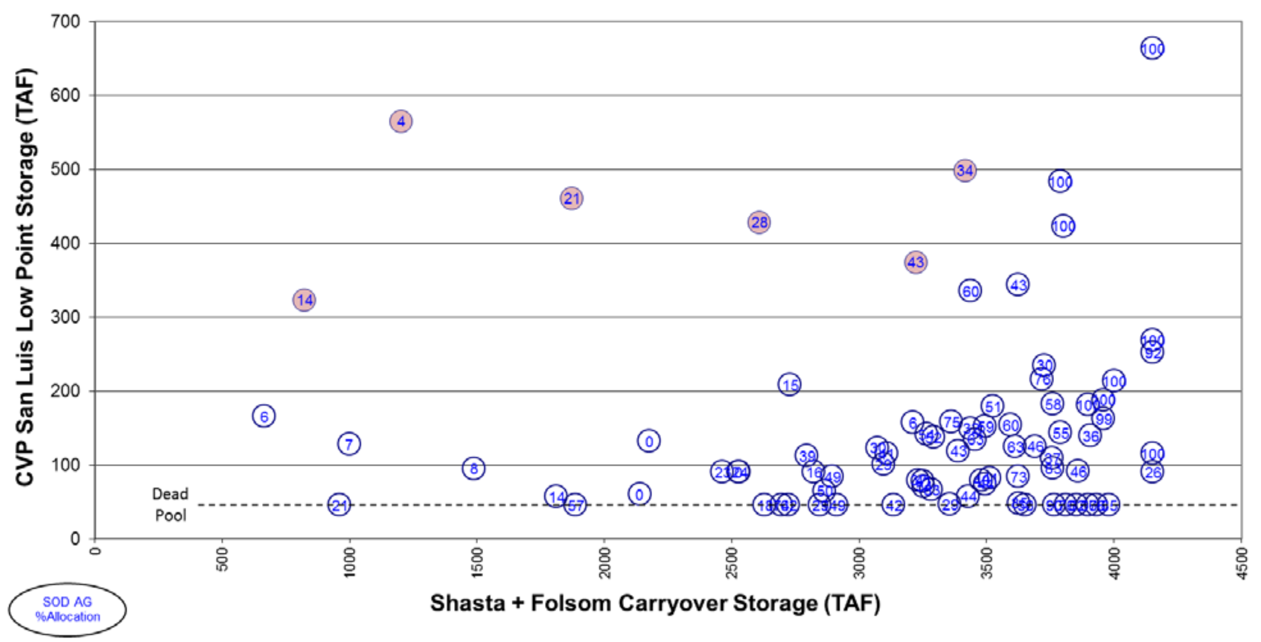


**Figure 10. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015 with SOD Ag Service allocation data label**

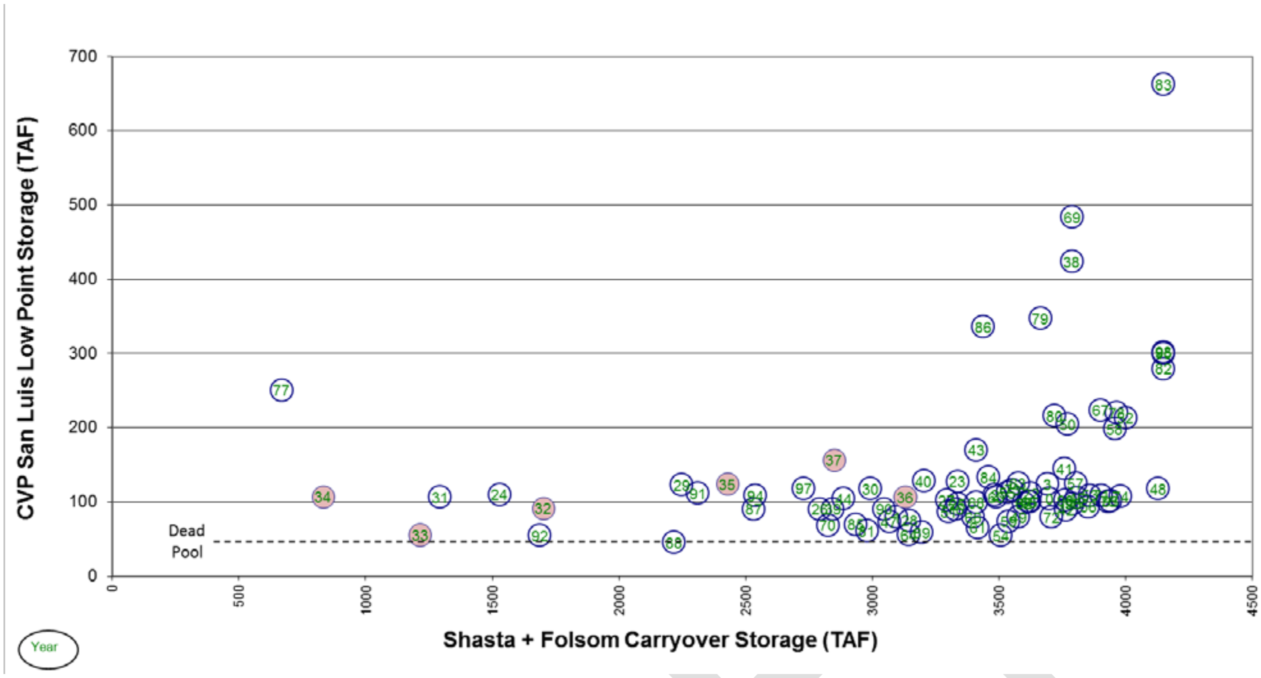


**Figure 11. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015_Revised with contract year data label**

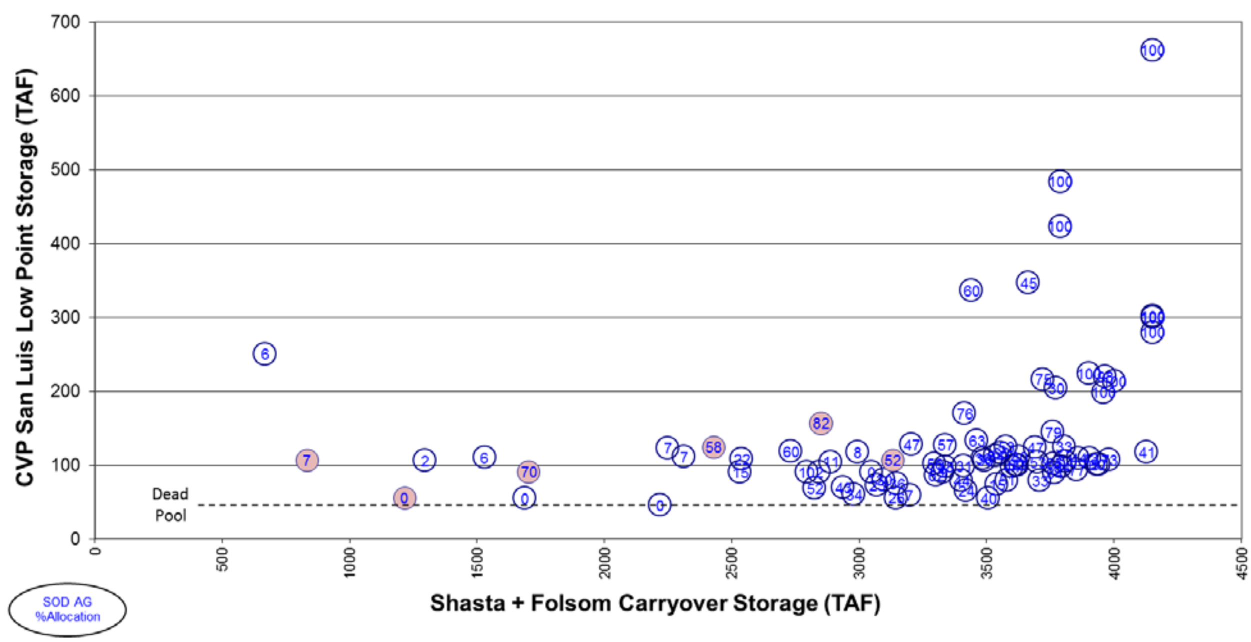


**Figure 12. CVP San Luis low point storage versus combined Shasta and Folsom carryover in CalSim_27JAN2015_Revised with SOD Ag Service allocation data label**

As discussed above, CalSim_27JAN2015_Revised results as plotted in Figure 5, Figure 6, Figure 7, Figure 8, Figure 11, and Figure 12 were significantly influenced by the revised export forecast used in CVP and SWP allocations and the reformulation of CVP allocation logic in 1932–1937. Two more changes were also made to CalSim_27JAN2015_Revised that affected results. However, while important to NOD-SOD storage balance, these changes are less significant than those already discussed. The first of these additional edits is refinement of San Luis rulecurve for the SWP and CVP, and the second is an adjustment to operational logic under an ANN negative carriage constraint; these edits are detailed below.

## Rulecurve

The purpose of rulecurve is to prioritize balance between NOD storage and San Luis for both the CVP and SWP. Rulecurve controls upstream release for export when there is a choice between storing water in upstream reservoirs and releasing water for export and storing it in San Luis. Operational constraints such as flood pool, minimum instream flow requirements, export regulations, H&S pumping requirements, and physical pump capacity override rulecurve; and when any of these control operations, choices for balancing NOD storage are limited.

During the winter, rulecurve is set to encourage the filling of San Luis though it rarely controls. Incidental Delta inflow typically drives San Luis filling during the rainy season. Upstream reservoir releases are often controlled by flood pool or minimum flow requirements, and exports are controlled by OMR flow requirements or maximum pumping capacity. Since rulecurve does not play a significant role in driving winter San Luis operations, there was no need to modify wintertime rulecurve logic.

Where rulecurve does make a difference (or should make a difference) is during irrigation season when there are windows of opportunity to coordinate upstream reservoir releases with Delta exports. During the summer, SOD project demand typically exceeds Delta exports. As such, SOD project demand is met with a combination of Delta exports and San Luis releases, and if rulecurve is controlling, it influences the balance between Delta exports and San Luis reservoir releases. If rulecurve is set lower, exports decrease and San Luis releases increase. When set higher, the opposite occurs. Ideally the combination of San Luis releases and project exports over the irrigation season is sufficient to satisfy project allocations and San Luis targeted carryover storage, and rulecurve should be set to encourage the appropriate balance.

Therefore, formulation of rulecurve during the irrigation season should boil down to an export scheduling problem, to be solved by determining how much to export within a season to achieve delivery and carryover goals, how to distribute these exports from month to month, and where to set SWP and CVP rulecurve to encourage those Delta exports and the supporting upstream releases. The problem with the current irrigation season rulecurve formulations in CalSim is that they do not consider the amount of exports needed over the season. In fact, for both the SWP and CVP, the rulecurve formulation assumes exports of 60 TAF per month whether that is sufficient to meet operational objectives or not. Rulecurve levels are driven by this export assumption.

The implemented fix to the irrigation season rulecurve formulation is to incorporate export scheduling in CalSim_27JAN2015_Revised; SWP and CVP formulations vary slightly. With the CVP, exports need to be scheduled to ensure the project can meet peak summer demand and prevent San Luis low point issues through the end of September. The SWP has similar concerns, but must also consider Article 56 carryover into the next calendar year with the added complication of Feather River flow limitations for half of October and all of November that can interfere with the

State's ability to make Oroville releases for export. So while the CVP's export scheduling formulation extends from May through September, the SWP's starts in April and extends through December. As an example, the SWP export schedule–based rulecurve formulation for the months of April–December is outlined below.

First, needed exports are calculated from the beginning of the current month of the simulation through the end of December (Required_Exports_NowtoDec (TAF)).

(1) Required_Exports_NowtoDec = max(0, remainDem_SOD + remain_evap + remain_loss + max(110, carryover_final + 55) – Beg_Month_SWP_San_Luis_Storage)

Where

- remainDem_SOD is the remaining Table A allocations to be delivered from now to the end of December (TAF)
- remain_evap is an estimate of total evaporation over the rest of the calendar year (TAF)
- remain_loss is an estimate of the total California Aqueduct losses over the rest of the calendar year (TAF)
- 110 is the SWP San Luis carryover target (TAF)
- carryover_final is the quantity of water needed in San Luis at the end of December to make Article 56 deliveries (TAF)
- 55 is SWP San Luis dead pool capacity (TAF)
- Beg_Month_SWP_San_Luis_Storage is SWP San Luis storage at the beginning of the current month of simulation (TAF)

Next, the amount that should be exported this month (Required_Exports (TAF)) in order to achieve the export goal for the remainder of the calendar year (Required_Exports_NowtoDec) is calculated. Assume exports will be scheduled uniformly over the remaining months of the calendar year, except for half of October and all of November due to Feather River flow restrictions. During the Feather River flow restrictions, we assume Banks pumping is held to the H&S level (300 cfs), which equals approximately 27 TAF over 1.5 months or 18 TAF over 1 month. So the formulation varies by month:

For the months April–September, the formulation is:

(2a) Required_Exports = (Required_Exports_NowtoDec - 27)/(remain_months - 1.5)

For the month of October, the formulation is:

(2b) Required_Exports = (Required_Exports_NowtoDec - 18)/(remain_months - 1)

And for the months of November–December the formulation is:

(2c) Required_Exports = Required_Exports_NowtoDec/remain_months

Where

- remain_months is the number of months remaining in the calendar year starting from the beginning of this month of simulation to the end of December

At this point in the calculation, SWP exports could be prioritized up to Required_Exports such that Oroville releases would be made to support those exports. But that is not the modeling technique used in CalSim. As discussed, the balance of upstream storage and San Luis storage is guided with rulecurve; so to prioritize SWP exports up to Required_Exports, rulecurve must be appropriately set. Expected change in San Luis storage (Change_San_Luis_Storage (TAF)) if exports equal Required_Exports is now calculated. The formulation is:

(3) Change_San_Luis_Storage = Required_Exports – This_Month_Forecasted_Delivery – This_Month_Forecasted_Loss – This_Month_Forecasted_Evap

Where

- This_Month_Forecasted_Delivery is this month's estimated Table A deliveries (TAF)
- This_Month_Forecasted_Loss is this month's estimated California Aqueduct losses (TAF)
- This_Month_Forecasted_Evap is this month's estimated SWP San Luis evaporation (TAF)

Given the calculated Change_San_Luis_Storage, the rulecurve (SWP_Rulecurve (TAF)) that will encourage sufficient Oroville releases to support SWP exports at Required_Exports is determined as follows:

(4) SWP_Rulecurve = Beg_Month_SWP_San_Luis_Storage + Change_San_Luis_Storage

## Negative Carriage Operations

Delta carriage is the additional Delta outflow above minimum required Delta outflow (MRDO) necessary to meet D-1641 salinity standards. When salinity is controlling, an increase in exports requires an increase in release from upstream reservoirs to the Delta that equals the export increase plus carriage. In other words, carriage is the water cost of Delta exports when salinity standards are controlling. While higher exports typically result in higher carriage, there are times of the year when Rock Slough and Emmaton salinity standards can be met with higher exports and negative carriage. Essentially, when a negative carriage salinity constraint is controlling, a unit increase in Delta exports is supplied partially by a decrease in carriage (decrease in Delta outflow) and the remainder by an increase in upstream reservoir release. While negative carriage might be counterintuitive, it is an actual phenomenon observed in Delta operations.

Negative carriage in CalSim presents problems of prioritization. In CalSim, Delta outflow above MRDO, whether the outflow is surplus or carriage, is given a highly negative weight (low priority). The intent is to discourage any Delta outflow in excess of MRDO. So when a negative carriage salinity constraint is controlling operations, CalSim will operate to minimize Delta outflow even though it might cause an imbalance between NOD and SOD storage. Delta outflow is reduced through increased exports, but some water still has to be released from upstream reservoirs to support part of the increased export. If NOD reservoirs are relatively full, this could be a desirable operation, but if NOD reservoirs are low and further exports are not needed to support this year's allocation, minimizing Delta outflow at the expense of upstream storage is an unwarranted operational decision. During the critical periods, CalSim makes several of these decisions that result in the transfer of NOD storage to San Luis when the water would be better kept NOD.

The implemented negative carriage operation fix in CalSim_27JAN2015_Revised is to remove the model flexibility to make an unwarranted decision. In CalSim, SWP and CVP export estimates are made to guide operations when salinity standards are controlling (C400_MIF logic). This is used to ensure that needed exports are made even if positive carriage must be paid. In CalSim_27JAN2015_Revised, similar export estimates are now used to limit how much carriage can be reduced through increases in exports under a negative carriage constraint. Essentially, under an Emmaton or Rock Slough negative carriage constraint, the carriage is held at the level to support the estimated export – no more and no less. CalSim does not get an objective function benefit of releasing more water from upstream storage for a fractional reduction in Delta outflow.

## Comparison of CalSim_27JAN2015 and CalSim_27JAN2015_Revised Results

The revisions in CalSim_27JAN2015_Revised change the storage balance between Oroville and SWP San Luis. Figure 13 and Figure 14 relate SWP San Luis low point storage to Oroville carryover in each year of the CalSim_27JAN2015 simulation. The only difference between the two figures is that data in Figure 13 is labeled by year and data in Figure 14 is labeled by Table A allocation. Note the years that SWP San Luis low point is at dead pool. This occurs over a wide spectrum of Oroville carryover and Table A allocations. Also note the four data points highlighted in red—1925, 1932, 1949, and 1955 with Table A allocations of 37%, 28%, 29%, and 38%, respectively. Ideally, higher allocations would have been made in these years, reducing San Luis low point storage. Figure 15 and Figure 16 relate SWP San Luis low point storage to Oroville carryover storage in each year of the CalSim_27JAN2015_Revised simulation. Compare Figure 15 and Figure 16 to Figure 13 and Figure 14, respectively to see the effect of the model edits (export forecast, rulecurve, and negative carriage) on the overall San Luis-Oroville storage balance. Note that the San Luis low point has been largely lifted above dead pool in CalSim_27JAN2015_Revised. Also note the red highlighted data points in Figure 15 and Figure 16, which correspond to the same years highlighted in red in Figure 13 and Figure 14. The combined effect of the model edits creates a more ideal balance between Oroville storage, SWP San Luis storage, and Table A allocations.

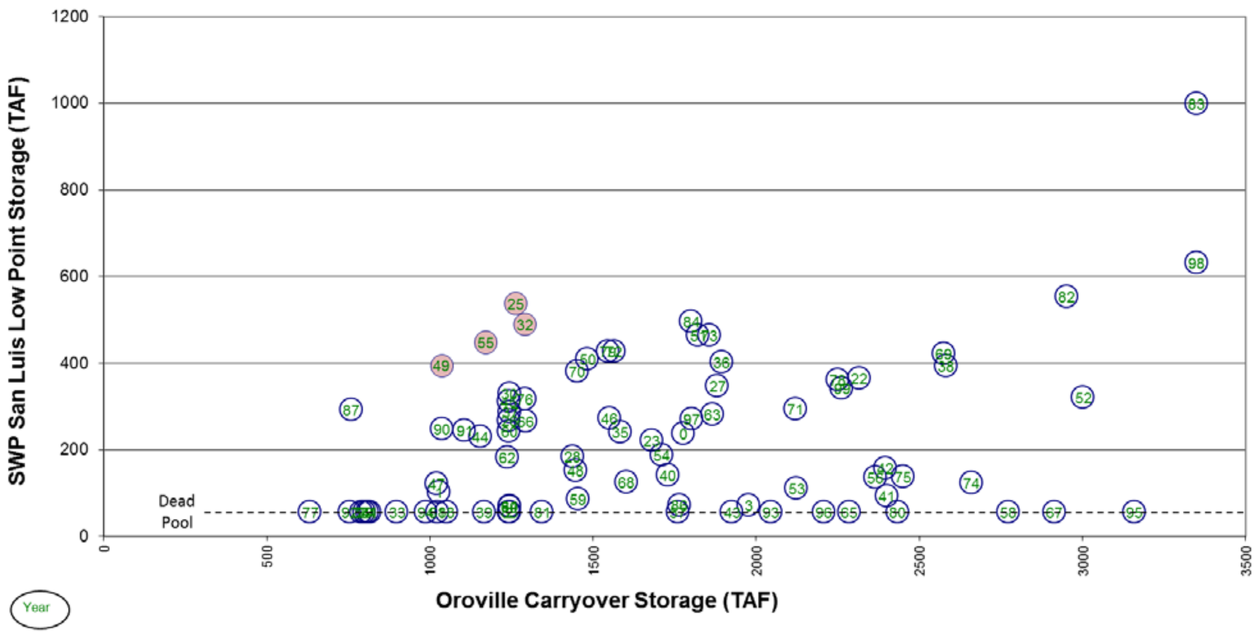


**Figure 13. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015 with contract year data label**

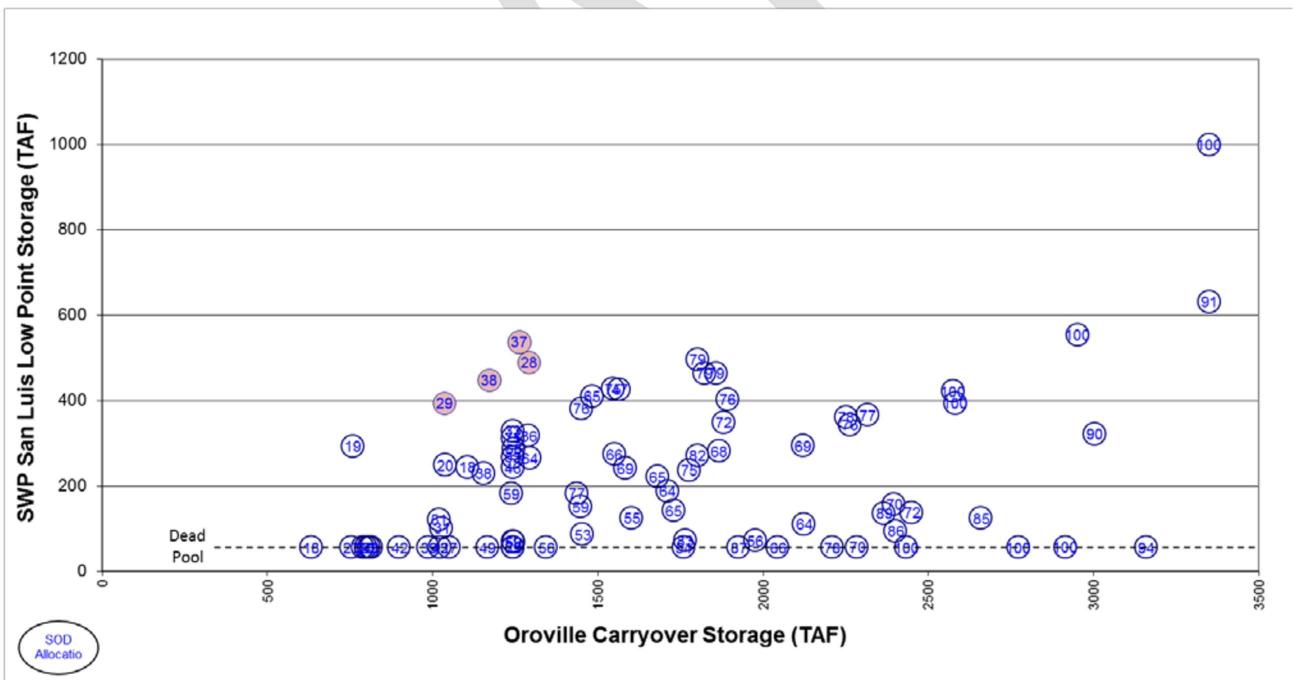


**Figure 14. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015 with Table A allocation data label**

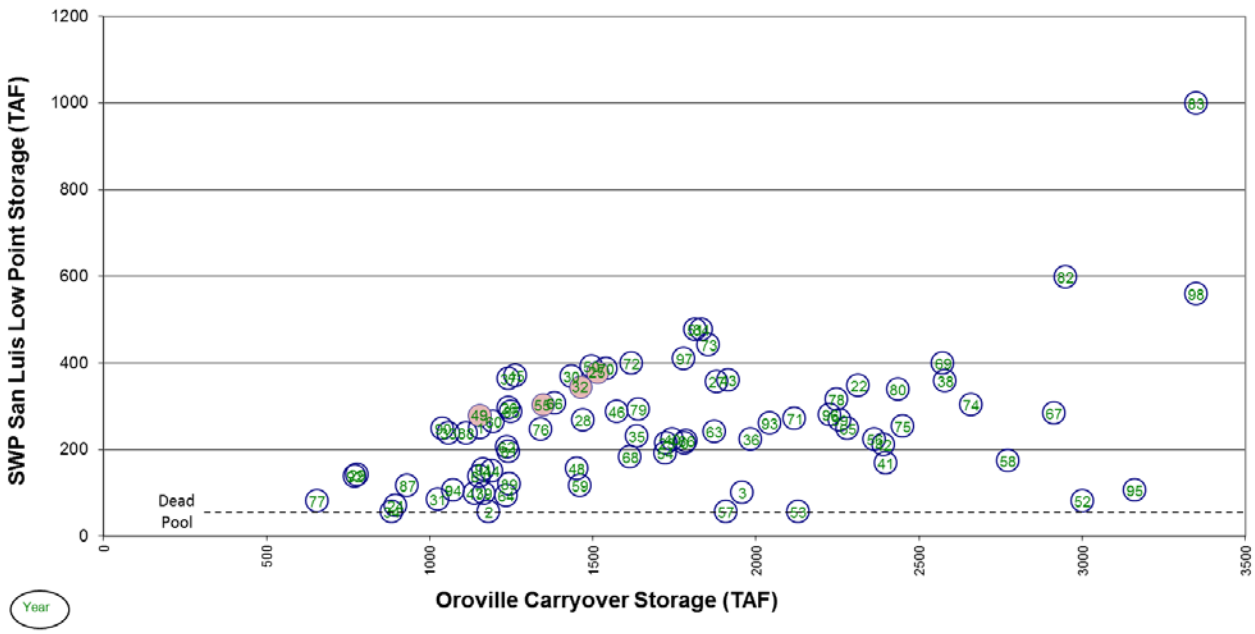


**Figure 15. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015_Refined with contract year data label**

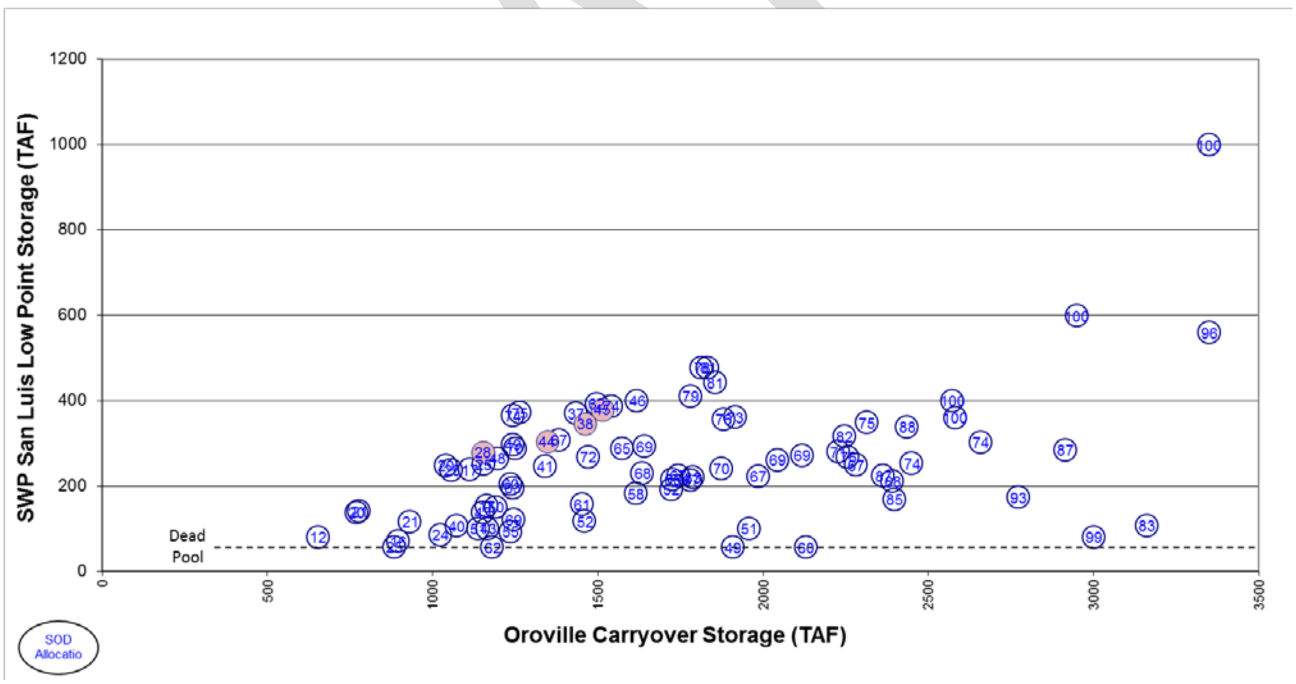


**Figure 16. SWP San Luis low point storage versus Oroville carryover in CalSim_27JAN2015_Revised with Table A allocation data label**

CVP San Luis storage often hits its annual low point in August. Figure 17 compares CVP San Luis end of August storage probability of exceedance curves for CalSim_27JAN2015 and CalSim_27JAN2015_Revised. In CalSim_27JAN2015, there is an almost 20% chance that end of August CVP San Luis storage is at dead pool; there is only slightly more than a 1% chance in

CalSim_27JAN2015_Revised. Also, in CalSim_27JAN2015_Revised, CVP San Luis is consistently drawn down to the 90 TAF low point target used in the CVP SOD export forecast allocation logic, whereas CalSim_27JAN2015 tends to diverge from this target.

SWP San Luis storage often hits its annual low point in October. Figure 18 compares SWP San Luis end-of-October storage probability of exceedance curves for CalSim_27JAN2015 and CalSim_27JAN2015_Revised. In CalSim_27JAN2015, there is a greater than 16% chance that end-of-October SWP San Luis storage is at dead pool; there is only a 3% chance in CalSim_27JAN2015_Revised. The low point target used in SWP export forecast allocation logic is 110 TAF. There is no obvious drawdown to this target in Figure 18 because of Article 56 carryover. CalSim_27JAN2015_Revised does a better job of preserving Article 56 requested by contractors. This is more evident when comparing CalSim_27JAN2015_Revised and CalSim_27JAN2015 Article 56 deliveries.

Model revisions also affect NOD carryover storage (end of September). Figure 19 through Figure 22 show the CalSim_27JAN2015 and CalSim_27JAN2015_Revised carryover storage probability exceedance curves for Trinity, Shasta, Folsom, and Oroville reservoirs, respectively. As shown, the model revisions had a largely positive effect on upstream carryover storage.

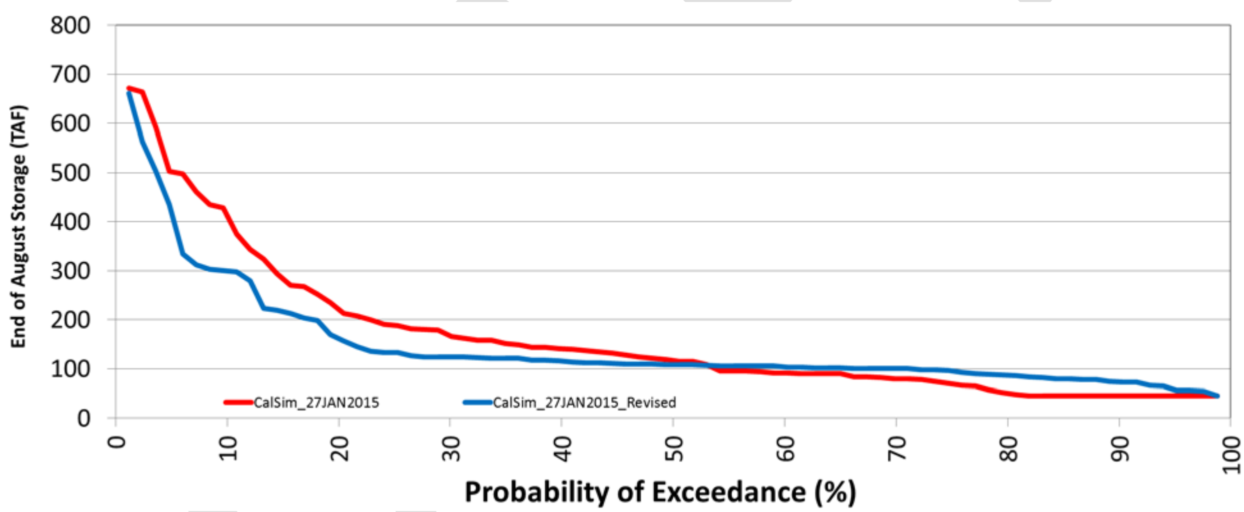


**Figure 17. CVP San Luis end of August storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

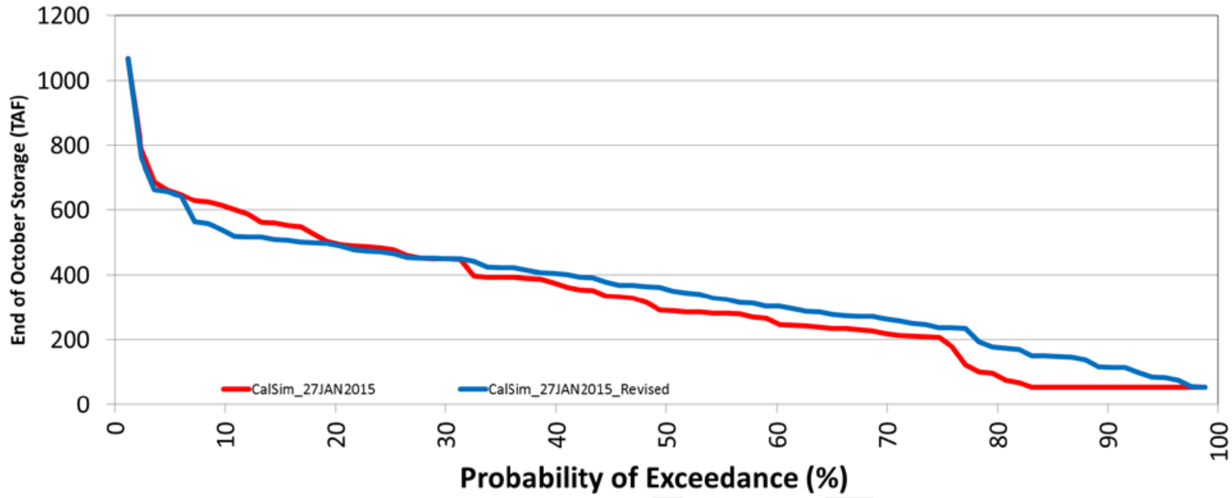


**Figure 18. SWP San Luis end of October storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

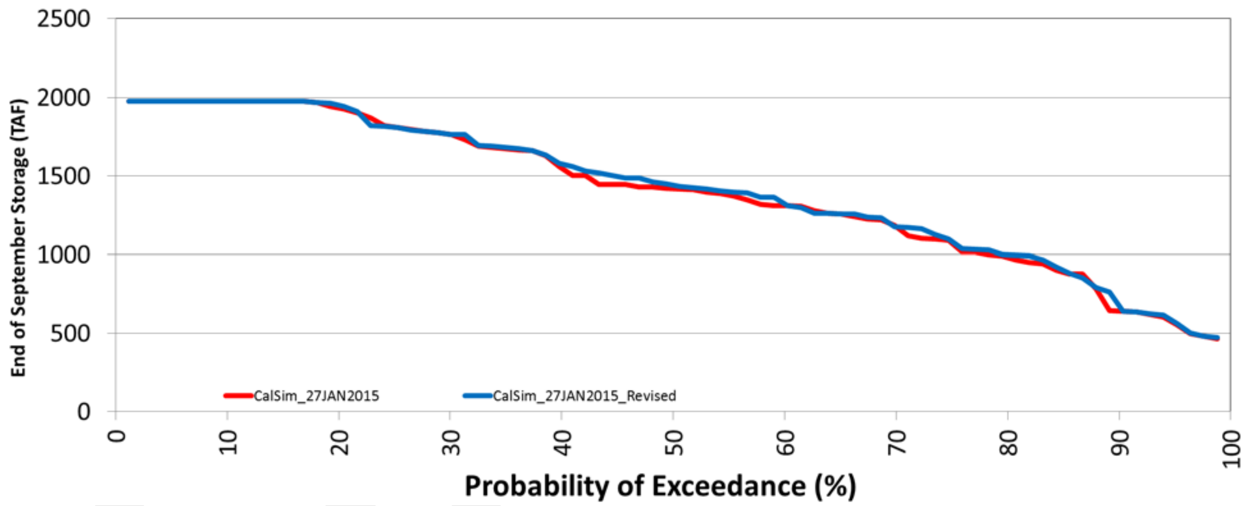


**Figure 19. Trinity carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

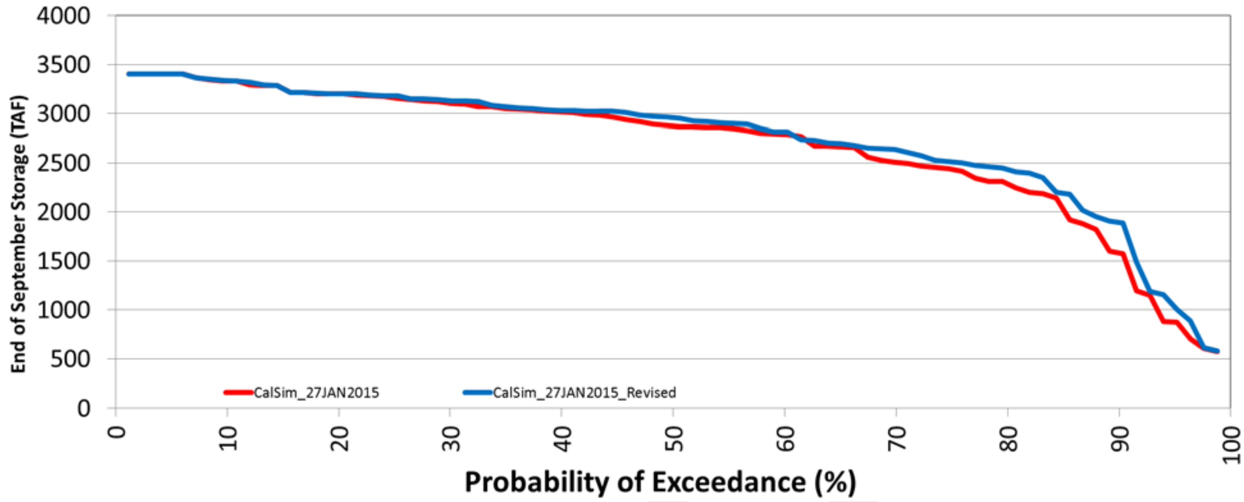


**Figure 20. Shasta carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

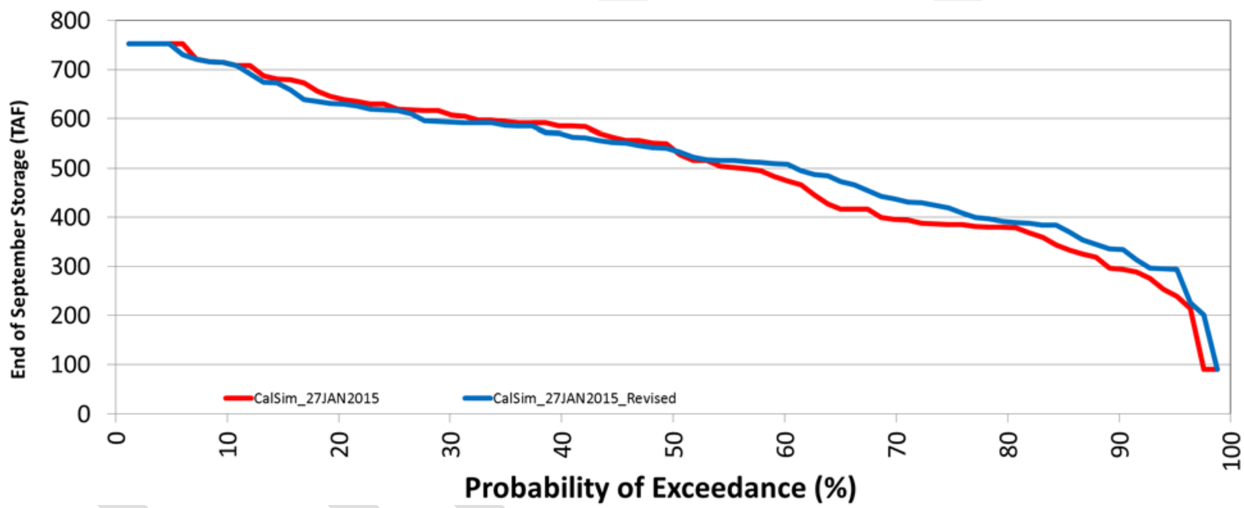


**Figure 21. Folsom carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

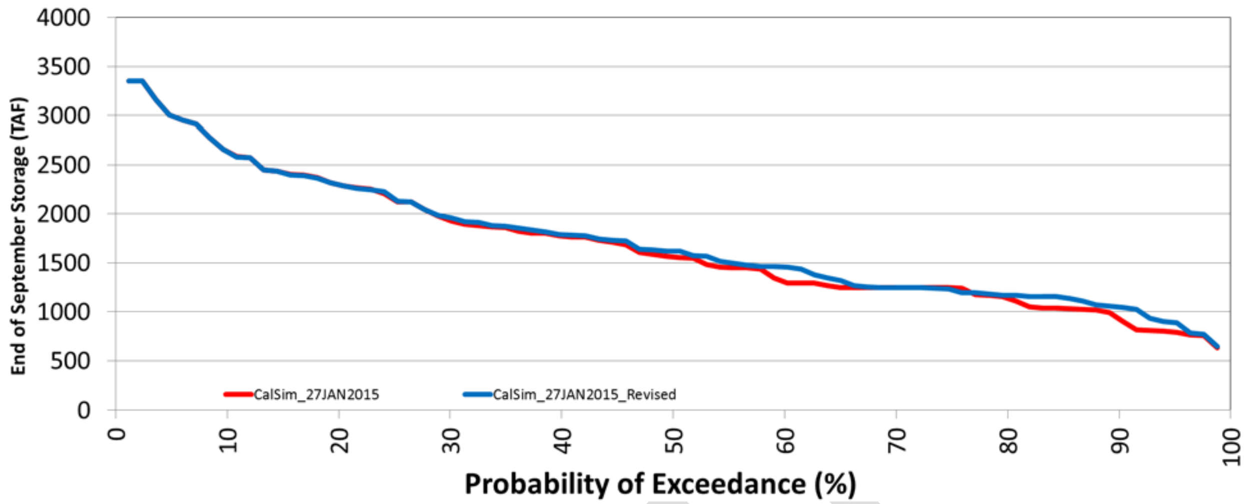


**Figure 22. Oroville carryover storage probability of exceedance for CalSim_27JAN2015 and CalSim_27JAN2015_Revised**

Significant changes in project reservoir operations necessarily affect project deliveries. Table 5 and Table 6 quantify the difference in CVP NOD and SOD project deliveries by month and water year type. Overall, CVP NOD project deliveries increased by 13 TAF, whereas CVP SOD project deliveries decreased by 25 TAF.

**Table 5. Change in total CVP NOD project deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| AN | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 | 2 | 1 | 8 |
| BN | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 7 | 8 | 7 | 3 | 34 |
| D | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 4 | 3 | 1 | 16 |
| C | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 10 |
| All | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 3 | 2 | 1 | 13 |

**Table 6. Change in total CVP SOD project deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | -2 | -1 | -2 | -3 | -4 | 2 | -3 | -3 | -5 | -6 | 11 | -2 | -18 |
| AN | -3 | -2 | -3 | -5 | -5 | 4 | -4 | -5 | -8 | -10 | 3 | -2 | -41 |
| BN | 0 | 0 | 0 | -1 | -1 | 9 | 8 | 9 | 14 | 18 | 13 | 4 | 73 |
| D | 0 | 0 | 0 | 0 | 0 | 1 | -6 | -8 | -13 | -16 | -9 | -4 | -57 |
| C | -1 | -1 | -1 | -2 | -2 | -4 | -7 | -12 | -17 | -22 | -13 | -6 | -89 |
| All | -1 | -1 | -1 | -2 | -2 | 2 | -2 | -4 | -6 | -7 | 2 | -2 | -25 |

Table 7 through Table 9 quantify the difference in SWP Table A, Article 56, and Article 21 project deliveries by month and water year type. Overall, Table A deliveries decreased 44 TAF, Article 56 deliveries increased 7 TAF, and Article 21 deliveries decreased 11 TAF. It is expected that reduced Table A allocations would result in fewer Article 56 requests. The reason for higher Article 56 deliveries is that the improved San Luis operation results in fewer Article 56 shortages.

**Table 7. Change in SWP Table A deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | -2 | 6 | -2 | 1 | -3 | 11 | -10 | -11 | -11 | -8 | -7 | -6 | -41 |
| AN | 21 | -10 | -25 | 1 | 0 | 1 | -12 | -13 | -15 | -16 | -16 | -12 | -97 |
| BN | 0 | -3 | -14 | 8 | -6 | -6 | -4 | -3 | -1 | 0 | 0 | 0 | -30 |
| D | -9 | -6 | -40 | 1 | 1 | 2 | 15 | 9 | 7 | 6 | 14 | 14 | 13 |
| C | 10 | 7 | -6 | 0 | 0 | -1 | -1 | -18 | -30 | -39 | -38 | 17 | -97 |
| All | 2 | 0 | -16 | 2 | -2 | 3 | -3 | -6 | -9 | -9 | -7 | 2 | -44 |

**Table 8. Change in SWP Article 56 deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 0 | 0 | 0 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 11 |
| AN | 0 | 0 | 0 | -4 | -2 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | -7 |
| BN | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |
| D | 0 | 0 | 0 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| C | 0 | 0 | 0 | 4 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 9 |
| All | 0 | 0 | 0 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 7 |

**Table 9. Change in SWP Article 21 deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 0 | 0 | 0 | -7 | -6 | 7 | -2 | 0 | 0 | 0 | 1 | 0 | -7 |
| AN | 0 | 0 | -1 | -2 | -1 | -1 | 0 | 0 | 0 | 0 | 1 | 0 | -4 |
| BN | 0 | 0 | 0 | 0 | -1 | -25 | 0 | 0 | 0 | 0 | 0 | 0 | -25 |
| D | 0 | 0 | 0 | 0 | -4 | -2 | 0 | 0 | 0 | 0 | 1 | 0 | -6 |
| C | 0 | 0 | 0 | 0 | -14 | -7 | 0 | 0 | 0 | 0 | 0 | 0 | -20 |
| All | 0 | 0 | 0 | -2 | -5 | -4 | -1 | 0 | 0 | 0 | 1 | 0 | -11 |

Table 10 quantifies the difference in Feather River Settlement Contractor fall rice decomposition deliveries by month and water year type. The annual average difference between the CalSim_27JAN2015_Revised and CalSim_27JAN2015 is 8 TAF. CalSim meets less than the rice decomposition demand when Oroville storage drops below 1.2 MAF. Since CalSim_27JAN2015_Revised maintains higher Oroville storage than CalSim_27JAN2015, the revised study is able to meet more of the rice decomposition demand annually.

**Table 10. Change in Feather River Settlement Contractor rice decomposition deliveries between CalSim_27JAN2015_Revised and CalSim_27JAN2015 (TAF)**

| Indx | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 |
| AN | -2 | -2 | -1 | -1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -6 |
| BN | 4 | 6 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| D | 4 | 4 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| C | 4 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12 |
| All | 2 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |

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