Appendix C

System Reoperation: Phase III

STATE WATER PROJECT AND CENTRAL VALLEY PROJECT INTEGRATED OPERATIONS ANALYSIS

Prepared by

MBK ENGINEERS

455 University Avenue, Suite 100
Sacramento, California 95825
916.456.4400 (phone) ◆ www.mbkengineers.com

TABLE OF CONTENTS

Figures

I. Introduction

The California Department of Water Resources (DWR) is conducting a system reoperation study (SRS) in cooperation with other state and federal agencies, local water districts, groundwater managers, and other stakeholders to identify potential strategies for reoperation of the statewide flood protection and water supply systems. The opportunity to reoperate portions of California's statewide water system to yield increased water resources–related benefits was recognized by the State Legislature in Senate Bill (SB) X2 1 (Perata, 2008 – Water Code Section 83002.5).

In support of the legislative objectives, DWR developed the SRS to identify viable reoperation strategies and understand how integrated management can:

- Improve the reliability of municipal and irrigation water supply
- Reduce flood hazards
- Restore and protect ecosystem function and habitat conditions
- Buffer the hydrologic variations expected from climate change
- Improve water quality

A component of the SRS is to evaluate how operational improvements of the state and federal water Projects in California may increase water supply and enhance ecosystem function and habitat. The Central Valley Project (CVP) generally has more storage and less conveyance flexibility; the opposite is generally true for the State Water Project (SWP). The SWP and CVP are operated by DWR and the U.S. Bureau of Reclamation (Reclamation), respectively. The operation of the two Projects is coordinated in accordance with the 1986 Coordinated Operating Agreement and other agreements. Though the operation is coordinated, the SWP and CVP are operating as two distinct units. They each have different contractual obligations and operating constraints. Operational improvements using strengths and assets of both Projects may result in improved operational efficiency and help achieve goals of the SRS. The purpose of this effort is to assess potential benefits of operating the SWP and CVP as a single, integrated Project.

Background

CVP and SWP Facilities

This reoperation analysis focuses on the major CVP and SWP storage facilities in the Sacramento River Basin, Delta export facilities, CVP and SWP San Luis Reservoir, and components of the Bay-Delta watershed affected by these Projects.

The major components of the CVP include Trinity Lake on the Trinity River, Shasta Lake on the Sacramento River, and Folsom Lake on the American River. Water from Trinity River is stored in Trinity Lake and re-regulated in Lewiston Lake and Whiskeytown Reservoir, and diverted through a system of tunnels and power plants into the Sacramento River. Water is also stored and re-regulated in Shasta Lake on the Sacramento River and Folsom Lake on the American River. Reclamation operates each of these facilities as an integrated unit to satisfy a multitude of diverse objectives. CVP supplies are delivered to contractors directly from or immediately below the dams' outlet works. Other CVP contractors, Sacramento River water right contractors, and water right holders divert water directly from the Sacramento and American rivers. A key component of CVP operations is protection of environmental conditions and providing suitable habitat for various species of fish and wildlife.

The Sacramento River carries water to the Sacramento-San Joaquin Delta. The CVP's Jones Pumping Plant (Jones) at the southern end of the Delta lifts the water into the Delta-Mendota Canal. This canal delivers water to CVP water service contractors, exchange contractors on the San Joaquin River, and water rights contractors on the Mendota Pool. CVP water is also conveyed to San Luis Reservoir for deliveries to CVP contractors through San Luis Canal. Water from San Luis Reservoir can also be conveyed through Pacheco Tunnel to CVP contractors in Santa Clara and San Benito counties.

Lake Oroville stores and re-regulates Feather River water. SWP contractors and Feather River water rights contractors divert water from the Feather and Sacramento rivers. SWP water flows in the Sacramento River to the Delta and is exported from the Delta at Banks Pumping Plant (Banks). Banks lifts water into the California Aqueduct, which delivers water to SWP contractors and conveys water to San Luis Reservoir. SWP contractors are in the southern Bay Area, southern San Joaquin Valley, Central Coast area, and Southern California. The SWP also delivers water to the Cross Valley Canal (CVC) for CVP water service contractors when the systems have capacity.

The CVP has a storage capacity of about 8 million acre-feet (MAF) in the Sacramento River Basin while the SWP storage capacity is about 3.5 MAF. The CVP has a maximum Delta export capacity of about 4,600 cubic feet per second (cfs), while the SWP has a maximum export capacity of about 10,300 cfs, but these capacities are often restricted by regulations. Figure 1 shows the major components of the CVP and SWP.

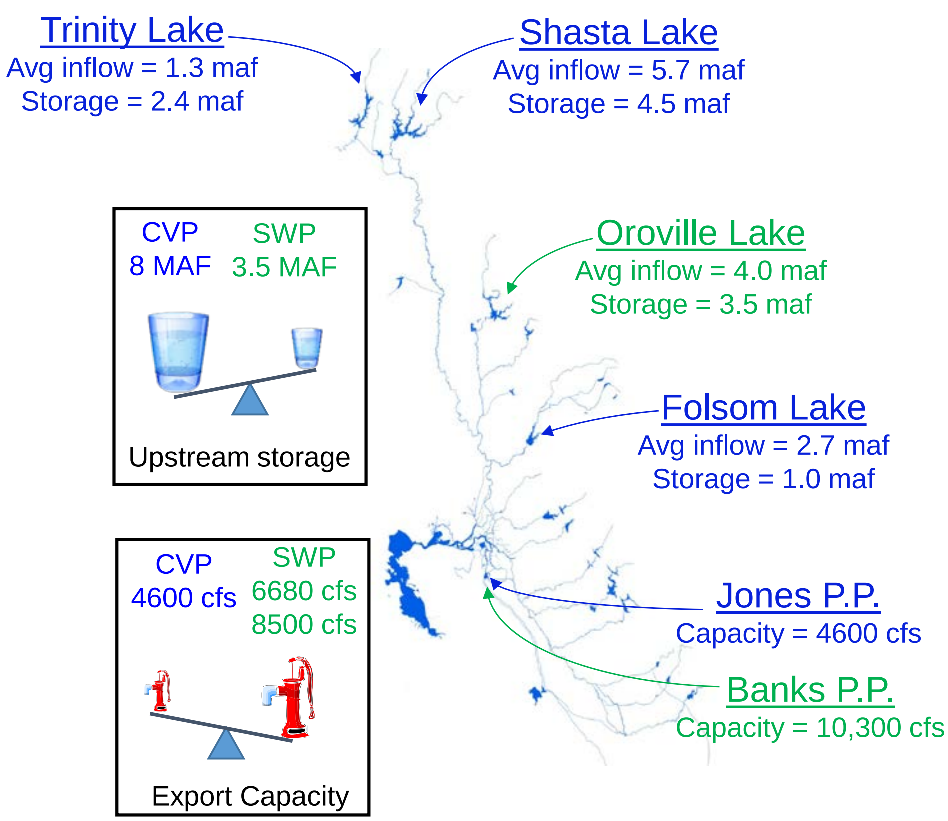

Figure 1. Major Components of the CVP and SWP

CVP and SWP Operating Criteria and Regulations

CVP and SWP operations are constrained by a myriad of requirements and agreements, including State Water Resources Control Board (SWRCB) orders and decisions, U.S. Army Corps of Engineers (USACE) requirements, National Marine Fishery Service (NMFS) biological opinions (BO) for protection of salmon, the U.S. Fish and Wildlife Service (USFWS) BO for protection of delta smelt, and others. These requirements generally specify operational limits such as maximum allowable storage, minimum river flows, maximum diversions, minimum water quality, and other criteria. In addition to criteria that set flow and reservoir requirements, the Coordinated Operating Agreement (COA) is foundational to how the CVP and SWP share obligations for meeting Delta requirements and share water supplies.

Coordinated Operating Agreement

CVP and SWP operations upstream of and in the Delta are coordinated and linked through the COA. The COA is both an operations agreement and a water rights settlement. Its history extends back to Reclamation protests of SWP water rights applications around 1960. The purpose of the COA is to ensure that the CVP and SWP each obtains its appropriate share of water from the Delta and bears its share of obligations to protect the other beneficial uses of water in the Delta and Sacramento Valley. Coordinated operation by agreed-on criteria can increase the efficiency of both the CVP and the SWP. The CVP and SWP (collectively, the Projects) use a common water supply in California's Central Valley. The Projects have built water conservation and delivery facilities in the Central Valley to deliver water supplies to affected water right holders as well as Project contractors. The Projects' water rights are conditioned by the SWRCB to protect the beneficial uses of water within each respective Project and jointly for the protection of beneficial uses in the Sacramento Valley and Sacramento-San Joaquin Delta Estuary (the Delta). The COA memorializes these facts and objectives into an agreement so the Projects can use the water resources for Project purposes and meet the common beneficial uses in the Sacramento Valley and the Delta.

In summary, the COA:

- Defines the Project facilities and their water supplies
- Sets forth procedures for coordination of operations
- Identifies formulas for sharing joint responsibilities for meeting Delta standards and other legal uses of water
- Identifies how unstored flow will be shared
- Sets up a framework for exchange of water and services between the SWP and CVP
- Provides for periodic review every five years, though it has not been updated since it was signed in 1986

The CVP and SWP use the Sacramento River and the Delta as common conveyance facilities. Reservoir releases and Delta exports must be coordinated to ensure that each Project achieves its share of benefit from shared water supplies and bears its share of joint obligations to protect beneficial uses.

In-basin uses are defined in the COA as legal uses of water in the Sacramento Basin, including the water required under the provisions of COA Exhibit A which is titled *Standards for the Sacramento-San Joaquin Delta*. The standards for the Sacramento-San Joaquin Delta at the time of the signing of the COA were defined in SWRCB Decision 1485 (D-1485). D-1485 ordered the CVP and SWP to guarantee certain conditions for water quality protection for agricultural, municipal and industrial (M&I), and fish and wildlife use. Each Project is obligated to ensure that water is available for these uses, but the degree of obligation depends on several factors and changes throughout the year. One factor is whether the Delta is in a balanced or excess condition. Balanced water conditions are defined in the COA as periods when it is agreed that releases from upstream reservoirs plus unregulated flows downstream of Project reservoirs approximately equal the water supply needed to meet Sacramento Valley in-basin uses plus exports. Excess water conditions are periods when it is agreed that releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in-basin uses plus exports. Reclamation's Central Valley Operations Office (CVOO) and DWR's SWP Operations Control Office (SWPOCO) jointly decide when balanced or excess water conditions exist.

During excess water conditions, sufficient water is available to meet all beneficial needs and the CVP and SWP are not required to supplement the supply with water from reservoir storage. Under Article 6(g) of the COA, during excess water conditions, Reclamation and DWR have the responsibility to store and export as much water as possible, within physical and contractual limits. In these cases, no accounting for responsibility is required. However, during balanced water conditions, the Projects share in meeting in-basin uses. Balanced water conditions are further defined according to whether water from upstream storage is required to meet Sacramento Valley in-basin use or unstored water is available for export. When water must be withdrawn from reservoir storage to meet in-basin uses, 75 percent of the responsibility is borne by the CVP and 25 percent is borne by the SWP. When unstored water is available for export (i.e., balanced water conditions plus when exports exceed storage withdrawals), the sum of CVP stored water, SWP stored water, and the unstored water for export is allocated 55/45 to the CVP and SWP, respectively.

II. INTEGRATION ANALYSIS

Analytical Approach

The purpose of this analysis is to evaluate how the CVP and SWP may operate to meet SRS goals without the constraints of the COA. Although DWR and Reclamation may have the ability to adjust the COA, they do not have the ability to alter other operational criteria and obligations. For the purpose of this analysis all flow and water quality requirements specified by the SWRCB, USFWS, NMFS, USACE, and others will be satisfied. In addition to flow and quality requirements, contractual obligations that DWR and Reclamation have with their contractors will be honored.

It is important to emphasize that by definitions in the COA, the CVP and SWP are already operating in an integrated manner. The Projects share available water supply and obligations to satisfy operational criteria. To operate in an integrated manner, COA accounting is performed on a daily basis and a cumulative account is maintained where COA debt, by either Project, may be accumulated over several months. Operators strive to operate as efficiently as possible and the COA provides operational flexibility through its accounting and allowance of COA debt. Project operators satisfy environmental criteria and meet obligations to the best of their ability and then tabulate COA accounting. COA debt is then repaid based on mutual agreement between Project operators.

Because the CVP has more storage and less conveyance flexibility and the opposite is true for the SWP, fundamental objectives of this analysis are for the Projects to benefit from unconstrained sharing of available conveyance capacity and variations in sharing of reservoir release obligations.

This analysis first evaluates historical CVP/SWP operations to identify how the COA may have limited operational efficiency over the past three decades, and then includes a simplified modeling analysis in which the CVP and SWP are operated as a single Project. The purpose of reviewing historical operations is to estimate the degree of system integration in the past and the potential that may have existed to increase operational efficiency.

Historical Operations Analysis

Review of historical operations provides insight into how the Projects operate in an integrated manner, and how they may have been able to operate more efficiently. The focus of this evaluation is historical sharing of Delta export facilities and sharing of reservoir release obligation. To perform this analysis, historical Project operations data was collected and evaluated. Evaluation of the historical data can then demonstrate how the Projects have operated in an integrated fashion and enable speculation regarding how they may have been able to increase benefits.

With highly variable hydrology, changing regulatory conditions, and nuances specific to each year of operation, it is difficult to interpret historical operations data and speculate how operators could have operated more efficiently. Therefore it is important to consider that this speculation is done without considering availability of information when operational decisions were made and the constraints and considerations that existed historically. This evaluation may therefore overestimate efficiency gains or benefits of more integrated operations.

Historical Sharing of Delta Export Facilities

Sharing of Delta export facilities has occurred frequently since both Projects have been in operation in the early 1970s. Because the SWP export facility has more capacity than the CVP facility, most of the past export sharing has been done by the CVP using SWP Banks to convey CVP supplies. Sharing of Delta export facilities is known as Joint Point of Diversion (JPOD). A description of JPOD can be found on DWR's website:

> The CVP and SWP historically have shared Delta export pumping facilities to assist with project deliveries and to aid each project during times of facility outages. In 1978, DWR agreed to, and the State Water Board permitted, the CVP to use the SWP Banks facility to export up to 195,000 acre-feet annually to replace pumping capacity lost at the CVP Jones facility because of striped bass pumping restrictions in D-1485. In 1986, Reclamation and DWR formally agreed that "either party may make use of its facilities available to the other party for pumping and conveyance of water by written agreement" and that the SWP would pump CVP water to make up for striped bass protection measures (California Department of Water Resources 2003a). Per D-1641, use of JPOD is subject to an operations plan that protects fish and wildlife and other legal users of water. Thus, such joint point pumping essentially occurs only under conditions acceptable to NOAA Fisheries, DFG, USFWS, and the State Water Board, among other considerations.[1]

Since 1977, annual CVP exports at SWP Banks have ranged from just under one-half million acre-feet to zero (Figure 2). Prior to the mid-1990s, federal pumping at Banks occurred in significant quantities in most years but has decreased considerably as regulatory requirements have increased. Changes in regulatory conditions have altered the need and ability to use JPOD; these changes include:

- SWRCB D-1641
- Stanislaus ROP NMFS BO (June 2009) Actions III.1.2 and III.1.3

[1] DWR BDO website: http://baydeltaoffice.water.ca.gov/sdb/sdip/features/ccf_diversions.cfm

- Trinity Preferred Environmental Impact Statement (EIS) Alternative
- NMFS 2004 Winter-Run BO
- NMFS BO (June 2009) Action I.2.1
- SWRCB WR90-5
- Central Valley Project Improvement Act (CVPIA) (b)(2) flows
- NMFS BO (June 2009) Action I.2.2
- American River Flow Management NMFS BO (June 2009) Action II.1
- Vernalis SWRCB D-1641 Vernalis flow and WQ and NMFS BO (June 2009) Action IV.2.1
- Delta D-1641 and NMFS Delta Actions, including Fall X2 USFWS BO (December 2008) Action 4
- Export restrictions, including NMFS BO (June 2009) Action IV.11.2v Phase II, Old and Middle Rivers (OMR) USFWS BO (December 2008) Actions 1–3; and NMFS BO (June 2009) Action IV.2.3v
- Others

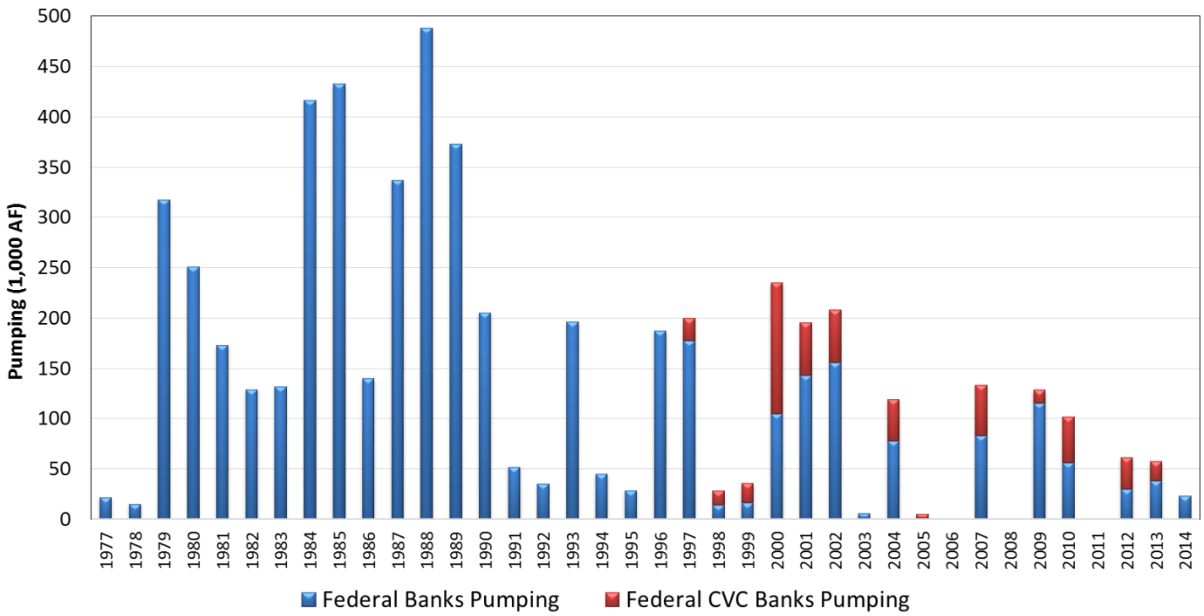

Figure 2. Historical JPOD – Federal Pumping at Banks Pumping Plant

In addition to the CVP using SWP Banks to convey supplies to contractors from the Delta-Mendota Canal and the California Aqueduct, the SWP conveys CVP water to the CVC; the quantity of CVC water exported at Banks is displayed in Figure 2. Although CVC exports at Banks comprise an important water supply, additional deliveries to CVC contractors are not considered in this analysis.

The opportunity to increase Delta exports through export sharing can be estimated by assessing historical unused capacity at Banks. Figure 3 shows historical annual pumping at Banks and unused capacity from 1985 through 2014. Unused capacity is tabulated for July through October because this is when JPOD may have been used. In many years there is ample capacity to export additional supply from the Delta.

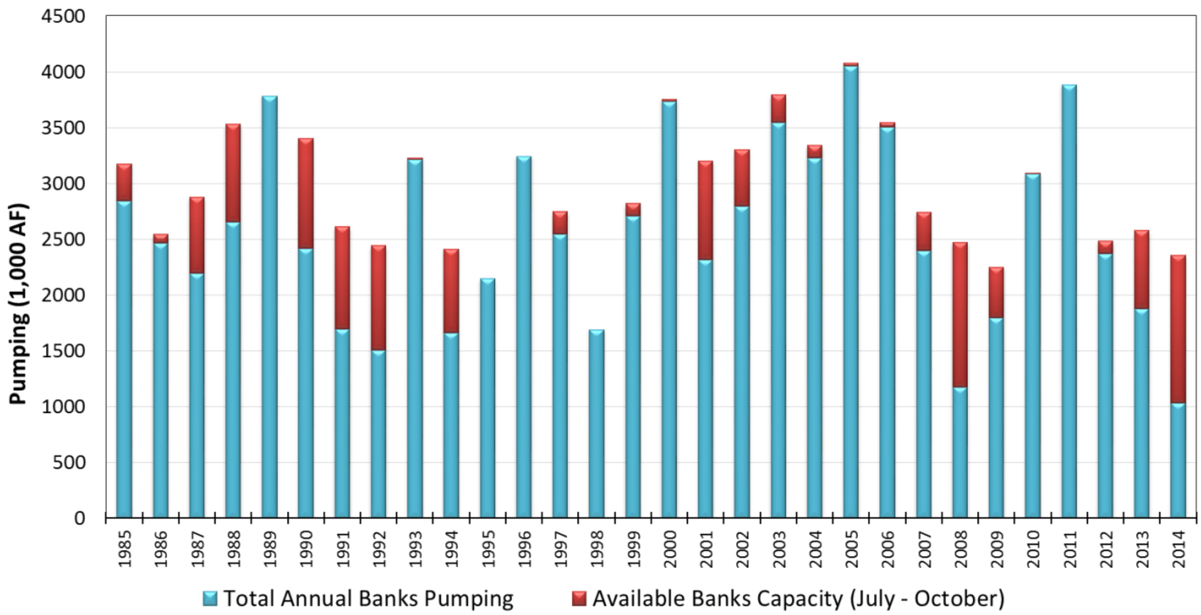

Figure 3. Banks Pumping and Available Capacity

The ability to export additional supply is a key component in estimating how much JPOD use could have been expanded historically, but availability of supply must also be considered. Estimation of available water supply can be made by taking historical carryover storage in upstream CVP reservoirs and assuming they could have been drawn to lower levels to increase water deliveries. Figure 4 and Figure 5 contain a chart of historical end-of-September (carryover) storage in Shasta Lake and Folsom Lake, respectively. Available supply is estimated by assuming that when Shasta carryover was above 3 MAF and Folsom carryover was above 450 thousand acre-feet (TAF), these reservoirs could be drawn down to increase water deliveries. The volume of available supply is shown in Figure 4 and Figure 5 as red bars.

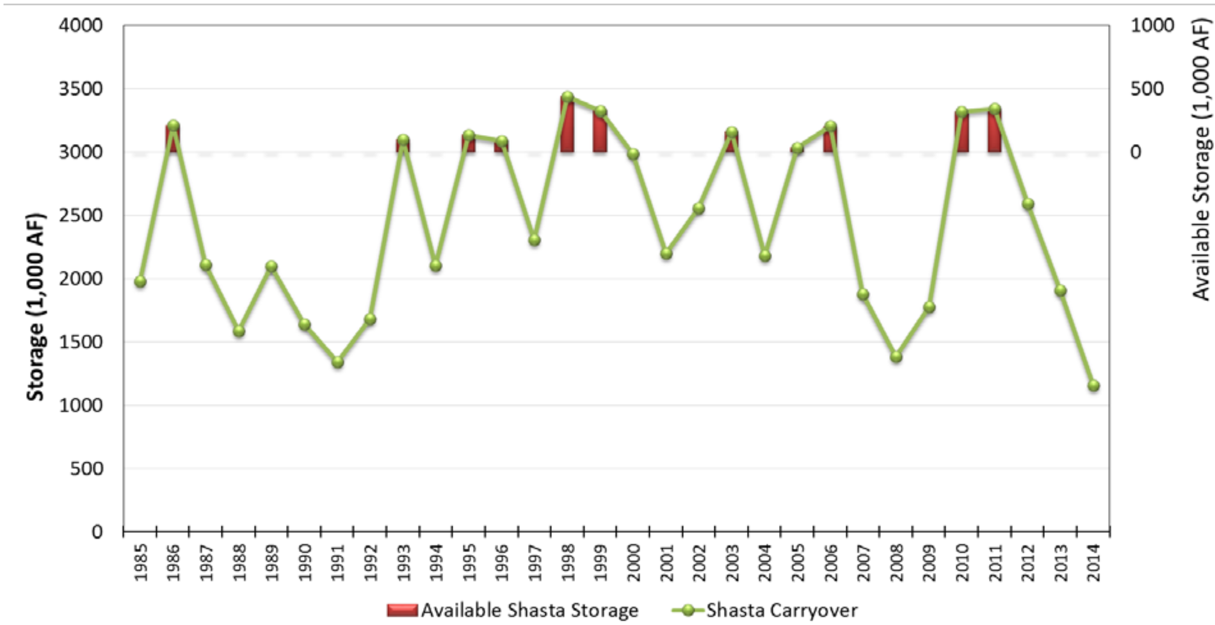

Figure 4. Historical Shasta Carryover and Potential Available Supply

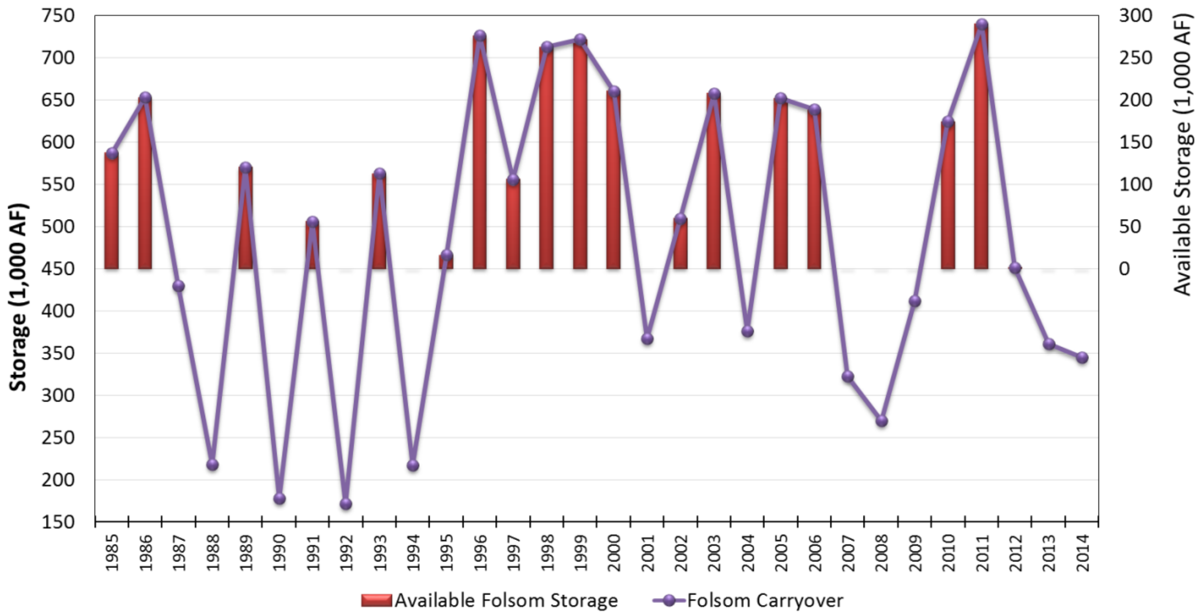

Figure 5. Historical Folsom Carryover and Potential Available Supply

Additional historical JPOD use may be estimated by taking the minimum of unused JPOD capacity and supply available in both Shasta and Folsom lakes. Figure 6 contains a chart showing available annual export capacity and supply in upstream reservoirs; the red numbers show the estimated potential to increase JPOD use. Based on review of this data, there was a potential to increase average annual exports about 31 TAF. This value does not consider south-of-Delta conditions, need for additional supply, or numerous other factors operators must consider.

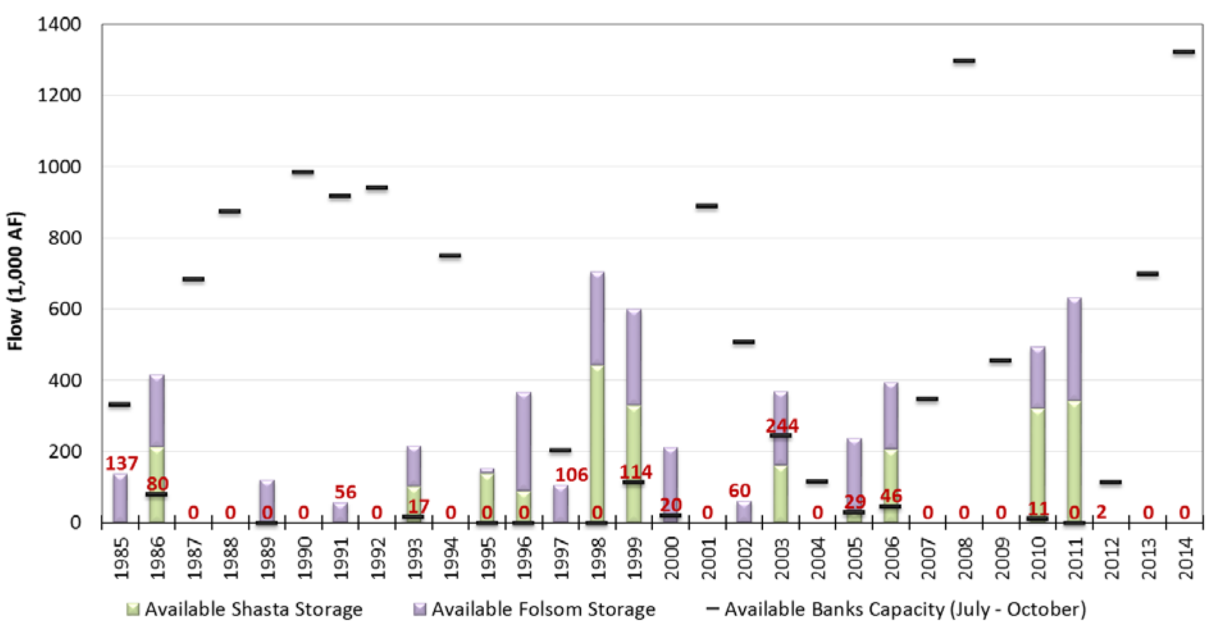

Figure 6. Historical Evaluation of Potential Increased JPOD Use

Historical Sharing of Reservoir Release Obligation

Sharing of reservoir release obligation occurs when one of the Project's reservoir releases are constrained, resulting in one of the Projects either falling short or exceeding its obligation of shared system flow requirements; then COA debt is established between the Projects that must be paid back in the future. This has occurred many times in the past due to facility outages, flow constraints for environmental protections, and basic release scheduling. Accumulated COA debt can be short-term and small volume or can occur over several months with debt in excess of 100 TAF. The ability to incur debt is a COA accounting tool designed to allow operators flexibility to maintain efficiency. It is difficult to determine reasons for accumulated COA debt from public records, however there are clear examples when COA debt was incurred to protect environmental conditions. Historical COA accounting shows the CVP owing water to the SWP and vice versa on numerous occasions. One of the clearest examples when COA debt was accumulated to protect environmental conditions happened in the spring and summer of 2015.

Example Sharing of Reservoir Release Obligation – Spring 2015

During the spring of 2015 there was concern that temperature in the Sacramento River below Keswick would be too high to protect the endangered winter-run Chinook salmon. A component of the temperature management plan for protection of winter-run salmon was to limit releases from Shasta Dam and Keswick to preserve cold water for the fall period. Because of the limitation placed on releases from Shasta during the spring and summer of 2015, the CVP could not meet its portion of shared Delta outflow requirements; during this time the SWP reacted by exporting less from the Delta and increasing releases from Oroville to meet the unmet CVP share of Delta outflow. Figure 7 contains a plot of daily Lower Feather River flow below Thermalito from March 1 through mid-June of 2015. In mid-April releases were increased to satisfy Delta requirements and this release increased to about 3,750 cfs in mid-May. During the period from late March to mid-June, Oroville releases increased while Shasta releases were capped; and the CVP incurred over 100 TAF of COA debt that could not be made up from Folsom or Trinity releases or from reduced CVP exports. Figure 8 contains a plot of COA accounting: the solid black line is COA debt, which shows how much the CVP owes the SWP over this period. This example demonstrates how Project operators are operating within the bounds of the COA for the purpose of protecting environmental conditions.

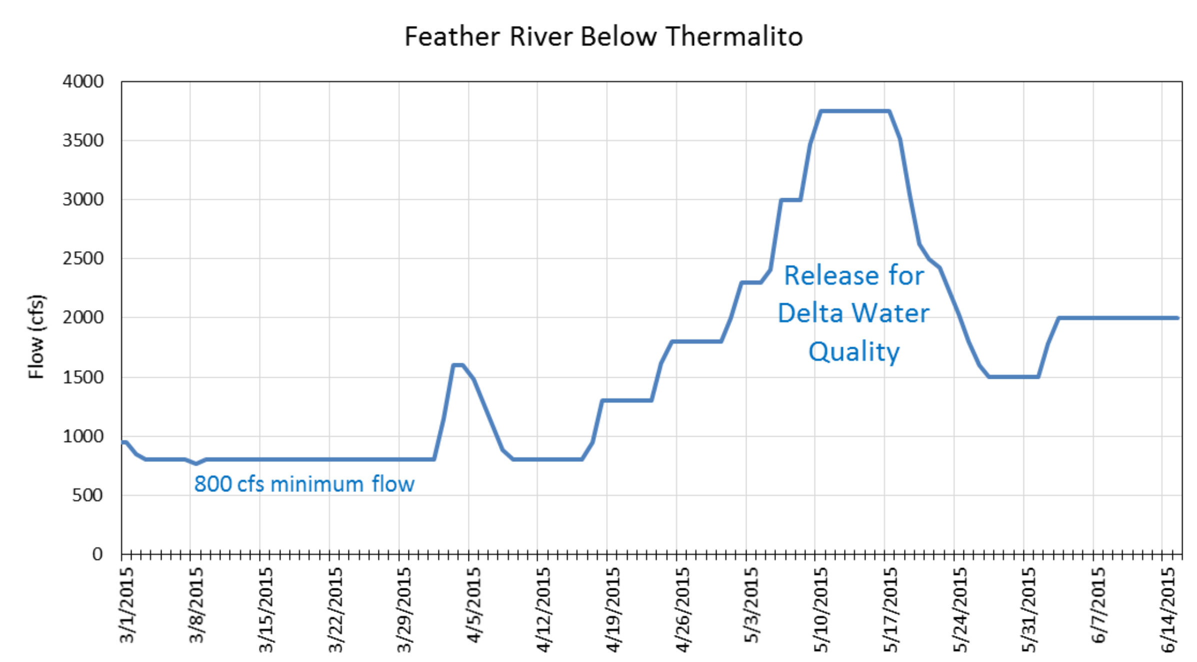

Figure 7. Lower Feather River Flow below Thermalito

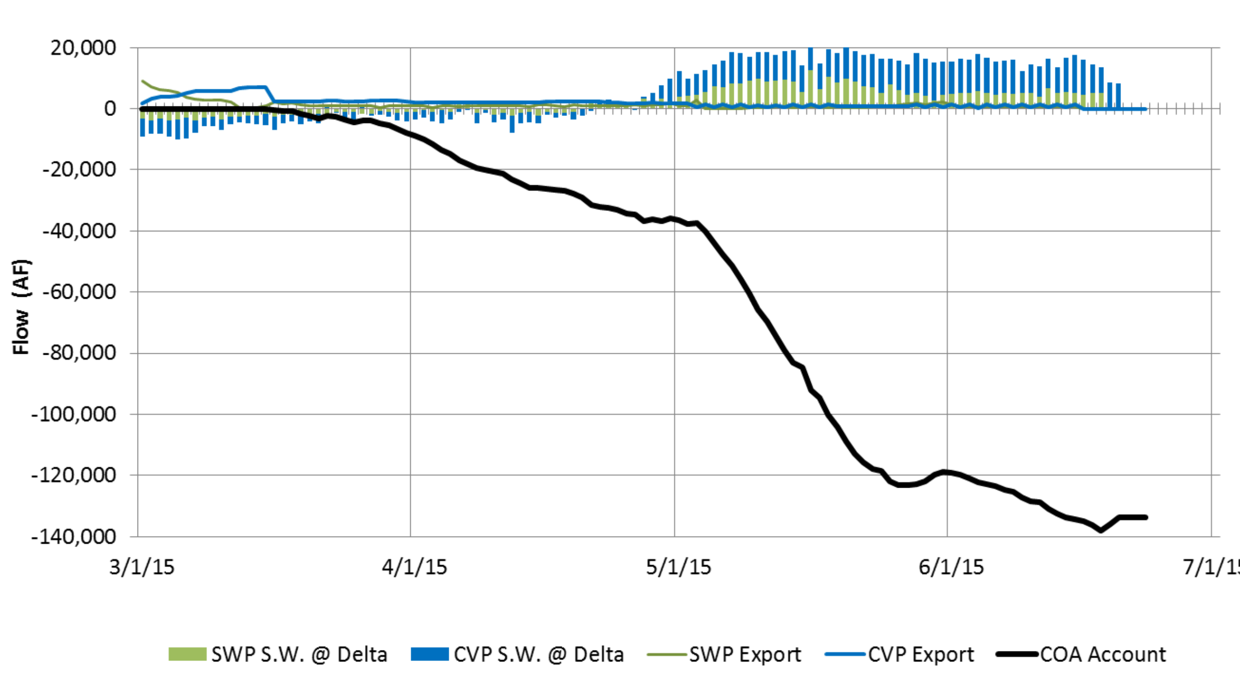

Figure 8. COA Accounting

Modeling Analysis

A review of historical operations clearly demonstrates that the Projects are operated in an integrated manner as described in the COA. Although there are potential limitations embedded in the COA, operators use flexibility within COA accounting to benefit environmental conditions and water supply. Even though the CVP and SWP are operated in an integrated manner and there is flexibility in the COA, it would be possible to increase water supply and ecosystem benefits by operating the two Projects as a single Project. Therefore this modeling analysis estimates potential benefits from operating the CVP and SWP as one Project.

The basic premise of this analysis is to treat CVP and SWP exports as a single diversion, and balance upstream Project reservoirs as though they belong to the same Project rather than assigning release responsibility based on the COA. For the purposes of this analysis, CVP and SWP export operations are combined and changes in exports cannot be attributed to either Project, only as a total. Currently, each Project's obligation to satisfy Delta requirements is determined by COA sharing; in this analysis a reservoir's release obligation is determined based on the status of each reservoir relative to the status of all Project reservoirs and system-wide conditions. For example, if one of the Project reservoirs is high in storage while others have low storage conditions, then the reservoir with high storage will satisfy a larger portion of Delta requirements. This operational approach allows reservoirs to be operated to improve upstream environmental conditions while increasing water supply.

The objective of the integrated operation analysis is to improve ecosystem function and habitat conditions and improve the reliability of municipal and irrigation water supply. The primary improvement to the ecosystem is generated by rebalancing reservoir release obligations to protect reservoir cold pools, river temperature and changes in annual and seasonal river flow regimes. Water supply benefits are increased by expanded JPOD and changes in upstream releases primarily made possible by JPOD, but also by changes in reservoir balancing. Although integrated operations may buffer the hydrologic variations expected from climate change, little reduction of flood hazards is expected through this operation.

Operating the CVP and SWP as a single Project increases operational flexibility, allowing operators to more easily rebalance system benefits. In addition to reallocating reservoir release obligation, there is increased opportunity to either draw reservoirs down to lower levels to increase average annual water supply, or hold reservoirs higher and decrease average deliveries but increase dry-year reliability. This tradeoff between higher average annual deliveries and dry-year reliability is formally referred to as *hedging*. This increased operational flexibility may be the most significant benefit of system integration; however, the benefits derived from this flexibility are dependent on how operators choose to operate. For the purpose of this analysis, various hedging rules were used to create a range of potential benefits.

A spreadsheet model of the CVP/SWP was developed to analyze potential benefits of system integration. The spreadsheet uses hydrology and operational parameters from CalSim II along with simplified operations logic to evaluate system integration. The model has similar resolution as CaLite, but more simplified operations logic. The model can either be run based on existing COA accounting or as if the CVP and SWP are a single Project. A Baseline operation was developed by operating the model with existing contracts, operational criteria, and COA; then alternatives were evaluated by running the model with existing contracts, operational criteria, and replacing existing COA with integrated operations logic. Alternative model runs were then compared to the Baseline model run to derive benefits. Benefits derived from the modeling analysis may be overstated, because the Baseline does not contain the level of system integration that occurs in actual operations.

With increased operational flexibility made possible through system integration there are numerous potential operational strategies. Determination of the most appropriate strategy is subjective and based on which operational objective is most important. Operational strategies must consider tradeoffs between ecosystems on each tributary and in the Delta, increase in dry-year reliability versus increases in average annual yield, and water supply tradeoffs among various regions.

With numerous alternatives being evaluated, average annual water supply benefits ranged from about 100 TAF to 150 TAF, depending on hedging assumptions. Alternatives with more aggressive allocation rules (greater reservoir drawdown) increased yield by about 150 TAF, while less aggressive rules, with higher reservoir storage targets, increased yield by just over 100 TAF.

System integration that increases project yield will likely decrease total upstream reservoir storage (Trinity, Shasta, Oroville, and Folsom) in all but the driest of years. This is due to increased ability to deliver additional supplies through JPOD and integrated reservoir operations. Increased reservoir drawdown in wet years is minimal due to surplus conditions prevalent in these years. In above-normal, below-normal and dry years, total reservoir drawdown ranges from about 100 TAF to 150 TAF due to JPOD and reservoir integration. In critical years, when upstream ecosystems are in need, total reservoir storage increases ranged from about 20 TAF to 300 TAF, depending on hedging rules. With increased flexibility for reservoir balancing, there are increased storage levels when specific reservoirs reach low levels. These increases in storage during dry hydrologic conditions are likely to benefit instream temperature conditions.

III. CONCLUSION

Operation of the Central Valley Project and State Water Project is highly integrated. The Projects share available natural flow, obligation for meeting system requirements, and export capability. Although system requirements and facilities have changed since COA was developed and COA may need to be updated, COA does provide a means for the CVP and SWP to integrate their separate Project operations.

Review of historical operations has demonstrated that operators integrate Project operations to increase water supply and protect the ecosystem. Even though a great deal of benefit is already being realized through integrated operations, there is some level of additional benefit derived by expanding the degree of integration.

The theoretical modeling analysis of operating the CVP and SWP as a single Project shows that water supply and ecosystem conditions may be improved through increased integration. Many of the potential benefits from fully integrating CVP and SWP operations can be possible within the context of the COA with additional agreements or arrangements. Expanded JPOD and sharing reservoir release obligations are only two examples of how benefits of increased integration may increase operational efficiency.