California Department of Water Resources

System Reoperation Program

Phase 1 - Plan of Study

June 16, 2011

Prepared by:
HDR Engineering
ESA PWA
Natural Heritage Institute
Newfields

Contents

Figures

Tables

Appendices

Acronyms & Abbreviations

BDCP	Bay Delta Conservation Plan
CalEPA	California Environmental Protection Agency
CDFG	California Department of Fish and Game
CEC	California Energy Commission
Comp Study	Sacramento-San Joaquin Comprehensive Study
CVFMP	Central Valley Flood Management Planning Program
CVFPB	Central Valley Flood Protection Board
CVP	Central Valley Project
CVP-IRP	Central Valley Project Integrated Resource Plan
CWC	California Water Code
CWP 2009	California Water Plan Update 2009
DCA	Decision Consequence Analysis
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	Department of Water Resources
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
FBO	Forecast-based Operations
FCO	Forecast Coordinated Operations
FS	USDA Forest Service
GCID	Glenn-Colusa Irrigation District
GCM	Global Circulation Models
GWMP	Groundwater Management Program
HCP	Habitat Conservation Plan
IDC	Isolated Delta Conveyance
IRWM	Integrated Regional Water Management
IWRSS	Integrated Water Resources Science and Services
NIDIS	National Integrated Drought Information System
NOAA	National Oceanic and Atmospheric Administration
NODOS	North-of-the-Delta Offstream Storage Investigation
NRDC	Natural Resources Defense Council
OCAP	Operations Criteria and Plan
Reclamation	U.S. Bureau of Reclamation
SAFCA	Sacramento Area Flood Control Agency

Acronyms and Abbreviations Continued

SB X2 1	Senate Bill X2 1
SJRRP	San Joaquin River Restoration Program
SLWRI	Shasta Lake Water Resources Investigation
SPFC	State Plan of Flood Control
SRDST	System Reoperation Decision Support Tool
SRP	System Reoperation Program
SRP Team	DWR and its consultant team
Study	Study Plan
SWP	State Water Project
USRBSI	Upper San Joaquin River Basin Storage Investigation
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
USRDOM	Upper Sacramento River Daily Operation Model
WEAP	Water Evaluation and Planning System

Glossary of Terms

Building Block	A broad category of system reoperation changes or actions under which the full range of potential system reoperation measures are captured
Conjunctive Use	Coordinated and planned use of both surface water and groundwater resources to maximize availability and reliability of water supplies in a region to meet various water management objectives
Constraint	A restriction that limits the extent of formulation of a strategy, plan, project etc.
Cost Opinion	An inexact cost estimate based on judgment and experience with similar studies or projects
Ecosystem Protection and Restoration	Restoration and protection of ecosystem functions and habitat
Feasibility Level Assessment	An in-depth assessment of the engineering, environmental, legal and institutional considerations of a strategy
Fixed Constraint	A constraint that is universal to any potential reoperation measure and limits the formulation of a measure
Flood Hazard Reduction	Physical changes or management actions that lower the potential of flooding of damageable property
Goal	Desired end result, broadly stated
Malleable Constraint	An institutional or legal restriction or barrier that must be overcome in order to implement a measure; however, it does not limit the formulation of a measure
Measure	Physical change or management action that takes advantage of opportunities identified in the planning process to meet objectives and work toward achieving the SRP's mission. A viable measure cannot violate a planning constraint.
Mission	The three basic purposes, or areas of concern of reoperation, flood hazard reduction, water supply reliability, and ecosystem restoration and preservation
Objective	Specific and measureable targets for accomplishment of a goal, specifically stated

Glossary of Terms Continued

Opportunity	Existing conditions that provide a pathway toward achieving an objective
Optimization	Capitalizing on existing and future water supply reliability and availability so as to result in the greatest possible benefits.
Problem/Need	Undesirable condition that act as impediments to achieving objectives and can change with time
Reconnaissance Level Assessment	An assessment of the engineering, environmental, legal and institutional considerations of a strategy based largely upon existing information and limited analyses
Reoperation	Changes to existing operations and management procedures for existing reservoirs and conveyance facilities to increase water related benefits from these facilities
Strategy	An assemblage of interconnected reoperation measures that work in concert to meet reoperation objectives

Chapter 1 - Introduction

Background

California's statewide water system is comprised of a diverse set of local, state, and federal projects, as depicted in Figure 1. These projects include facilities such as dams and reservoirs, hydropower plants, canals, and water diversion structures. Many of these facilities were developed in the 20th century, and were not designed, constructed or operated as an integrated water supply and flood management system. Over time, operations of the two largest projects, the State Water project (SWP), operated by the State, and the Central Valley Project (CVP), operated by the federal government, have been integrated to a certain degree. The current level of integration is based on the Coordinated Operating Agreement that was initiated in the 1970's and finalized in 1986.

System reoperation is generally defined as changing the operational and management procedures of existing water system facilities to obtain water resources related benefits. Reoperation is considered an alternative to constructing major new facilities, although it may consist of physical modification of existing facilities. The specifics associated with a system reoperation strategy will vary among water purveyors depending upon the complexity of their system and their interest in participating in local and or interregional efforts.

Authority

There may be opportunity to reoperate portions of California's statewide water system to yield increased water resources related benefits. This opportunity was recently recognized by the State Legislature in Senate Bill X2 1 (SB X2 1) (Perata, 2008 – Water Code Section 83002.5), which mandated and allocated resources for "planning and feasibility studies to identify potential options for the reoperation of the state's flood protection and water supply systems that will optimize the use of existing facilities and groundwater storage capacity." Specifically, SB X2 1 stipulated that "the studies shall incorporate appropriate climate change strategies and be designed to determine the potential to achieve the following objectives:

(I) Integration of flood protection and water supply systems to increase water supply reliability and flood protection, improve water quality, and provide for ecosystem protection and restoration.

(II) Reoperation of existing reservoirs, flood facilities, and other water facilities in conjunction with groundwater storage to improve water supply reliability, flood hazard reduction, and ecosystem protection and to reduce groundwater overdraft.

(III) Promotion of more effective groundwater management and protection and greater integration of groundwater and surface water resource uses.

(IV) Improvement of existing water conveyance systems to increase water supply reliability, improve water quality, expand flood protection, and protect and restore ecosystems.

Source: CaSIL, 2009; DWR, 1993 | G:\154462 DWR System Reop TO1\map docs\Figure1 Major Rivers Facilities.mxd

California's Major Rivers and Facilities

FIGURE 1

DWR System Reoperation Program
Phase 1 Plan of Study

06/16/2011

System Reoperation Program

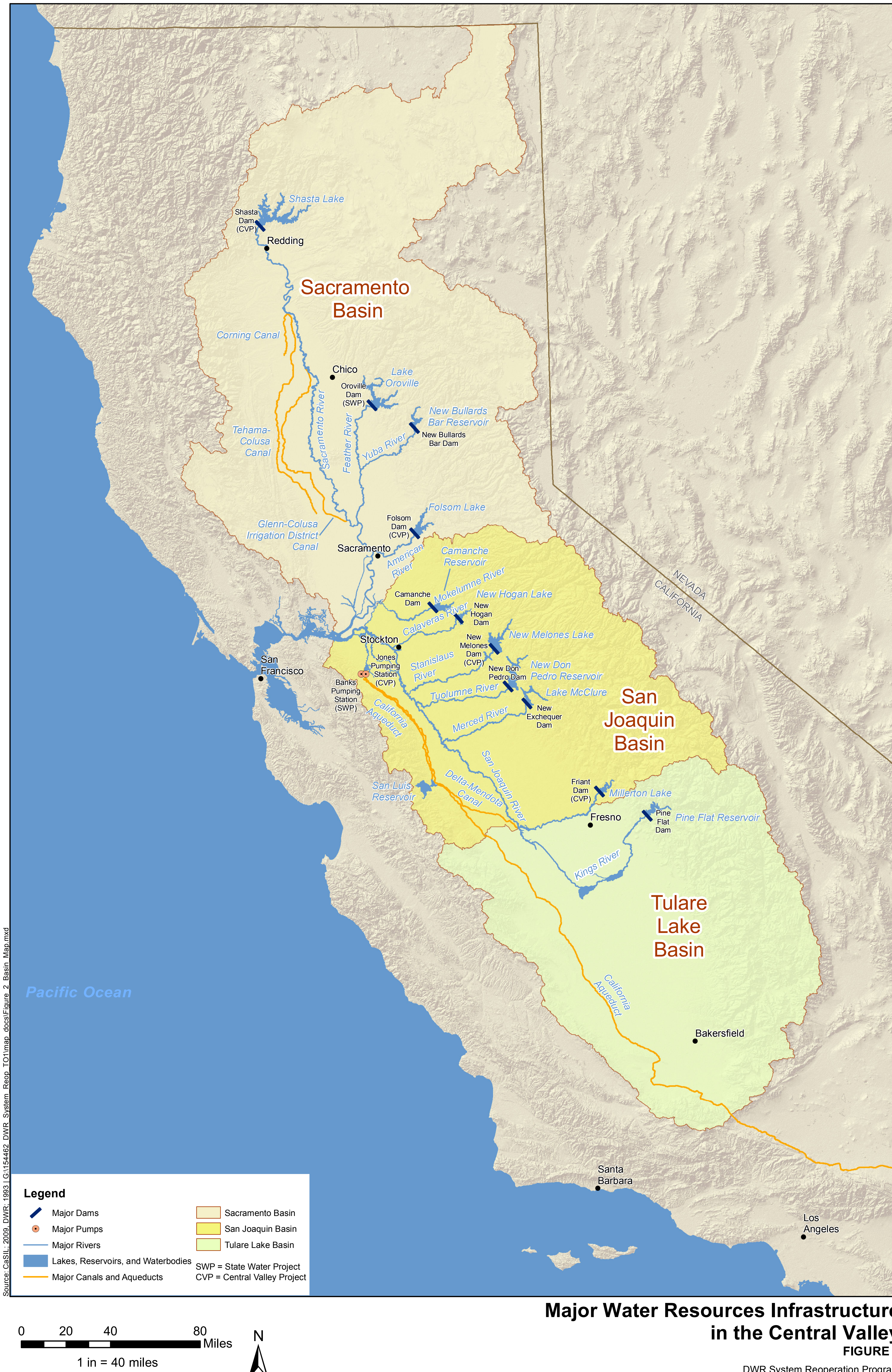
In support of the legislative objectives the California Department of Water Resources (DWR) is developing a System Reoperation Program (SRP) that will identify viable reoperation strategies. These reoperations strategies will be assessed with respect to their ability to improve water supply reliability, flood hazard reduction, ecosystem protection and restoration, and water quality improvement (primarily as it pertains to ecosystem conditions). Therefore, the three-fold mission of the SRP that guides the development and evaluation of system reoperation strategies (and forms the core of this Study Plan) is to achieve improvements in:

1) *water supply reliability*
2) *flood hazard reduction*
3) *ecosystem protection and restoration*

The SRP has the potential to benefit from its timing and relatedness to FloodSAFE (the State's program to develop an integrated, system-wide approach for sustainable flood management in California) and the Bay Delta Conservation Plan (BDCP – the ongoing collaborative program to restore the Sacramento-San Joaquin Delta's ecosystem and protect water supplies). Close coordination will be maintained between the SRP and these programs.

Geographic Scope

The legislative mandate focuses this study on the "state's flood protection and water supply systems". This suggests that emphasis should be given to those areas of the state where both of these systems are found. Much of the state's flood control infrastructure is located in the Central Valley, shown in Figure 2. That is also where the greatest concentration of interconnected water supply infrastructure is located. Additionally, as shown in Figure 3, a significant percentage of water supply originates in the Central Valley. Because this infrastructure has had a profound effect on aquatic ecosystems, the greatest potential for ecosystem restoration through infrastructure reoperation is also found in the Central Valley. For these reasons, the initial geographic scope for identifying system integration will be limited to the Central Valley. Future efforts could include other watersheds within the state provided cooperators can be found.

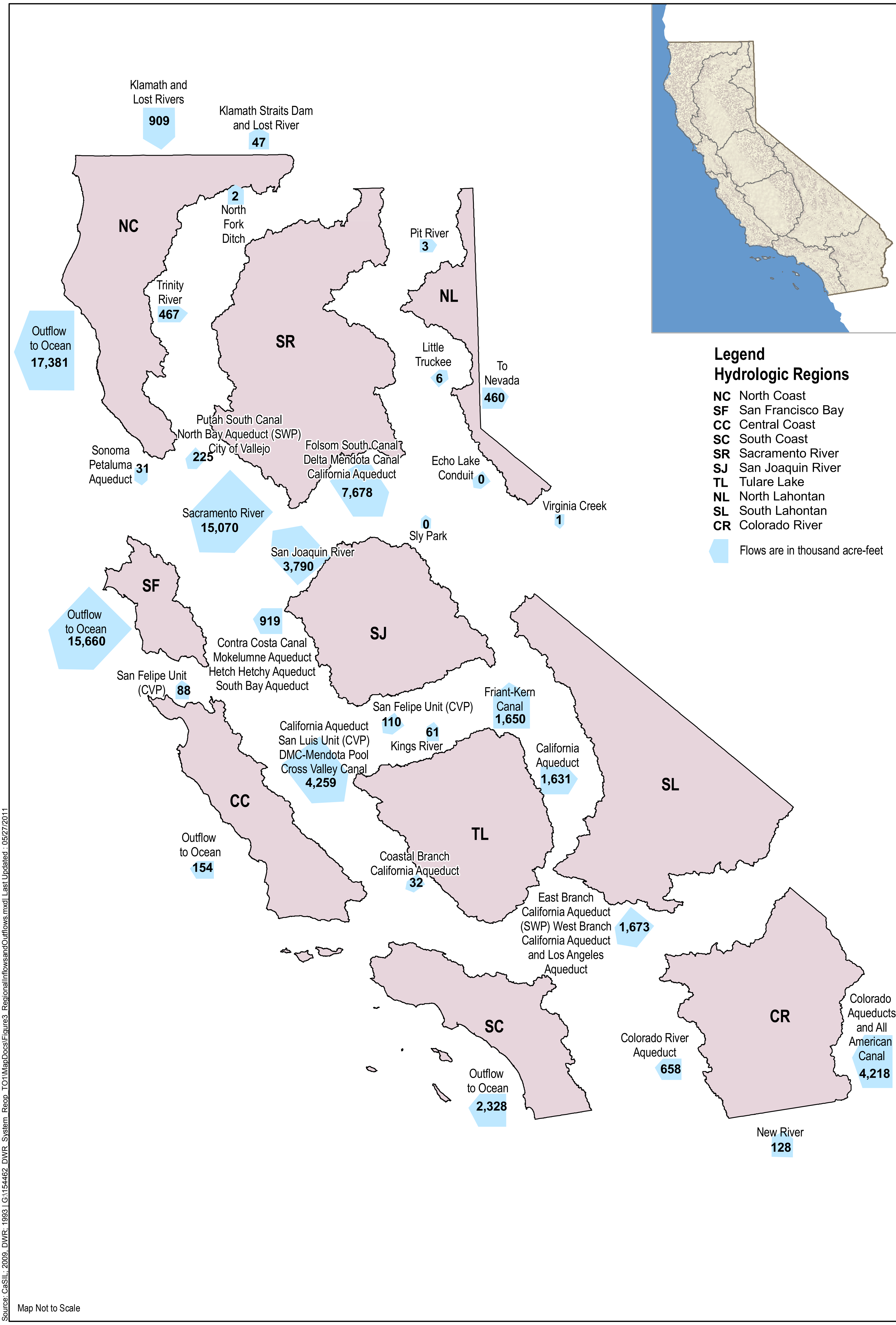


Major Water Resources Infrastructure in the Central Valley

FIGURE 2

DWR System Reoperation Program
Phase 1 Plan of Study

07/25/2011



Regional Inflows and Outflows, Water Year 2005

FIGURE 3

DWR System Reoperation Program
Phase 1 Plan of Study

6/14/2011

Assurances

Experience has demonstrated that as new studies and proposals are introduced it has been helpful to discuss not only the changes that will be evaluated but to also offer assurances as to what will not change. In development of the SRP, DWR has adopted a set of guiding principles drawn (with minor modifications) from the California Water Plan Update 2009 (CWP 2009) as follows:

1) Water supply benefits resulting from reoperation will be shared with the owners of the projects as negotiated with the owners.
2) Reoperation studies of regional and local projects will be performed with the collaborative and voluntary participation of reservoir owners and operators.
3) Priority for study will be reoperation opportunities that simultaneously reduce flood hazards, improve water supply reliability, and restore damaged ecosystems.
4) A reasonable range of predictions regarding anticipated changes in hydrology run-off patterns associated with climate change studies will be taken into account in the reoperations studies.

Chapter 2 - Study Plan Overview

Development of the SRP is a multi-phased effort, commencing with this Plan of Study, referred to as the Study Plan. The primary purpose of the Study is to: (1) define the five phases of the SRP such that it can be used as a guide to implement each phase and to document the planning process undertaken in Phase 1; and (2) identify and formulate reoperation strategies.

The five phases of the SRP and their associated primary tasks are illustrated in Figure 4 and are briefly summarized below. The Study Plan was developed to guide the SRP from Phase 1 through Phase 4. Phase 5 is not a part of this Study.

Phase 1: Preliminary Reoperation Strategy Formulation

In Phase 1, the relevant existing literature, related programs, and available tools were assessed for use in subsequent phases. The planning process to formulate preliminary reoperation strategies was established and followed. This phase is important in that it established the "ground rules" for developing the SRP.

Phase 2: Strategy Formulation and Refinement

In Phase 2, the preliminary reoperation strategies from Phase 1 will be further formulated and refined. In order to comply with the assurances presented in Chapter 1, Phase 2 will entail a three-tier process involving input and identification of fatal flaws from technical experts, affected parties, as well as outreach and coordination with other relevant programs. Phase 2 will yield specific reoperation strategies determined to warrant continued consideration in Phase 3.

Phase 3: Reconnaissance Level Assessment

Strategies carried forward from Phase 2 will be evaluated at a reconnaissance level, which will be largely based upon existing information and judgment. The purpose of the reconnaissance level assessment will be to identify fatal flaws and rank the reoperation strategies relative to one another. Doing so will provide a sound basis for selecting strategies that warrant feasibility level analyses and the associated commitment of additional resources.

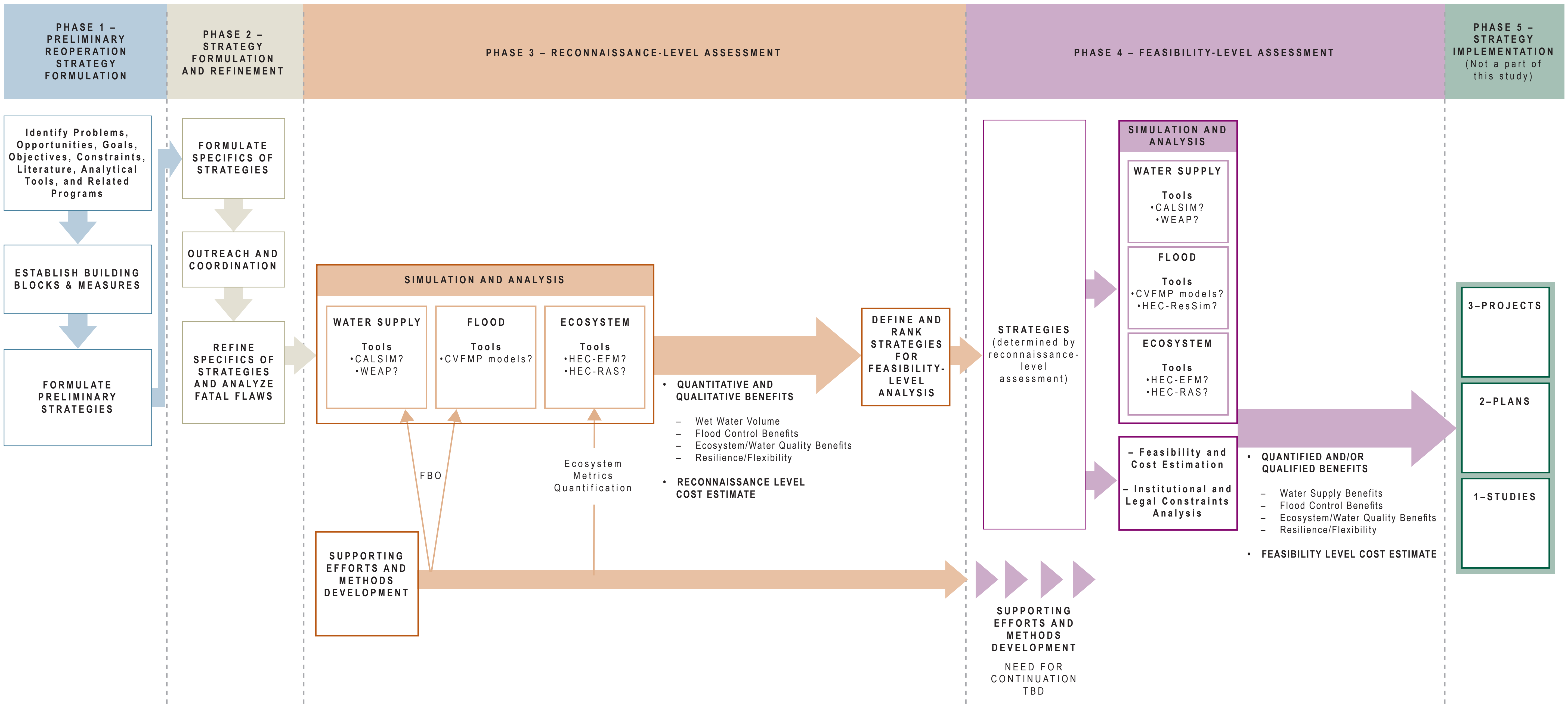
Phase 4: Feasibility Level Assessment

Strategies carried forward from Phase 3 will be subject to a feasibility level assessment. The feasibility level assessment will be performed at a more detailed level than the reconnaissance level assessment, and is anticipated to build upon existing tools (e.g., water supply, flood and ecosystem related models). The purpose of the assessment will be to determine whether or not the selected strategies warrant advancement to the implementation phase, develop a relative ranking of the reoperation strategies, and identify needed funding and key steps necessary for implementation.

Phase 5: Strategy Implementation

The final phase of the SRP will consist of implementing strategies advanced from the feasibility level assessment conducted in Phase 4. Strategies may take the form of studies, plans, or projects. The specifics required for implementation will likely vary by strategy and are unknown at this time. Strategy implementation is not a part of this Study.

Figure 4 – System Reoperation Program Phases



Chapter 3 - Phase 1 Preliminary Reoperation Strategy Formulation

This Chapter presents the planning process used to formulate preliminary reoperation strategies. The process provides a structured approach to develop strategies that are consistent with the mission of the SRP and that are appropriate for being carried forward for further evaluation in later stages of the SRP. This process is depicted in Figure 5.

Existing Reoperation Literature

One of the initial steps in the SRP planning process was the compilation of existing literature that is relevant to the SRP and that will support formulation and evaluation of strategies. A list of the entries is included in Appendix A.

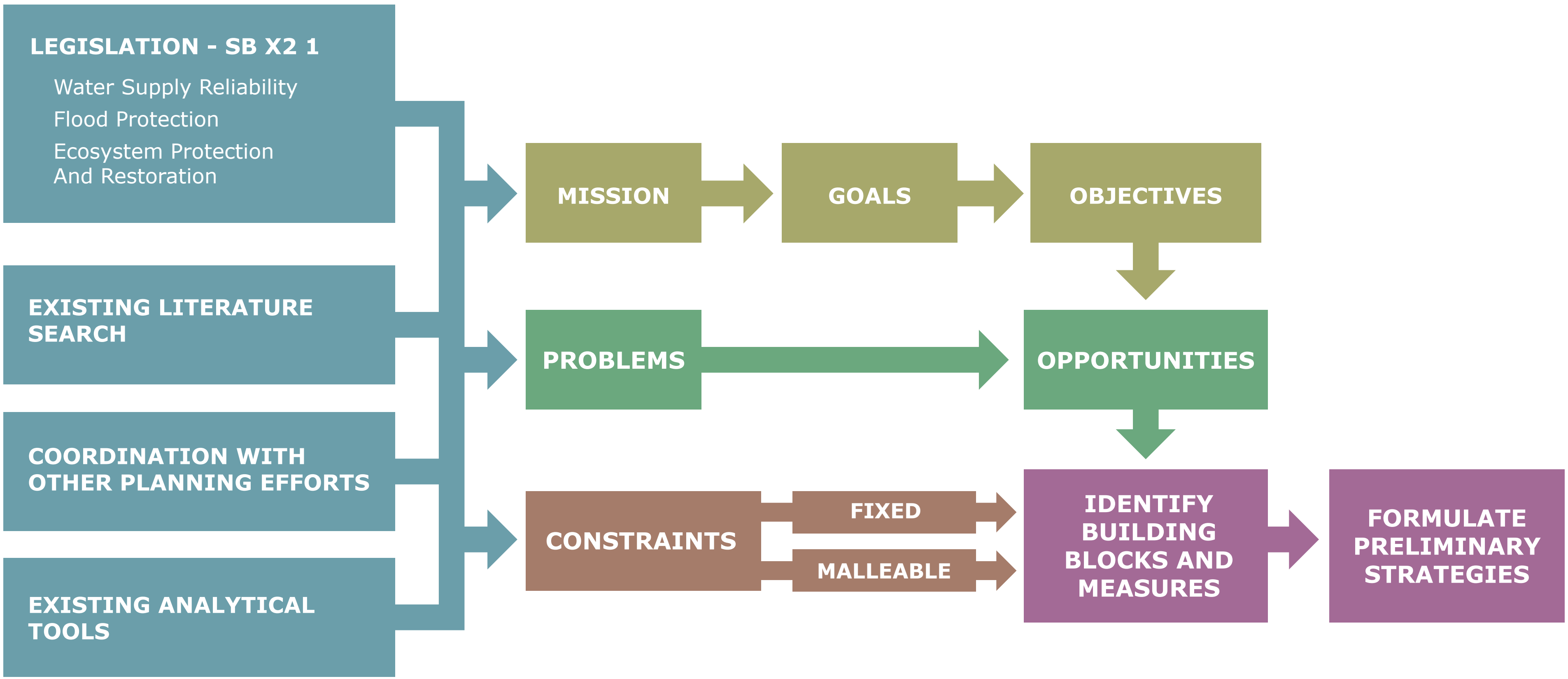
Coordination with Existing and Proposed Water Resources Planning Efforts

The timing of the development of the SRP creates a potential opportunity to integrate with and leverage elements of major ongoing water resources planning efforts. Close coordination with existing and proposed water resources planning efforts are critical for the effective and efficient development and implementation of the SRP. Coordination with some programs has already begun (e.g., FloodSAFE). The activities proposed within other programs could, if implemented, expand potential system reoperation improvements in water supply reliability, flood hazard reduction, and ecosystem protection and restoration. Continuous coordination throughout the remaining phases of the SRP will be important. A brief description of relevant programs and planning efforts is provided in Appendix B as a guide for identifying efforts with which the SRP may coordinate as it progresses.

Existing Analytical Tools

An inventory was prepared of existing analytical tools that are presently available and either in use for system management and planning or could be used in the SRP. After the inventory was developed, an assessment of the utility of each of the tools for the purposes of analyzing system reoperation strategies was conducted. The assessment included a list of recommended tools and identified tool improvements that may be needed. The inventory and assessment are summarized in Chapter 8, and additional detail is included in Appendix C.

FIGURE 5. Preliminary Reoperation Strategy Formulation Process



Mission, Goals, and Objectives

To maintain consistency and clarity in the formulation and evaluation of system reoperation strategies, the planning process included establishing and documenting the mission, goals, and objectives of the SRP. As introduced in Chapter 1, the three-fold mission of the SRP includes improvements in water supply reliability, flood hazard reduction, and ecosystem protection and restoration. The SRP goals (defined as the desired end result, broadly stated) were developed directly from SB X2 1 language and were correlated with the three-fold mission. The SRP objectives were then established as specific and measurable targets for accomplishing the goals.

The established mission, goals, and objectives of the SRP are documented in Table 1. Goals and objectives are presented specific to water supply reliability, flood hazard reduction, and ecosystem protection and restoration. This was done to simplify the process of identifying specific objectives for each of the three mission elements. However, it is important to note that future phases of the SRP will consider the goals and objectives for all three elements, concurrently.

Problems and Opportunities

The existing configuration and operation of California's water system, in addition to the natural and modified geomorphic and ecological conditions of the landscape, yields both problems and opportunities with respect to water management in the State. Therefore, building upon the identification of goals and objectives described above, problems and opportunities associated with each objective were identified to facilitate development of system reoperation strategies. The initial problem statements are summarized in Table 1 and are based on information contained in the CWP 2009 (CWP 2009) and other planning documents, as well as from brainstorming sessions and discussions within the SRP team. Problems were defined as undesirable conditions that act as impediments to achieving objectives and can change with time. Opportunities were also developed by the SRP team and are summarized in Table 1. Opportunities were defined as existing conditions that provide a pathway toward achieving an objective. Often, examination of opportunities leads to identification of solutions to problems or challenges. However, opportunities are not themselves solutions.

Table 1 – Mission, Goals, Objectives and Opportunities of the SRP

Mission [1]	Goal [2] Desired end result, broadly stated	Objective [2] [3] Specific and measurable targets for the accomplishment of a goal, specifically stated	Problem Undesirable condition that act as impediments to achieving objectives and can change with time	Opportunity Existing condition that provide a pathway toward achieving an objective
A. Flood Hazard Reduction	A-G1 Integration of flood protection and water supply systems to improve flood protection	A-Ob1 Reduce flood risk in specified floodplain A-Ob2 Conserve flood storage space in a flood protection system A-Ob3 Increase resilience to hydrologic perturbations due to climate change by adding flood protection storage flexibility under extreme storm conditions	A-P1 Limited storage capacity A-P2 Inadequate flood operations flexibility	A-Op1 New technologies coupled with available data allow for improved development of decision support and management tools
			A-P3 Hydrologic extremes increasing with climate change, resulting in larger and more frequent flood events	A-Op2 Adding flexibility to reservoir management and downstream releases may result in increased resilience of flood management systems
			A-P4 Limited coordination of system operations between water supply and ecosystem requirements	A-Op3 Efficiencies may be achieved by taking a larger, system-wide approach that integrates facilities and resources originally intended for single or limited purposes
	A-G2 Reoperation of existing reservoirs, flood protection facilities, and other water facilities in conjunction with groundwater storage to improve flood control	A-Ob1 Reduce flood risk in specified floodplain A-Ob2 Conserve flood storage space in a flood protection system A-Ob3 Increase resilience to hydrologic perturbations due to climate change by adding flood protection storage flexibility under extreme storm conditions	A-P5 Limited storage capacity	A-Op4 Storage capacity may be conserved by expanding outlet works and reoperating dam to increase releases. Releases could be accommodated through levee improvements, treating hydraulic constraints, and managed flow to floodways and floodplains
			A-P6 Inadequate flood operations flexibility	A-Op5 New river forecasting systems and remote sensing allow more efficient reservoir operations and storage A-Op6 There are groundwater storage options associated with reservoirs that may allow for an increase in flood storage at no cost to other purposes
			A-P7 Hydrologic extremes increasing with climate change resulting in larger and more frequent flood events	A-Op7 Flexibility in managing reservoirs using conjunctive use, forecast-based, or forecast coordinated operations may result in increased resilience of flood management systems
	A-G3 Improvement of existing water conveyance systems to improve flood protection	A-Ob1 Reduce flood risk in specified floodplain areas A-Ob2 Conserve flood storage space in a flood protection system	A-P8 Floodplain development is increasing flood risk and reducing options for floodway reconfiguration and reducing choke points	A-Op8 There are areas in floodways with land uses that are compatible with infrequent flooding and may therefore be designated as managed floodplains, thereby reducing flood risk to flood-tolerant areas A-Op9 There are regulatory and incentive mechanisms available to restrict development to flood-tolerant uses
			A-P9 Limited conveyance capacity A-P10 Inconsistent distribution of flood protection infrastructure (i.e., level of protection not always commensurate with level of risk and consequences)	A-Op10 Expansion of flood corridors (channels, bypasses, and floodplains) can improve conveyance and ecosystem conditions A-Op11 Weak and unsafe levees are being identified; levees can be retrofitted to correct deficiencies A-Op12 Through state regulations and system-wide planning, levee and channel improvements may be prioritized and sized as appropriate to the local context
			A-P11 Hydrologic extremes increasing with climate change	A-Op13 Existing climate change studies may provide information that informs more adaptable and dynamic flood protection design

Mission[1]	Goal[2] Desired end result, broadly stated	Objective[2 3] Specific and measurable targets for the accomplishment of a goal, specifically stated	Problem Negative conditions found in the world; problems can be global to local	Opportunity Positive conditions found in the world; can be global to local
B. Water Supply	B-G1 Integration of flood protection and water supply systems to increase water supply reliability and improve water quality	B-Ob1 Increase water supply storage B-Ob2 Increase resiliency to hydrologic perturbations due to climate change; increase water supply storage under drought conditions compared to pre-project conditions B-Ob3 Improve the quality of water supplies	B-P1 Water quality degradation (e.g., due to sea level rise and increases in salinity)	B-Op1 Diversions in the Delta and possibly other estuaries may be retrofitted and reoperated to reduce salt water intrusion B-Op2 Integrating separate projects in a system, such as SWP and CVP as well as USACE facilities, may provide the flexibility to make releases for improving water quality, such as reducing salinity
			B-P2 Lack of dry period reliability	B-Op3 Integration of system facilities and project operations has the potential to increase system-wide storage capacity
			B-P3 Use of antiquated tools and constrained institutional structure for incorporating current and future hydrologic uncertainty in water supply planning B-P4 Limited coordination with operations for flood protection and ecosystem requirements	B-Op4 Existing and emerging technologies coupled with available data create opportunities for improved development of decision support and management tools B-Op5 There appear to be ways in which SWP and CVP can complement each other. USACE has facilities that could complement and support water supply projects in the system
	B-G2 Reoperation of existing reservoirs, flood protection facilities, and other water facilities in conjunction with groundwater storage to improve water supply reliability and to reduce groundwater overdraft	B-Ob1 Increase water supply storage space B-Ob2 Increase resiliency to hydrologic perturbations due to climate change; increase water supply storage under drought conditions compared to pre-project conditions B-Ob4 Replenish overdrawn aquifers B-Ob5 Increase average annual seasonal carryover of stored water	B-P5 Water quality degradation (e.g., due to sea level rise and increases in salinity)	B-Op6 Diversions in the Delta and possibly other estuaries may be retrofitted and reoperated to reduce salt water intrusion
			B-P6 Use of antiquated tools and constrained institutional structure for incorporating current and future hydrologic uncertainty in water supply planning	B-Op7 Existing and emerging technologies coupled with available data create opportunities for improved development of decision support and management tools
			B-P7 Lack of information and planning on optimal configurations for a multi-purpose system	B-Op8 There are a variety of funding sources for evaluation of opportunities for reservoir reoperation in conjunction with groundwater banking and back stopping
			B-P8 Allocation of water to uses with lesser beneficial value	B-Op9 Conveyance infrastructure could be retrofitted or constructed to facilitate water transfers B-Op10 Market incentives could be used to allocate water to more beneficial uses, especially in agriculture. B-Op11 Multi-year water purchase arrangements groundwater banks, reverse auction arrangements with irrigators could be used to match supply with the most beneficial uses
			B-P9 Lack of dry period reliability	B-Op12 Efficiency and water supply reliability could be improved by increasing the flexibility of dam operations in the system B-Op13 New river forecasting systems and remote sensing allow more efficient reservoir operations and storage B-Op14 Surface water – groundwater systems are common, thus there is great potential, through conjunctive use, to connect and manage these resources together
			B-P10 Preventable physical losses of water from the system	B-Op15 Reservoir release schedules could be timed to reduce the amount of flow (water supply and flood protection) permanently exiting the system

Mission[1]	Goal[2] Desired end result, broadly stated	Objective[2 3] Specific and measurable targets for the accomplishment of a goal, specifically stated	Problem Negative conditions found in the world; problems can be global to local	Opportunity Positive conditions found in the world; can be global to local
	B-G3 Improvement of existing water conveyance systems to improve water quality and to expand water supply	B-Ob1 Increase water supply storage B-Ob2 Increase resiliency to hydrologic perturbations due to climate change; increase water supply storage under drought conditions compared to pre-project conditions B-Ob4 Reduce groundwater overdraft and replenish overdrawn aquifer B-Ob5 Increase average annual seasonal carryover of stored water	B-P11 Physical losses of water from the system	B-Op16 System losses due to percolation, evaporation, or flows leaving the system could be reduced by upgrading infrastructure
			B-P12 Mismatch in space and time between water supply and demand	B-Op17 Conveyance infrastructure could be retrofitted and/or constructed in conjunction with water transfers to link water supply to demand
			B-P13 Water quality degradation (e.g., due to sea level rise and increases in salinity)	B-Op18 Conveyance capacity could be improved to facilitate delivery of fresh water to polluted water bodies
	B-G4 Promotion of more effective groundwater management and protection and greater integration of ground water and surface water resource uses	B-Ob4 Reduce groundwater overdraft and replenish overdrawn aquifer	B-P14 Lack of dry period reliability B-P15 Groundwater overdraft exhausts aquifers	B-Op19 Surface water – groundwater systems are common, thus there is great potential to connect and manage these resources together through conjunctive use
				B-Op20 System-wide efficiencies in water allocation, conveyance, and conjunctive use allow groundwater to be better managed and groundwater overdraft avoided
			B-P16 Increasing demand for water from the system	B-Op21 New industries and new technologies increase opportunities for water reuse and wastewater recycling B-Op22 New technologies and adjustments to institutional constraints could create incentives to replace inefficient conveyance and on-farm application techniques and technologies with more efficient alternatives
			B-P17 Preventable physical losses of water from the system	B-Op23 Water supply infrastructure to reduce losses B-Op24 Physical losses in agricultural water use may be reduced through evaporation reduction techniques and deep percolation to salt sinks

Mission[1]	Goal[2] Desired end result, broadly stated	Objective[2 3] Specific and measurable targets for the accomplishment of a goal, specifically stated	Problem Negative conditions found in the world; problems can be global to local	Opportunity Positive conditions found in the world; can be global to local
C. Ecosystem Protection and Restoration	C-G1 Integration of flood protection and water supply systems to improve water quality and provide for ecosystem protection and restoration	C-Ob1 Increase viability, productivity of wildlife habitat C-Ob2 Increase acreage of habitat type C-Ob3 Increase reliability and productivity of in-stream fish habitat C-Ob4 Improve the quality of water in aquatic ecosystems	C-P1 Human-induced hydrologic and hydraulic changes C-P2 Changes in sediment transport processes C-P3 Water quality degradation	C-Op1 New technologies coupled with available data could allow improved development of decision support and management tools C-Op2 Adding flexibility to reservoir management can increase opportunities for more natural flow regimes C-Op3 Environmental flow and sediment transport assessments could help determine effective management of reservoirs for the benefit of downstream ecosystems C-Op4 Integrating separate projects in the system, such as SWP and CVP as well as USACE facilities, may provide flexibility to make releases that improve water quality and ecosystem conditions
			C-P4 Limited coordination with reservoir operations for flood protection and ecosystem requirements	C-Op5 Flood control operations could be better integrated with releases for ecosystem benefits through multi-purpose operations planning and overcoming institutional constraints
			C-P5 Water temperature regulations	C-Op6 Naturalized flow regimes could restore cooler water temperature patterns that benefit ecosystems
			C-P6 Invasive species	C-Op7 Restoration of more natural hydrographs could favor native species
			C-P7 Insufficient instream flow data and understanding	C-Op8 More specific models and other tools that link geomorphology and habitat creation / maintenance with hydraulic models could help determine beneficial instream flows in different systems
			C-P8 Fragmented aquatic ecosystem restoration efforts	C-Op9 The extent and connectivity of ecosystem restoration projects within the system boundaries could be increased through floodplain reconnection
			C-P9 Lack of long-term environmental stewardship	C-Op10 Larger scale / long term / broader scope planning and management of SWP and CVP could be incentivized by overcoming institutional constraints
			C-P10 Inability to address true limiting factors for species, populations, communities, and ecosystems	C-Op11 Technology and biological data are available to develop tools capable of determining more realistic species' habitat requirements
			C-P11 Barriers to species migration	C-Op12 Integrated water management could expand wildlife corridors within system conveyance facilities
	C-G2 Reoperation of existing reservoirs, flood facilities, and other water facilities in conjunction with groundwater storage to improve ecosystem protection	C-Ob1 Increase viability, productivity of wildlife habitat C-Ob3 Increase reliability and productivity of in-stream fish habitat	C-P12 Human-induced hydrologic and hydraulic changes C-P13 Changes in sediment transport processes	C-Op13 New river forecasting systems and remote sensing allow more efficient and flexible reservoir operations, thereby increasing opportunities for releases that benefit the downstream ecosystem C-Op14 Flexibility of storage and diversions could be increased to enable restoration of ecologically valuable flows by reoperating existing reservoirs, flood protection facilities, and other water facilities in conjunction with groundwater storage

Mission[1]	Goal[2] Desired end result, broadly stated	Objective[2] [3] Specific and measurable targets for the accomplishment of a goal, specifically stated	Problem Negative conditions found in the world; problems can be global to local	Opportunity Positive conditions found in the world; can be global to local
			C-P14 Water quality degradation C-P15 Water temperature regulations C-P16 Invasive species C-P17 Limited area for ecosystem restoration	C-Op15 Flexibility and efficiency of flood and water supply storage operations at reservoirs could be improved to make more water available for release to benefit downstream ecosystems C-Op16 New river forecasting systems and remote sensing could allow more efficient reservoir operations which could make more water available for release to benefit downstream ecosystems C-Op17 Surface water – groundwater systems are common, thus there is great potential to connect and manage these resources together as conjunctive use, which could provide additional land and water to benefit ecosystems
			C-P18 Lack of long-term dynamic environmental planning	C-Op18 Larger scale/longer term/broader scope planning and management of SWP and CVP could be incentivized by overcoming institutional constraints
			C-P19 Loss of aquatic ecosystems such as freshwater marsh and riparian forests C-P20 Limited area for ecosystem restoration	C-Op19 Wetlands could be restored in designated and managed floodplains as a floodplain compatible land use
	C-G3 Improvement of existing water conveyance systems to improve water quality, and protect and restore ecosystems	C-Ob1 Increase viability, productivity of wildlife habitat C-Ob2 Increase acreage of habitat type C-Ob3 Increase reliability and productivity of in-stream fish habitat C-Ob4 Improve the quality of water in aquatic ecosystems	C-P21 Changes in sediment transport processes	C-Op20 Conveyance facilities could be realigned or otherwise altered to restore more natural sediment-energy balance
			C-P22 Barriers to species migration	C-Op21 By creating broader and natural floodways and conveyance facilities, migration barriers could be removed
			C-P23 Habitat loss (fragmentation, encroachment, degradation) C-P24 Water temperature regulations C-P25 Invasive species C-P26 Fragmented ecosystem restoration efforts	C-Op22 Expanded flood corridors could create opportunities to create new aquatic and riparian habitats C-Op23 More natural habitat along river channels could reduce water temperature
			C-P27 Water quality degradation	C-Op24 Conveyance capacity could be improved to facilitate delivery of fresh water to polluted water bodies
			C-P28 Limited appropriate sites for aquatic ecosystem restoration	C-Op25 Reoperation could reduce hydraulic efficiency requirements, and thus allow for more complex channel habitats

[1]To provide the key organizational structure to the table as all goals, objectives, problems and opportunities are directly linked to specific areas of concern (flood protection, waters supply, and ecosystem protection and restoration). Source: CWP 2009
[2]Goals and Objectives definitions are based on descriptions from USACE Planning Manual
[3]Objectives were developed from the CWP 2009 and professional expertise

Constraints

Following development of the SRP goals, objectives, problems, and opportunities, constraints were identified to help bound the development of system reoperation strategies. Reoperation strategies will be formulated to meet the SRP objectives without violating the established constraints. The adopted constraints are presented in Table 2.

Constraints were derived from DWR direction, legislation, SRP team input, and Chapters six, seven, and eight of the CWP 2009. Constraints were categorized as either “fixed” or “malleable.” Fixed constraints are those that are universal to any potential reoperation measure considered as part of this SRP.

Malleable constraints are not true constraints, as they do not limit the formulation of measures. However, malleable constraints will have to be overcome to varying degrees in order for certain measures to be implemented. Many malleable constraints are related to the SRP assurances described in Chapter 1 and reflect institutional or legal restrictions or barriers. They are significant restrictions that would typically require support by owners, beneficiaries, and other stakeholders, or appropriate policy and/or legislative changes in order to be overcome. Malleable constraints could increase the difficulty of implementing certain system reoperation measures.

Table 2 - Fixed and Malleable Constraints

Constraint Statement[1]	Source
Fixed Constraints	
Construction will be limited to features that support reoperation at existing facilities. New features may support conjunctive use, and water transfers. Reoperation does not include construction of major new facilities (e.g., a new reservoir).	DWR direction
No benefit will accrue to one (or more) mission(s) at the expense of a competing mission without mitigation. Missions include (as specified in CWC 83002) improving water supply reliability, flood hazard reduction, water quality, decreasing groundwater overdraft, restoring or protecting the ecosystem.	Water Code 83002
Water quality regulations for application of surface water to the groundwater system shall be adhered to.	CWP 2009. p 8-14
Existing and changing environmental and water quality requirements may reduce the flexibility for reoperation of the system. Changes shall not violate existing environmental regulations.	CWP 2009. p 6-14, Institutional Constraints
Projects will not cause unmitigated harm to California and Federal listed threatened and endangered species.	State and Federal Endangered Species Acts
Malleable Restrictions to Implementation	
DWR will perform reoperation studies of regional and local projects with the collaborative and voluntary participation of reservoir owners and operators.	
If a proposed system change causes an exceedance of the existing capacity of reservoir outlets, storage, pumping, and conveyance, capacity shall be increased to compensate for the exceedance.	CWP 2009. p 6-13
California's priority system of surface water rights, including areas of origin water rights, shall not be violated without mitigation and owner consent.	CWP 2009. p 6-14, Institutional Constraints
Contractual obligations for water deliveries shall not be violated without contractor/contractee consent and compensation.	
Flood rule curves shall not be changed without coordination, cooperation, and approval of the responsible agency.	
Coordinated operating agreements shall not be violated or changed without coordination, cooperation, and approval of all signatories to the agreement.	
Changes in project purposes for federal projects will require authorization from Congress.	
Conjunctive management projects must adhere to local ordinances in addition to State and federal laws and regulations.	CWP 2009. p 8-7
Existing tribal water rights and adjudications pertaining to both surface water and groundwater shall not be violated without mitigation and voluntary participation from tribes.	CWP 2009. p 8-15
Basin management objectives and other groundwater ordinances shall not be violated without written approval from responsible agencies.	CWP 2009. p 8-28

[1]Development of constraints supports the planning process. A constraint is a restriction that limits the extent of the formulation of a plan. Measures are evaluated on the extent to which they avoid planning constraints.

Building Blocks and Measures

The core work of the SRP phases described in this Study Plan will be the development and evaluation of system reoperation strategies. A system reoperation strategy is an assemblage of discrete physical improvements, called "building blocks" that can be made in a water system to achieve specified optimization objectives. In the case of the SRP, discrete physical improvements to at least two of the three mission elements (water supply reliability, flood hazard reduction, and ecosystem restoration and protection) must be achieved. To that end, a framework was developed to organize the selection and combination of individual system reoperation measures, ultimately for the purpose of evaluation of the assembled strategies. An initial list of system reoperation measures was generated through brainstorming sessions conducted by the SRP team and from review of documents in the SRP literature library described earlier in this chapter. The following is a list of system reoperation building blocks:

- Integrate CVP, SWP, U.S Army Corps of Engineers (USACE), and other local projects Currently, only some aspects of the operation of the CVP and SWP are coordinated. Additional future integration of operations could yield water supply, flood hazard reduction, and ecosystem benefits.
- Reoperate reservoirs – The building block includes changes to existing operations and management procedures for existing reservoirs, for example, changes in reservoir release patterns. Reservoirs can be reoperated in many ways in conjunction with any of the building blocks in this list.
- Integrate management of groundwater and surface water - Utilizing dewatered aquifer space for storage in conjunction with reservoir reoperations is one technique for backstopping reservoirs to mitigate the risk of inadequate refill under reoperation conditions.
- Facilitate water transfers- Market transfers among willing parties can reallocate limited supplies from existing water rights holders to uses bearing a higher economic or social value. Most reoperation strategies will involve some transfer arrangements to make them work.
- Change flow regimes (stream flow patterns) - Changes in the magnitude, duration, frequency, timing and location of both high and low flow events below reservoirs to emulate the natural hydrograph can improve the physical conditions conducive to ecosystem health and productivity.
- Expand through-valley flood conveyance, reactivate floodplains – This building block is the expansion of through-valley flood conveyance via implementation of levee set-backs, expanded flood bypasses, increased transitory storage, and other expansions to the physical footprint of the state's flood conveyance system. The extra conveyance enables increased rates of release at reservoirs for flood control, thereby allowing higher average storage levels during the runoff period.

- Retrofit dams - Changes in outlet size, outlet location, and installation of multi-level outlets as well as increasing spillway size, retrofitting sluice gates, and other such physical changes allow changes in reservoir flow releases.
- Change points, timing and / or volume of diversions - To reduce or alter stream depletions due to diversions for consumptive use, changes to the exercise of the diversion right may be beneficial. For example, the Isolated Delta Conveyance (IDC) facility is proposed within BDCP to make just these changes to Delta operations.
- Establish conveyance interconnections - Conveyance interconnections can increase the flexibility of water storage and delivery in the Central Valley.
- Augment Surface Storage – New surface storage is included due to a high level of interest, but would not meet the planning constraints of the SRP and therefore, will not be developed.

General measures were formulated and placed under the first six building block categories. The measures and strategy development of Phase 1 did not reach a degree of detail that resulted in measures for the following building blocks: Retrofit Dams, Change Points, Timing and or Volume of Diversions, and Establish Conveyance interconnections. As more detail is forthcoming, measures for these building blocks will become more apparent.

Table 3 presents general measures that met SRP constraints and generally demonstrates the correspondence between measures and the specific objectives identified for the SRP. This link between the measures and the SRP objectives identifies which measures, or group of measures, meet multiple objectives and therefore have the potential to address the State's water resources challenges via the missions and goals established for the SRP in an integrated fashion. More detailed measures identifying specific facilities were also formulated in Phase 1. However, to comply with the assurances, these measures must be vetted through Phase 2 before they are ready for public release.

Table 3 – Preliminary Measures and Potential to Meet SRP Objectives

Measure (Building Blocks are in bold Italics)	Flood Hazard Reduction			Water Supply					Ecosystem Protection and Restoration			
	A-Ob1	A-Ob2	B-Ob3	B-Ob1	B-Ob2	B-Ob3	B-Ob4	B-Ob5	C-Ob1	C-Ob2	C-Ob3	C-Ob4
Description	Reduce probability of flooding	Conserve flood storage	Increase resilience to climate change	Increase water supply storage	Increase resiliency to climate change	Improve the quality of water supplies	Reduce groundwater overdraft and replenish overdrawn aquifers	Increase annual seasonal carryover of stored water	Increase viability, productivity of wildlife habitat	Increase acreage of habitat type	Increase viability, productivity of in-stream fish habitat	Improve the quality of water in aquatic ecosystems
Integrate CVP, SWP, USACE, and other Local Projects												
Modify existing institutional/legal operating rules	X	X	X	X	X	X	X	X	X		X	X
Develop modeling tools for evaluation of system integration	X	X	X	X	X	X	X	X	X		X	X
Remove physical operating constraints	X	X	X	X	X	X	X	X	X		X	X
Implement Integration Program	X	X	X	X	X	X	X	X	X		X	X
Mutually co-operate CVP & SWP pumping south of Delta	X	X	X	X	X	X		X	X		X	X
Deliver CVP/SWP water to local project south of Delta (conserve Lake Meade water)	X	X	X	X	X	X		X	X		X	X
Co-operate CVP/SWP storage north of Delta	X	X	X	X	X	X			X		X	X
Coordinate/integrate available local agency reservoir-stored water in Sacramento River watershed to CVP and SWP	X	X	X	X	X	X			X		X	X
Co-operate storage with local agency reservoirs and CVP in San Joaquin River watershed	X	X	X	X	X	X			X		X	X
Coordinate/integrate USACE reservoirs in San Joaquin River watershed available for SWP storage				X	X							X
Reoperate Reservoirs												
Modify existing institutional/legal operating rules	X	X	X	X	X	X	X	X	X		X	X
Remove physical operating constraints	X	X	X	X	X	X	X	X	X		X	X
Modify resource management strategies	X	X	X	X	X	X	X	X	X		X	X
Develop modeling tools for reoperation evaluations	X	X	X	X	X	X	X	X	X		X	X
Improve water supply forecasting	X	X	X	X	X	X		X	X		X	X
Implement forecast-coordinated operations	X	X	X	X	X	X		X	X		X	X
Implement forecast-based operations	X	X	X	X	X	X	X	X	X		X	X
Implement reoperation to support conjunctive management and groundwater storage	X	X	X	X	X	X	X		X		X	X
Reoperate CVP reservoir for San Joaquin River restoration and water supply	X	X	X	X	X	X			X		X	X
Institute forecast-based operations at CVP/SWP reservoirs in Sacramento River watershed	X	X	X	X	X	X		X	X		X	X

Measure (Building Blocks are in bold Italics)	Flood Hazard Reduction			Water Supply					Ecosystem Protection and Restoration			
	A-Ob1	A-Ob2	B-Ob3	B-Ob1	B-Ob2	B-Ob3	B-Ob4	B-Ob5	C-Ob1	C-Ob2	C-Ob3	C-Ob4
Description	Reduce probability of flooding	Conserve flood storage	Increase resilience to climate change	Increase water supply storage	Increase resiliency to climate change	Improve the quality of water supplies	Reduce groundwater overdraft and replenish overdrawn aquifers	Increase annual seasonal carryover of stored water	Increase viability, productivity of wildlife habitat	Increase acreage of habitat type	Increase viability, productivity of in-stream fish habitat	Improve the quality of water in aquatic ecosystems
Promote forecast-based/coordinated operations at facilities in the Yuba River watershed	X	X	X	X	X	X		X	X		X	X
Operate upstream reservoirs to better manage cold water				X	X	X		X	X		X	X
Institute forecast-coordinated operation in the Sacramento River System	X	X	X	X	X	X		X	X		X	X
Forecast-based reoperation of major San Joaquin basin reservoirs	X	X	X	X	X	X		X	X		X	X
Forecast coordinated reoperation of San Joaquin basin reservoirs	X	X	X	X	X	X		X	X		X	X
Reoperate to take advantage of new analysis tools and new data	X	X	X	X	X	X	X	X	X		X	X
Rebalance operation to better meet resource management goals	X	X	X	X	X	X	X	X	X		X	X
Integrate Management of Groundwater and Surface Water												
Modify existing institutional/legal operating rules	X	X	X	X	X	X	X	X	X		X	X
Remove physical operating constraints	X	X	X	X	X	X	X	X	X		X	X
Modify resource management strategies	X	X	X	X	X	X	X	X	X		X	X
Develop groundwater management tools	X	X	X	X	X	X	X	X	X		X	X
Modify surface water supply and other facilities to support conjunctive use	X	X	X	X	X	X	X		X		X	X
Implement project-specific integrated surface water/groundwater operations.	X	X	X	X	X	X	X		X		X	X
Enlarge conjunctive use in the Sacramento River watershed	X	X	X	X	X	X	X	X	X		X	X
Enlarge conjunctive use in the San Joaquin River watershed	X	X	X	X	X	X	X	X	X		X	X
Replenish groundwater aquifers				X	X		X		X	X	X	X
Surface-groundwater conjunctive use between the Lower Tuscan Aquifer and associated reservoirs	X	X	X	X	X	X	X	X	X		X	X

Measure (Building Blocks are in bold Italics)	Flood Hazard Reduction			Water Supply					Ecosystem Protection and Restoration			
	A-Ob1	A-Ob2	B-Ob3	B-Ob1	B-Ob2	B-Ob3	B-Ob4	B-Ob5	C-Ob1	C-Ob2	C-Ob3	C-Ob4
Description	Reduce probability of flooding	Conserve flood storage	Increase resilience to climate change	Increase water supply storage	Increase resiliency to climate change	Improve the quality of water supplies	Reduce groundwater overdraft and replenish overdrawn aquifers	Increase annual seasonal carryover of stored water	Increase viability, productivity of wildlife habitat	Increase acreage of habitat type	Increase viability, productivity of in-stream fish habitat	Improve the quality of water in aquatic ecosystems
Facilitate Water Transfers												
Modify existing institutional/legal operating rules	X	X	X	X	X	X	X	X	X		X	X
Remove physical operating constraints	X	X	X	X	X	X	X	X	X		X	X
Modify resource management strategies	X	X	X	X	X	X	X	X	X		X	X
Develop modeling tools for water transfer evaluations	X	X	X	X	X	X	X	X	X		X	X
Facilitate water marketing arrangements to encourage highest economic use				X	X	X			X		X	X
Construct new conveyance facilities to facilitate water transfers	X	X	X	X	X	X		X	X		X	X
Study acceptable ways to identify, lessen, and distribute economic impacts from agricultural water transfers				X	X				X		X	
Improve on current methods to identify and quantify water consumption and savings involved in transfers				X	X	X	X	X	X		X	
Study how to streamline the state/federal approval process for water transfers	X	X	X	X	X	X	X		X		X	X
Change Stream Flow Regimes/Patterns												
Modify existing institutional operating rules, purchase lands and easements	X	X	X	X	X	X	X	X	X	X	X	X
Remove physical operating constraints	X	X	X	X	X	X	X	X	X		X	X
Modify resource management strategies	X	X	X	X	X	X	X	X	X		X	X
Develop modeling tools for stream flow - environmental effects evaluations	X	X	X	X	X	X	X	X	X		X	X
Implement policies and programs	X	X	X	X	X	X	X	X	X		X	X
Implement a corridor management policy on the Sacramento River and tributaries	X	X	X	X	X	X		X	X		X	X
Implement a corridor management policy on the San Joaquin River and tributaries	X	X	X	X	X	X		X	X		X	X
Expand Through-Valley Conveyance/Reactivate Floodplains[b]												
Construct set back levees	X		X	X	X	X	X		X	X	X	X
Construct flood bypasses	X		X	X	X	X	X		X	X	X	X
Construct transitory storage flood plains	X		X	X	X	X	X		X	X	X	X

Measure (Building Blocks are in bold Italics)	Flood Hazard Reduction			Water Supply					Ecosystem Protection and Restoration			
	A-Ob1	A-Ob2	B-Ob3	B-Ob1	B-Ob2	B-Ob3	B-Ob4	B-Ob5	C-Ob1	C-Ob2	C-Ob3	C-Ob4
Description	Reduce probability of flooding	Conserve flood storage	Increase resilience to climate change	Increase water supply storage	Increase resiliency to climate change	Improve the quality of water supplies	Reduce groundwater overdraft and replenish overdrawn aquifers	Increase annual seasonal carryover of stored water	Increase viability, productivity of wildlife habitat	Increase acreage of habitat type	Increase viability, productivity of in-stream fish habitat	Improve the quality of water in aquatic ecosystems
Purchase flood easements and manage areas as restored floodplains in the Sacramento River Basin	X		X	X	X	X	X		X	X	X	X
Purchase flood easements and manage areas as restored floodplains in the San Joaquin River Basin	X		X	X	X	X	X		X	X	X	X
Restore wetlands in managed floodplains in Sacramento River Basin	X		X	X	X	X	X		X	X	X	X
Restore existing river corridors to a more natural configuration	X		X	X	X	X	X		X	X	X	X
Additional Building Block[c]:												
Retrofit Dams (Size of outlets, Location of outlets, Multi-level outlets, Increase size of spillway, Sluice gates, etc.)												
Change Points, Timing and/or Volume of Diversions												
Establish Conveyance Interconnections												
Augment Surface Storage												

a. "X" = Measure may help meet corresponding objective

b. The measures for *Expand Through-Valley Conveyance/Reactivate Floodplains* may not meet SRP constraints, but were developed due to a high level of interest

c. No measures were formulated under these Building Blocks. Subsequent phases may provide more detail that will result in formulation of measures for these building blocks. The measures for *Augment Surface Storage* would not meet the SRP constraints and will not be developed, but the building block was included due to a high level of interest.

Preliminary Strategies

Preliminary system reoperation strategies that were formulated under Phase 1 are presented in Table 4. Each strategy was formulated by assembling multiple measures into a complete, integrated reoperation concept. The table includes a list of associated measures and a general description for each strategy. The formulation of strategies was based on review of prior investigations and development of reoperation concepts as described above.

Twenty-four more detailed reoperation strategies were formulated under Phase 1. However, to comply with assurances, these strategies must be vetted through Phase 2 before they are ready for public release.

Table 4 – Preliminary Strategies

Reoperations Strategies and Measures		Description of Strategy
<u>Integrate Groundwater and Surface Water Operations</u>		
Sacramento River Watershed Reservoirs and Groundwater Aquifers		
1.	Integrate Operations of Reservoirs in American River Watershed with Groundwater-Pumping Operations of groundwater authorities in Sacramento area near American River	Reoperate reservoir (in American River watershed) at lower carryover storage levels by delivering additional water for environmental restoration and groundwater banking in Sacramento area near American River. Recover from bank in years when reservoir does not entirely refill.
	a. Reoperate reservoir for groundwater-surface water integration	
	b. Implement forecast-based flood operations at reservoir	
	c. Construct diversion/conveyance facilities from American River to current groundwater users	
	d. Construct conveyance facilities from wells to back-stop water users	
	e. Reoperate existing groundwater wells	
	f. Construct new groundwater wells	
	g. Develop water transfers	
	h. Integrate operations with existing statewide water supply system	
	i. Integrate operations with existing statewide water supply system and BDCP facilities	
Sacramento River Watershed Reservoirs and San Joaquin River Groundwater Aquifers*		
2.	Integrate Operations of Reservoirs in Sacramento River Watershed with Groundwater-Pumping Operations of San Joaquin County Groundwater Users	Reoperate reservoir (in Sacramento River watershed) at lower carryover storage levels by delivering additional water for environmental restoration and groundwater banking in San Joaquin County. Use existing conveyance capacity in existing water supply facilities between the two areas. Recover from bank in years when reservoir does not entirely refill.
	a. Reoperate Sacramento River Watershed Reservoirs for groundwater-surface water integration	
	b. Implement forecast-based flood operations at Sacramento River Watershed Reservoirs	
	c. Reoperate Sacramento River intake and associated conveyance facilities	
	d. Construct diversion/conveyance facilities conveying to current SJ County groundwater users	
	e. Construct diversion/conveyance facilities from wells to original water rights holders	
	f. Reoperate existing groundwater wells	
	g. Construct new groundwater wells	
	h. Develop water transfers	
	i. Integrate operations with existing statewide water supply system	
	j. Integrate operations with existing statewide water supply system and BDCP facilities	
3.	Integrate Operations of Reservoirs in Sacramento River Watershed with Groundwater-Pumping Operations of San Joaquin River or Tulare Basin Groundwater Users	Reoperate reservoirs in Sacramento River watershed at lower carryover storage levels by delivering additional water for environmental restoration and consumptive use in groundwater bank area. Reservoir would refill in most years. In years where reservoirs would not entirely refill, serve groundwater bank area with groundwater from existing and/or new wells in that area.
	a. Reoperate reservoirs for groundwater-surface water integration	
	b. Implement forecast-based flood operations at the reservoirs	
	c. Construct diversion/conveyance facilities conveying to current SJ Valley Groundwater Basin groundwater users	
	d. Construct diversion/conveyance facilities from wells to original water rights holders	
	e. Reoperate existing groundwater wells in SJ Valley Groundwater Basin	
	f. Construct new groundwater wells	
	g. Develop water transfers	

	Reoperations Strategies and Measures	Description of Strategy
	h. Integrate operations with existing statewide water supply system	
	i. Integrate operations with existing statewide water supply system and BDCP facilities	
4.	Reoperation and groundwater storage options to facilitate BDCP solutions**	BDCP is scoped to exclude actions by permittees outside of the Delta. Yet, the in-Delta conditions will be determined by upstream reservoir operations and the ability to store water diverted during times of high Delta inflows for use during times of low Delta inflows. Reservoir reoperations and south of Delta groundwater storage scenarios can increase Delta exports while reducing fishery impacts, compared to the status quo. This project will explore these storage operations to determine the optimal scenario for enhancing BDCP outcomes.
San Joaquin River Watershed Reservoirs and San Joaquin River Groundwater Aquifers		
5.	Integrate Operations of Reservoirs in San Joaquin River Watershed and Groundwater-Pumping Operations of Merced-Area Groundwater Users (Using In-Lieu Recharge)	Turn off pumps at end of irrigation season and substitute surface water deliveries to lower carryover storage in reservoir San Joaquin River watershed and increase groundwater storage in Merced area. In years when reservoir does not refill completely, backstop by using groundwater in lieu of surface water, release environmental flows.
	a. Reoperate Reservoir San Joaquin River Watershed for groundwater-surface water integration	
	b. Implement forecast-based flood operations at Reservoir San Joaquin River Watershed	
	c. Construct diversion/conveyance facilities from river in Reservoir San Joaquin River Watershed to current groundwater users	
	d. Construct conveyance facilities from wells to original surface water users	
	e. Reoperate existing groundwater wells	
	f. Construct new groundwater wells	
	g. Develop water transfers	
	h. Integrate operations with existing statewide water supply system	
	i. Integrate operations with existing statewide water supply system and BDCP facilities	
6.	Integrate Operations of Reservoirs in San Joaquin River Watershed and Groundwater-Pumping Operations of Madera-Area Groundwater Users (using Active Recharge)	Predeliver water from irrigation canal in San Joaquin River watershed to Madera-area irrigation district at end of irrigation season to lower carryover storage in reservoir San Joaquin River watershed, bank this water in Madera-area groundwater aquifer, draw on banked water at times when Madera-area canal is shut off to generate fishery restoration flows. Groundwater recharge in Madera area would be done actively.
	a. Reoperate reservoir San Joaquin River watershed for groundwater-surface water integration	
	b. Implement forecast-based flood operations at reservoir San Joaquin River watershed	
	c. Construct diversion/conveyance facilities from irrigation canal in San Joaquin River watershed to current groundwater users	
	d. Construct active-recharge facilities	
	e. Construct conveyance facilities from wells to original water rights holders	
	f. Reoperate existing groundwater wells	
	g. Construct new groundwater wells	
	h. Develop water transfers	
	i. Integrate operations with existing statewide water supply system	
	j. Integrate operations with existing statewide water supply system and BDCP facilities	
7.	Integrate Operations of Reservoirs in San Joaquin River Watershed and Groundwater-Pumping Operations of Merced- and Turlock-Area Districts Groundwater Users	Drill production wells in Merced- and Turlock-area irrigation districts proximate to irrigation canals. Before the end of the irrigation season, shut off wells and substitute surface water deliveries. Lower carryover storage in reservoirs in San Joaquin River watershed. In years that reservoir does not refill completely, use groundwater in-lieu of surface water to make up the difference, restore environmental flows in the river in the San Joaquin River watershed.
	a. Reoperate reservoirs in San Joaquin River watershed for groundwater-surface water integration	
	b. Implement forecast-based flood operations at reservoirs in San Joaquin River watershed	
	c. Construct diversion/conveyance facilities from river in San Joaquin River watershed to current groundwater users	
	d. Construct conveyance facilities from wells to original water rights holders	
	e. Reoperate existing groundwater wells	
	f. Construct new groundwater wells	

	Reoperations Strategies and Measures	Description of Strategy
	g. Develop water transfers	
	h. Integrate operations with existing statewide water supply system	
	i. Integrate operations with existing statewide water supply system and BDCP facilities	
Integrate SWP, CVP, USACE and Local Surface Water Operations		
8.	Integrate CVP-SWP Reservoir Operations	Reoperate CVP and SWP reservoirs at lower carryover storage levels (to increase flood storage capacity) by releasing additional water to achieve environmental flow targets in Sacramento and Feather Rivers, respectively, and for additional water supply in the Sacramento Valley. Implement forecast based flood operations in the reoperation strategy. Reservoir would refill in most years. In the ~ 15% of years when reservoirs would not entirely refill, make up the deficit (compared to current operations) by drawing on water in other reservoirs.
	a. Reoperate CVP Reservoir for surface water integration	
	b. Reoperate SWP Reservoir for surface water integration	
	c. Implement forecast-based flood operations at CVP Reservoir	
	d. Implement forecast-based flood operations at SWP Reservoir	
	e. Reoperate other reservoir(s)	
	f. Construct conveyance facilities from other reservoirs to back-stop water users	
	g. Develop water transfers	
	h. Integrate operations with existing statewide water supply system	
	i. Integrate operations with existing statewide water supply system and BDCP facilities	
9.	Integrate Operation of CVP, SWP, and South Delta Export Pumps	Jointly operate currently existing SWP/ CVP storage, diversion, & conveyance infrastructure north of and including the south Delta export pumps
	a. Reoperate CVP reservoirs	
	b. Reoperate SWP Reservoir	
	c. Reoperate SWP south-Delta export pumps	
	d. Reoperate CVP south-Delta export pumps	
	e. Reoperate California Aqueduct-Delta Mendota Canal Intertie	
	f. Develop water transfers	
	g. Modify Cooperative Operating Agreement	
	h. Integrate operations with existing statewide water supply system	
	i. Integrate operations with existing statewide water supply system and BDCP facilities	
10.	Integrate Operation of CVP Reservoir and USACE Reservoirs	Jointly operate currently existing CVP/USACE storage, diversion, & conveyance infrastructure south of the Delta
	a. Reoperate CVP reservoir	
	b. Reoperate USACE reservoir	
	c. Construct diversion/conveyance facilities and interconnections between San Joaquin watershed service areas	
	d. Develop water transfers	
	e. Integrate operations with existing statewide water supply system	
	f. Integrate operations with existing statewide water supply system and BDCP facilities	
11.	Integrate CVP-SWP Reservoir Operations and Local Reservoir Operations*	Jointly operate currently existing SWP/ CVP storage, diversion, & conveyance infrastructure north of and including the south Delta export pumps with local-owner reservoirs south of the Delta
	a. Reoperate CVP Reservoir	
	b. Reoperate SWP Reservoir	
	c. Reoperate local-owner reservoirs	

	Reoperations Strategies and Measures	Description of Strategy
	d. Construct diversion/conveyance facilities from local-owner reservoirs to CVP/SWP water users	
	e. Develop reservoir-storage lease agreements with local owner	
	f. Develop water transfers	
	g. Integrate operations with existing statewide water supply system	
	h. Integrate operations with existing statewide water supply system and BDCP facilities	
<u>Reactivate Floodplains for Improved Flood Hazard Reduction</u>		
12.	Reoperate flood control reservoirs in the Central Valley in conjunction with reactivated downstream floodplains**	There are 11 reservoirs with flood control functions in the Central Valley. All of these are currently operated under rule curves designed to prevent inundation of historic floodplains, which have become encroached by post-dam development. In many cases, levees are also a part of this flood control infrastructure. These operations are suboptimal with respect to all of the objectives of this project: flood hazard reduction, water (and power) supply, and environmental flows. Floodplain encroachment reduces the magnitude of dam releases that can be accommodated, and therefore the rate at which flood water can be released. This requires that more reservoir storage space be dedicated to flood reservation than would be necessary if floodplain constraints were ameliorated, at the expense of water supply, power generation and biological productivity. Under this scenario, the project will investigate the "pinch points" that constrain reservoir operations and strategies to alleviate them. We will focus on floodplains that would be of exceptional ecological value if reactivated. This work directly augments the FloodSafe California planning program and its Central Valley Flood Protection Plan that it is currently developing.
	a. Reoperate reservoirs	
	b. Set back levees	
	c. Construct flood bypasses	
	d. Construct transitory storage flood plains	
	e. Modify reservoir rule curves	
<u>Reduce Physical Losses of Water Supply Through Transfer Facilitation</u>		
13.	Reduction in physical losses of water supply through transfer facilitation**	Appreciable quantities of irrigation water are lost to evaporation and deep percolation because of underinvestment in water conservation technologies in the Central Valley. Market opportunities create the incentives for these investments. However, long-term transfer arrangements are necessary to amortize these investments. Long-term transfers do not occur because of an absence of mechanisms to store and convey conserved water. In this scenario, the project will investigate how such mechanisms could improve water use efficiency, making more water available for consumptive use and environmental flows, and how this could also allow irrigation reservoirs to operate a lower carryover storage levels to enhance flood control.
	a. Reoperate reservoirs	
	b. Develop water transfers	
	c. Construct storage facilities**	
	d. Construct conveyance facilities	
<u>Improve Reservoir Operations Using Forecasting</u>		
Sacramento River Watershed		
14.	Implement Forecast-Based Flood Operations at CVP Reservoir in Sacramento River Watershed	Incorporate weather predictions into rainfall-runoff models for CVP reservoir watershed. Modify flood control rule curve to account for predicted inflow. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify CVP reservoir rule curve	
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	
15.	Implement Forecast-Based Flood Operations at SWP Reservoir in Sacramento River Watershed	Incorporate weather predictions into rainfall-runoff models for SWP reservoir watershed. Modify flood control rule curve to account for predicted inflow. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify SWP reservoir rule curve	
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	

	Reoperations Strategies and Measures	Description of Strategy
16.	Implement Forecast-Based Flood Operations at Local-Owned Reservoir	Incorporate weather predictions into rainfall-runoff models for local-owned reservoir watershed. Modify flood control rule curve to account for predicted inflow. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify Local-Owned reservoir rule curve	
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	
17.	Implement Forecast-Coordinated Flood Operations at Sacramento River Watershed Reservoirs	Incorporate weather predictions into rainfall-runoff models for the watersheds of Sacramento River watershed reservoirs in order to minimize damages in the Marysville and Sacramento areas. Modify flood control rules curve to account for predicted inflows. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify Sacramento River watershed reservoirs rule curves	
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	
18.	Implement Forecast-Based Water Quality CVP/SWP Reservoirs	Develop a Delta-water-quality prediction tool and make releases from CVP/SWP for Delta-water-quality purposes based on those predictions. Avoid delivering water to the Delta unnecessarily as a result of changes in Delta water quality during the travel time of the reservoir releases.
	a. Develop forecasting and modeling tools for Delta water quality	
	b. Reoperate CVP/SWP reservoirs	
	c. Integrate operations with existing statewide water supply system	
	d. Integrate operations with existing statewide water supply system and BDCP facilities	
19.	Implement Forecast-Based Water-Supply-Delivery Releases at CVP/SWP Reservoirs	Develop a water-delivery prediction tool that better accounts for river depletions (diversions) from and accretions (discharges) into the streams that carry the deliveries to the south Delta export pumps. Make releases from CVP/SWP based on those predictions. Avoid losses by not delivering too much water to the Delta.
	a. Develop forecasting and modeling tools for river depletions (diversions) and accretions (discharges)	
	b. Reoperate CVP/SWP Reservoirs	
	c. Integrate operations with existing statewide water supply system	
	d. Integrate operations with existing statewide water supply system and BDCP facilities	
San Joaquin River Watershed		
20.	Implement Forecast-Based Flood Operations at CVP Reservoir in San Joaquin River Watershed	Incorporate weather predictions into rainfall-runoff models for watershed of CVP reservoir in San Joaquin river watershed. Modify flood control rule curve to account for predicted inflow. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify rule curve for CVP reservoir in San Joaquin river watershed	
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	
21.	Implement Forecast-Based Flood Operations at Local-Owned Reservoir in San Joaquin River Watershed	Incorporate weather predictions into rainfall-runoff models for watershed local-owned reservoir in San Joaquin River watershed. Modify flood control rule curve to account for predicted inflow. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify rule curve for local-owned reservoir in San Joaquin River watershed	

	Reoperations Strategies and Measures	Description of Strategy
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	
22.	Implement Forecast-Coordinated Flood Operations at CVP and Local-Owned Reservoirs in San Joaquin River Watershed	Incorporate weather predictions into rainfall-runoff models for the watersheds of CVP and local-owned reservoirs in San Joaquin River watershed in order to minimize damages in the Fresno, Modesto, and Stockton areas. Modify flood control rules curve to account for predicted inflows. Release flows early to prepare for predicted large runoff events and provide greater flood protection. Minimize releases to conserve as much water as possible without sacrificing flood protection levels.
	a. Develop forecasting and modeling tools for specific storms	
	b. Develop forecasting and modeling tools for water year types	
	c. Modify rule curves for CVP and local-owned reservoirs in San Joaquin River watershed	
	d. Integrate operations with existing statewide water supply system	
	e. Integrate operations with existing statewide water supply system and BDCP facilities	

**Isolated Delta Conveyance facility may be required.*

***This scenario would include the construction of new major infrastructure, and therefore would not meet the constraints criteria for the SRP.*

Chapter 4 - Phase 2 Strategy Formulation and Refinement

The purpose of Phase 2 is to develop additional strategies and to refine those measures and strategies that were prepared in Phase 1. Through outreach and coordination efforts such as workshops, brainstorming sessions, and meetings, Phase 2 will provide an opportunity for input and review by DWR staff, key agencies, system operators, and other experts and stakeholders. Phase 2 work will be completed in three tiers.

Tier 1 – Internal Formulation

This tier will include internal formulation and review of system reoperation measures and strategies in Phase 1 and inclusion of additional system reoperation strategies not identified by past work. This effort will be conducted in parallel to the creation of a comprehensive listing of potential changes to system operations and categorized into the building blocks for reoperation of the system including a listing of options unique to certain facilities and key geographies of the Central Valley. They will also focus on finding "fatal flaws" as the SRP team and other experts formulate a comprehensive suite of potential system reoperation strategies. The expertise of the entire project team will be deployed for this purpose.

Tier 2 – System Expert Refinement

This tier is designed to increase the field of experts and expand the review process beyond the SRP team. The outreach process widens in this tier to additional water system experts, particularly those whose infrastructure may present promising opportunities for reoperation to achieve the project objectives, (e.g. reservoir operators, irrigation system managers, flood system maintenance administrators, etc.) from a variety of water management entities across the state. The intent is to capture the collective experience of DWR staff whose work relates to the existing infrastructure and to assure coordination with other ongoing studies so as to benefit from findings and results. Beyond DWR, this tier will also harvest the expertise of other local, state and federal water management entities [e.g. U.S. Bureau of Reclamation (Reclamation), USACE, Sacramento Area Flood Control Agency, Yuba County Water Agency, irrigation and water districts such as Merced, Turlock, Metropolitan, etc.]. These experts will become team members to participate as strategies involve infrastructure or operations that attach to their systems.

Tier 3 – Outside Expert Refinement

This tier of evaluation will engage outside experts in water supply, flood hazard, and ecosystem improvement aspects of water system management. This group of outside experts may come from academia, consultants, private sector or other sources and will provide critical peer review and refinement of system reoperation measures and strategies. This tier will also engage relevant experts identified in Tiers 1 and 2. Completion of Tier 3 will help remove those system reoperation strategies found to be infeasible or not implementable. Strategies that appear to be beneficial and implementable will be retained and studied further in the reconnaissance level assessment of Phase 3.

Chapter 5 - Phase 3 Reconnaissance Level Assessment

Phase 3 includes reconnaissance level assessment of the system reoperation strategies advanced from Phase 2. The objective is to evaluate, sort and rank strategies based on their performance in meeting the goals and objectives of the SRP. The strategies will be examined for acceptability, completeness, effectiveness, and efficiency. The process will include the following:

a. Outreach
b. Establish baseline
c. Identify existing physical and operational constraints
d. Quantify new or modified physical facilities needed for potential system reoperation concepts
    i. Reservoir (and potentially generation) retrofits
    ii. Pumping and conveyance
    iii. Injection wells/recharge basins
    iv. New flood conveyance infrastructure
e. Evaluate system reoperation concept measures
    i. Reservoir reoperations (including forecast based operations)
    ii. Conveyance facilities
    iii. Aquifer characteristics
    iv. Conjunctive water management
    v. Integration with existing water management system
    vi. Integration with ecosystem/new habitat
    vii. Integration with other related projects [BDCP; Central Valley Flood Management Planning Program (CVFMP), etc]
f. Quantify potential system reoperation concept benefits
    i. Water supply
    ii. Flood hazard reduction
    iii. Ecosystem
g. Quantify potential system reoperation concept costs
    i. Retrofits and new facilities
    ii. Operation and maintenance
    iii. Hydropower generation
    iv. Environmental mitigation
    v. Identify primary constraints affecting potential implementation

These steps will be modified and/or completed for iterations that consider baseline conditions with and without BDCP, as appropriate.

The reconnaissance level assessments will be as streamlined to the extent practical. For example, the assessments will be limited to the use of existing data and tools. Where possible, results from CalSim model runs used for the BDCP will help establish baseline conditions. This phase will make use of existing data and tools in use by DWR, potentially including, but not necessarily limited to, the FloodSAFE/CVFED HEC-RAS models for flood hazard reduction evaluation, FESSRO's HEC-EFM and HEC-RAS models for ecosystem protection and restoration evaluation. The use of these and other tools will be limited primarily to post-processing of outputs and interpretation through a decision support tool (described, though some limited analysis may be completed to fill minor data gaps, confirm assumptions, and/or perform sensitivity analysis). Assessment in this phase will be performed at a level of effort consistent with what is typical of other reconnaissance level screening studies (e.g., those within the federal planning process).

DWR recognizes that some tools are well established and suited to evaluation of metrics familiar to the water resources community. In other instances, the tools are not of the same level of sophistication and some of the metrics have evolved with less confidence in their utility for comparison of benefits and results. With that concern in mind, the reconnaissance level assessment will include identification of potentially needed improvements for such metrics and associated analysis tools.

Define and Develop Strategy-Specific Benefit Metrics

In discussions with DWR staff, it has been determined that the identification and characterization of benefit metrics for some of the study objectives both for this study and other related studies have historically reflected less balance among and between metrics and there is a strong desire to make progress toward achieving balance in those characterizations.

At the initiation of the reconnaissance level assessment process, efforts will be made to consider potential benefits through the use of metrics to measure system properties that quantify achievement (total or partial) of an objective or target condition. Furthermore, in the case of this study, it is imperative to first define the *problems* and develop *objectives* for the desired system state being sought. Examples would include:

Problems	Objectives
• Unmet Supply Deliveries	• Increased Water Supply Deliveries constraints and operations
• Constraints on Operations	• Increased System Reliability and Flexibility
• Degraded habitat and declining populations of key species	• Improved ecosystem conditions
• Unsatisfactory flood management system performance	• Decreased flood hazard

To measure progress toward addressing the problems and achieving the objectives, it will be necessary to define a suite of metrics for each objective. Metrics developed in this task will be used in both the reconnaissance and feasibility level assessments of the SRP. Metrics may be natural, constructed, or proxy—and will be selected in that order of preference when multiple metric types are viable. In the course of refining the strategies, these metrics will then be modified, as applicable, to make them “strategy-specific,” thus acknowledging the potential changes in the system and making the metrics correspond to the benefits outlined in the strategies.

Metric development will occur in a manner and at a pace that compliments the SRP’s progress. While the advancement of the metric and analytical processes is desirable and a requested deliverable under this program it is secondary to the objectives of the SRP and therefore will not take precedence over meeting the objectives of the SRP.

Develop System Reoperation Decision Support Tool (SRDST)

This task will evolve in close coordination with metric development. A GIS-based SRDST to visualize and communicate relevant details of the California water system (initially, and to the extent practical, in support of Strategy refinement activities), catalog existing system conditions, track proposed system reoperation changes (generated through Strategy refinement activities, reconnaissance level assessment, and feasibility level assessment), organize and automate water supply, flood hazard, and ecosystem metric computations for benefit quantification, incorporate relevant modeling and analysis outputs, and to the extent warranted, support probability-based system reoperation decision making. The SRDST will be developed incrementally, with adequate detail and interconnectedness enabled at the formulation, reconnaissance, and feasibility phases of the SRP.

Develop Approval to Address Climate Change

California’s water resources and water management systems are vulnerable to the impacts of climate change. To the extent serviceable, the SRP will use tools developed by DWR and others to evaluate the resilience of system reoperation strategies to hydrologic changes due to climate change. These tools address changes in water supply reliability, flood hazard, and ecosystem conditions can be addressed as a function of projected changes in atmospheric temperature, precipitation, evapo-transpiration, snowpack accumulations, snowmelt timing and runoff, and sea level rise. Parameters for these changes can be derived through the approach detailed in the December 23, 2010 DWR paper “Climate Change Characterization and Analysis in California Water Resources Planning Studies.” That approach entails the selection of various emissions strategies as input to selected Global Circulation Models (GCM). The GCM output is then downscaled to a regional level that is used as input to hydrologic models that are utilized to run operational and impact models on the system. This methodology was put into practice as part of the BDCP. The findings may be used to provide a basis for a climate change impact analysis in the SRP.

Develop Approach for Baseline Conditions

To evaluate the performance of reoperations strategies, they must be compared to assumed baseline conditions. Therefore, baseline conditions for water supply, flood hazard reduction, and ecosystem will be developed and documented. The assumed physical system and operations will be defined, and the following items will be identified: assumed physical and operational constraints, assumed institutional constraints, competing beneficial uses, and considerations for climate change. To the extent practicable, information and assumptions from current studies will serve as source documents so as to expedite this process. An additional baseline condition will be developed that includes implementation of the BDCP so that the strategies can be evaluated for compatibility with BDCP.

Chapter 6 - Phase 4 Feasibility Level Assessment

This SRP phase includes a more detailed assessment of engineering feasibility and a more detailed cost estimation component. The feasibility level assessment will also consider the institutional and legal constraints that create potential impediments to the actual implementation of system reoperation strategies. The feasibility level assessment will follow steps similar to those described in the reconnaissance level assessment but will provide a more in-depth assessment of the most promising system reoperation strategies advanced from the reconnaissance level assessment. As merited and necessary to complete a more robust feasibility level assessment of the advanced strategies, additional supporting studies, data collection, and/or detailed methods development may occur during this phase of the SRP. Subsequent to the feasibility level assessment and analysis activities, a final review and ranking process will be conducted which considers the results of the feasibility assessment and benefits quantification. The ranking process will likely reflect factors such as acceptability, completeness, effectiveness and efficiency.

Study Plan Schedule

The tentative completion schedule for the SRP is as follows:

Phase	Estimated Completion
Phase 1 – Study Plan	June 2011
Phase 2 – Strategy Formulation and Refinement	October 2011
Phase 3 – Reconnaissance Level Assessment	May 2012
Phase 4 – Feasibility Level Assessment	June 2013

Chapter 7 - Phase 5 Implementation

After being determined to be feasible under phase four of the SRP, DWR can determine if one or more system reoperation strategies are appropriate for moving forward towards implementation. The implementation phase is not a part of this Study and could be carried out under future project(s) by organizations that could include DWR, other state, federal and local agencies. Implementation will require developing an implementation plan tailored for each selected strategy. Implementation plans would:

- identify a lead implementing organization;
- demonstrate the proposed reoperation is in compliance with all environmental laws and regulations (e.g., via preparation of an Environmental Impact Report or Environmental Impact Statement),
- establish a plan for satisfying all policy requirements of the implementing agency and its partners,
- identify potential sources of funding, and
- document financing, construction, operations and maintenance responsibilities.

Once implementation planning is complete, plans and specifications, construction, and new operations can be implemented, contingent on available funding. Projects, plans, studies, or other actions identified during the implementation plan development process could be implemented through funding sources authorized by State legislation, or by other sponsors, or the studies could be deemed more appropriate for implementation at a later time.

Chapter 8 - Analytical Tools Inventory, Assessment, and Needs

This chapter documents an inventory and assessment of existing analytic tools that could be used for the SRP. It also contains recommendations for which analytical tools will be appropriate for the SRP and for improvements to existing tools needed (if any). This information is presented in more detail in Appendix C.

Inventory of Existing Analytical Tools

Table C-1 in Appendix C contains an inventory of the available analytical tools that may be useful for the SRP. The tools in the table are grouped by resource topic, as follows: Water Supply, Flood Management, Water Quality, Groundwater, Ecosystem, and Economics. The information about the tools provided in Table C-1 of Appendix C can be referenced and updated during the SRP.

Assessment of Available Analytical Tools

Key analytical tools from Table C-1 in Appendix C were assessed for their usefulness in conducting the SRP. Due to the relatively short schedule and limited budget of the study, analytical tools that have been applied to the study area on recent studies will likely be deemed most useful in SRP phases. Also, the usefulness of each tool may vary based on the phase of the study. Ultimately, the usefulness of each tool will be determined for each reoperation strategy based on the specific details of the strategy. Thus, the assessment of tools in this appendix can only be discussed generally.

In the reconnaissance level assessment of the SRP, only approximate analyses are needed for the screening of strategies. However, during the feasibility level assessment of the SRP, more detailed analyses will be conducted for the study. Therefore, more time will be allocated to modifying existing inputs, utilizing analytical tools, developing post-processing tools, creating linkages between different analytical tools, and analyzing results. These activities will be done as necessary for gaining the appropriate level of certainty in selecting strategies at a feasibility-analysis level, and as time and budget allow.

Recommended Analytical Tools

The analytical tools listed in Table C-3 in Appendix C are recommended for use in the SR and are a subset of the existing analytical tools in Table C-1 which are the existing tools recommended for use in the SRP. Table 5 below is a short list of tools that are anticipated to be used most extensively in the SRP. This information is also included in Appendix C as Table C-3. Tools will be selected from these tables for each reoperation strategy based on the following three general factors:

- The match between study areas of the proposed strategy and of the tools

- The match between (1) the details of the strategy and (2) the analysis functions of the tools
- The relationship between (1) the time and budget needed to make any needed improvements to the analysis tools and (2) the available time and budget allotted for the associated proposed strategies

In Table C-3 in Appendix C, the tools are grouped in sets by the associated applications, or studies, for ease of reference, and also because it gives an indication of which tools have been linked and/or used in conjunction. That is, typically, pre- and post-processing tools are developed to integrate analysis tools to some degree, as well as to aid with data input and analysis.

Table 5 - Short List of Recommended Existing Analysis Tools

Resource Topic	System Reoperation Program Phase	Main Analysis Tool	Applicable Recent Study
Water Supply	Reconnaissance Level Assessment	CalSim II/USRDOM	FloodSAFE Supplemental Reservoir Operations Analysis BDCP NODOS
	Feasibility Level Assessment	CalLite/WEAP PA	CVP Integrated Resource Plan
		CalSim III[a]	N/A
Flood Hazard Reduction	Reconnaissance Level Assessment	HEC-5/UNET	CVFPP 2012 Supplemental Reservoir Operations Analysis
		Discharge-frequency stage-discharge, stage-damage, and damage-frequency curves	Sacramento-San Joaquin Comprehensive Study (Comp Study)
	Feasibility Level Assessment	HEC-ReSim/HEC-RAS	FloodSAFE Central Valley Hydrology Study
Ecosystem	Reconnaissance Level Assessment/Feasibility Level Assessment	To be determined based on selected metrics and proposed concepts	BDCP and others
		HEC-EFM	FloodSAFE
		DSM2 (Nutrients)	BDCP
		SRH	NODOS
Groundwater	Reconnaissance Level Assessment	Historical/hydrogeology studies/data CVHM	Various BDCP
	Feasibility Level Assessment	C2VSIM[b]	N/A

a. If available. Otherwise, CalSim II/USRDOM would be recommended.
b. If integration with CalSim III has been completed, otherwise, CVHM would be recommended.

The tools in Table C-3 in Appendix C and Table 5 may not be the only tools that are used during the System Reoperation Study. Other existing tools may need to be used, and new tools may need to be developed, as determined during further refinement of the SRP.

Recommended Tool Improvements

No significant improvements to the analytical tools are anticipated for the reconnaissance level assessment, but improvements discussed above could be needed for the feasibility level assessment. Potentially needed improvements have been identified for water supply and ecosystem analyses tools. Other needed improvements may be identified as the study plan is further refined in later phases of the SRP.

Potential water supply tool improvements that have been identified include:

- Developing and adding ecosystem and flood indices to the optimization routines (it should be noted that CalLite does already include an ecosystem flow index in its calculations)
- Adding water supply reliability analysis capability or using reliability analysis tool
- Adding or using existing automation/optimization capabilities to speed up strategy analysis
- Adding capabilities for analyzing forecast related operations
- Implementing surface water and groundwater interaction in CalSim II or CalLite if CalSim III is not available.

Potentially needed improvements to ecosystem tools will be highly dependent on the details of each strategy to be proposed and on the evaluation metrics to be developed. In general, new tools, in particular, those for analyzing ecosystem components and processes such as complex flow regime changes, nutrient cycling, and sediment transport, could be needed for the SRP. Due to schedule and budget constraints, the SRP may be limited to using only existing ecosystem tools and the tools that are currently being developed by other parties.

Chapter 9 - Outreach

This Study Plan describes a sequence of phases to compete the SRP. An Outreach Plan has been developed outlining stakeholder activities to be undertaken in support of SRP Phases 1, 2, and 3. Outreach-related goals have been identified for four key groups:

- DWR staff;
- Federal water management agencies (i.e., Reclamation and USACE);
- State and federal resource agencies [e.g., California Department of Fish and Game (CDFG), US Fish and Wildlife Service (USFWS) etc.]; and
- existing stakeholder groups (e.g, SWAN; and California Water Plan) / general public.

Table 6 outlines the anticipated activities associated with outreach goals for Phases 1, 2 and 3. Phase 1 has been completed. The plan for Phase 4 will be developed similar to the one for Phase 3 with any refinement needed

Table 6 - Outreach Summary Plan Table

	Phase 1	Phase 2	Phase 3
Goals	Goal 1A: Identify existing state and federal agencies, existing stakeholder groups and other potential stakeholders, potentially affected by the SRP Goal 1B: Establish and assign stakeholder "tiers" (e.g. directly affected, interested, associated, etc.) to preliminary list of stakeholders Goal 1C: Gather background materials and tools Goal 1D: Provide preliminary information to existing stakeholders about the SRP Goal 1E: Identify preliminary problems and opportunities (as advised from preliminary stakeholder input) Goal 1F: Confirm accuracy and appropriateness of baseline conditions / assumptions in the Study Plan	Goal 2A: Ensure continued understanding of preliminary measures and strategies by DWR staff, Federal water management agencies and State and Federal resource agencies as well as existing stakeholder groups / public Goal 2B: Gather substantive information from existing stakeholders / public as a means to reformulate strategies Goal 2C: Establish a transparent expert / peer review process as a means to refine strategies	Goal 3A: Ensure robust stakeholder understanding of reconnaissance review processes Goal 3B: Continue transparent review and comment processes for the SRP Goal 3C: Collect stakeholder input on reconnaissance level strategies and strategies review outcomes Goal 3D: Ensure continued understanding of preliminary measures and strategies by DWR staff, Federal water management agencies and State and Federal resource agencies as well as existing stakeholder groups / public
DWR Staff	1. Identify and communicate with appropriate DWR staff that has information, and stakeholder relationships regarding the SRP a. Ensure that key relationships between DWR staff and external parties (knowledgeable in system operation) are identified to enhance future communications. *(Goal 1A)* b. Develop stakeholder list, establishing tiers indicating likely level of interest and anticipated level of participation by State and Federal agencies, existing stakeholder groups and other potential stakeholders. *(Goal 1B)* c. Identify likely stakeholder participants, contact information, and sequence / frequency of interaction during Phases 2 and 3. *(Goal 1B)* d. Gather background information from DWR and assess initial assumptions / baseline conditions. *(Goal 1C)*	1. Continue to communicate and update appropriate DWR staff on progress toward key Study activities. *(Supports Outreach Goal 2A)* 2. Consider strategies identified in Phase 1 for reformulation *(Supports Outreach Goal 2B)*	1. Continue to communicate and update appropriate DWR staff on progress toward key Study activities. *(Supports Outreach Goal 3D)* *2.* Conduct workshop with key DWR staff and invitees to define and develop scenario-specific benefit metrics. *(Supports Outreach Goal 3D)*
Federal Water Management Agencies		1. Identify and communicate with appropriate staff at Federal water management agencies (e.g., BOR, USACE) a. Gather background information and assess initial assumptions / baseline conditions (Goal 1C) b. Ensure that fundamental problems and opportunities related to water management and resource impacts are considered. *(Goal 1E)* 2. Continue to communicate and update appropriate Federal Water Management Agencies on progress toward key Study activities. *(Supports Outreach Goal 2A)* 3. Ground truth initial assumptions / baseline conditions, system elements and building blocks; and ensure that fundamental problems and opportunities of the SRP related to other resource impacts are considered *(Supports Outreach Goals 2A and 2B)*	1. Continue to communicate and update appropriate Federal Water Management Agencies on progress toward key Study activities. *(Supports Outreach Goal 3D)*

<table>
<tr><th></th><th>Phase 1</th><th>Phase 2</th><th>Phase 3</th></tr>
<tr><td>State and Federal Resource Agencies</td><td></td><td>1. Identify and communicate with appropriate staff at other State and Federal-level resource trustee agencies.
a. Continue to communicate and update appropriate State and Federal Resource Agencies on progress toward key Study activities. (Supports Outreach Goal 2A)
2. Ground truth initial assumptions / baseline conditions, system elements and building blocks; and ensure that fundamental problems and opportunities of the SRP related to other resource impacts are considered. (Supports Outreach Goals 2A and 2B)</td><td>1. Continue to communicate with appropriate staff at other State and Federal-level resource agencies on progress toward key Study activities. (Supports Outreach Goal 3D</td></tr>
<tr><td>Existing Stakeholder Groups / Public</td><td></td><td>1. Conduct preliminary briefings with potentially affected stakeholders about the SRP, specifically through existing stakeholder venues including but not limited to the Central Valley Flood Management Plan process, California Water Plan, Statewide Flood Management Plan, etc.
a. Inform existing stakeholder groups about the SRP process (Goal 1D)
b. Gather and assess initial stakeholder perspectives about the SRP and the work conducted thus far on the Study Plan through existing stakeholder venues. (Goal 1E)
2. Compile information collected from the above activities and use to refine the Study Plan for completion of Phase 1. (Goal 1F)
3. Ground truth initial assumptions / baseline conditions, system elements and building blocks; and ensure that fundamental problems and opportunities of the SRP related to other resource impacts are considered. Accomplish this through designing and conducting a series of regional (Sacramento Basin, San Joaquin Basin, Tulare Basin) workshops.
a. Workshops may be sequential. A first round may focus on the review and refinement of building blocks and qualitative fatal flaws, followed by a second round that focuses on a review and refinement of strategies (that include the improved measures). Conversely, the series of workshops may take place once with focus on all aspects of Phase 2 happening simultaneously. (Supports Outreach Goals 2A and 2B)
4. Continue ongoing update briefings with existing stakeholders about the SRP, specifically through existing stakeholder venues. (Supports Outreach Goal 2A)
5. Develop an expert and peer review process including but not limited to:
b. Identifying and approving appropriate reviewers (Supports Outreach Goal 2C)
c. Identifying a review process (Supports Outreach Goal 2C)
d. Hold two expert / peer review meetings (Supports Outreach Goal 2C)
e. Identify reporting methods for public information (Supports Outreach Goal 2C)</td><td>1. Continue update briefings with potentially affected stakeholders about the SRP, specifically through existing stakeholder venues. (Supports Outreach Goals 3A - 3D)
2. Conduct 3 workshops in support of development of benefit metrics in order to:
a. Define methods / protocols / tools
b. Collect input and identify any opportunities for revision / improved protocols, etc.
c. Potentially revise the reconnaissance review approach based on stakeholder input (Supports Outreach Goal 3A - 3D)
3. Support Interview Preparation Activities
a. Provide interview question development support to support definition of the assumed physical system and operations, constraints, assumed institutional constraints, and competing beneficial uses, as well as identify considerations for climate change. (Supports Outreach Goals 3A – 3D)
b. Provide interview question development support etc. to support completion of the reconnaissance level assessment of the selected scenarios. (Supports Outreach Goals 3A – 3D)</td></tr>
</table>

Appendix A – Literature Inventory

SRP Literature Inventory

A literature and data library was developed that includes studies, programs, plans, and other resources relevant to system reoperation and the SRP. Library resources are listed in an inventory that is maintained by DWR. The inventory and resources are stored on a file sharing website called Knowledge Tree (www.knowledgetree.com). As new resources are discovered during the development of the SRP, they will be added to the library and resources inventory on the Knowledge Tree website.

The scope of the library is broad and includes projects, studies, documents, plans, programs, or actions pertaining to water supply, flood control, and aquatic ecosystem management within California that could be useful in characterizing the existing condition and analyzing reoperation scenarios. Entries include both completed and ongoing work. The titles, preparers, and dates of the resources that are currently listed in the library inventory are provided in the table, below.

	Title	Preparer	Date
1.	CALFED Surface Storage Investigations Progress Report	DWR	November 2010
2.	Statewide Flood Management Planning	DWR	Estimated 2013
3.	Central Valley Flood Protection Plan	DWR	Progress Report dated January 2011 Estimated Completion January 2012
4.	Hydrology Update - Base Data	DWR	TBD
5.	Climate Change-Based Hydrology	DWR	TBD
6.	Depletions and Accretions (Land Use)	DWR	November 2006
7.	Forecast Coordinated Operations (FCO)	DWR	Draft January 2011 Estimated Final May 2011
8.	Water Plan Update Resource Management Strategy	DWR	2009 Next Update 2013
9.	CVP/SWP Joint Operations Agreement and Operations Criteria and Plan (OCAP, 2008)	DWR	May 2008
10.	CalSim I and II Studies and Peer Review	DWR	August 2004
11.	Water Use Efficiency Program	DWR	Website Updated April 2010
12.	Groundwater Management Program (GWMP)	DWR	Website Updated July 2009
13.	Bay Delta Conservation Plan (BDCP)	DWR	Draft EIR/EIS Estimated Late 2011 Final EIR/EIS Estimated Late 2012
14.	Fish Restoration Program	DWR	
15.	Integrated Regional Water Management Planning program	DWR	November 2004
16.	Delta Risk Management Strategy	DWR	Website Updated March 2009

SRP Literature Inventory

	Title	Preparer	Date
17.	California Water Plan Update 2009	DWR	2009 Next Update 2013
18.	The State Water Project Delivery Reliability Report 2009 (Draft)	DWR	August 2010
19.	Climate Change Characterization and Analysis in California Water Resources Planning Studies - Final Report	DWR	December 2010
20.	San Joaquin River Management Program	DWR	Website Updated February 2009
21.	Climate Change Threshold Analysis Work Plan	DWR/FloodSAFE	Draft Technical Memorandum September 2010
22.	Draft FloodSAFE Strategic Plan	DWR/FloodSAFE	Draft June 2008
23.	Central Valley Integrated Flood Management Study	DWR/USACE	CVFPP estimated 2012 CVIFMS estimated 2015
24.	Folsom Reservoir Reoperation Program	USACE	
25.	Folsom Dam Raise Project	USACE	August 2001
26.	Delta Cross Channel Re-operation and Through-Delta Facility	DWR/Reclamation	Modeling of a Delta Cross Channel Gate Extension, Technical Memorandum, September 2007 Modeling of Value Engineering Study Alternatives for the Through Delta Facility, Technical Memorandum, September 2007 Value Engineering Study Final Report - Through Delta Facility, September 2007 Pilot Study to Evaluate Acoustic-Tagged Juvenile Chinook Salmon Smolt Migration in the Northern Sacramento-San Joaquin Delta 2006-2007, March 2008
27.	Bureau of Reclamation Central Valley Project Integrated Resources Plan	Reclamation	
28.	Central Valley Project Integrated Resource Plan Technical Approach	Reclamation	January 2011

SRP Literature Inventory

Title		Preparer	Date
29.	State of Bay-Delta Science, 2008	CALFED	2008
30.	CALFED End of Stage 1 Staff Report	CALFED	November 2007
31.	CALFED Record of Decision	CALFED	August 2000
32.	Conservation Strategy for Stage 2 Implementation	CDFG/ERP	July 2010
33.	CALFED Water Quality Program Stage 1 Final Assessment	CALFED	October 2007
34.	ERP Program Plans (annual 2003-2008)	CALFED	
35.	Science Program support of Delta Vision Strategic Plan	CALFED	2007
36.	Pelagic Organism Decline Overview	CALFED	Interagency Ecological Program 2010 Pelagic Organism Decline Work Plan and Synthesis of Results –December 2010
37.	Science Program Review of Delta Risk Management Strategy Phase 1 Report	CALFED	October 2008
38.	Investigations of the Role of Mountain Meadow Restoration in Improving Water Management in Sierra Nevada Watersheds	USDA-Forest Service	March 2010
39.	The San Joaquin River Restoration Program (SJRRP)	Leading Agency: Reclamation Current contact Person: Alicia Forsythe	Website Updated January 2011
40.	Upper Sacramento River Daily Operation Model (USRDOM)	Leading Agency: Reclamation Current contact person: Mike Tansey/David Lewis	2009
41.	Operational Models for Central Valley Project		
42.	Managing water scarcity: an evaluation of interregional transfers		Vaux, H. J., Jr., and R. E. Howitt (1984), Managing water scarcity: An evaluation of interregional transfers, Water Resour. Res., 20(7), 785–792, doi:10.1029/WR020i007p00785.
43.	Lower Tuscan Integrated Conjunctive Water Management Program	GCID and NHI	http://www.gcid.net/LowerTuscan.html Website Updated 2008
44.	Delta Habitat Conservation and Conveyance Program	DWR/Reclamation	
45.	Delta Flow Criteria	SWRCB	August 2010
46.	Water Resources White Paper	Delta Stewardship Council	December 2008
47.	Flood Risk White Paper	Governor's Delta Vision Blue Ribbon Task Force	October 2010
48.	Delta Vision Strategic Plan	Governor's Delta Vision Blue Ribbon Task Force	October 2008
49.	Technical Study #2: Evaluation of North Delta Migration Corridors: Yolo Bypass	Bay Delta Conservation Plan Integration Team	December 2008

SRP Literature Inventory

	Title	Preparer	Date
50.	Lower Tuscan Aquifer Monitoring, Recharge and Data Management Project and the Draft Initial Study / Proposed Mitigated Negative Declaration	Butte County Department of Water and Resource Conservation	January 2007
51.	A Water Plan for the 21st Century: Regional Self-Sufficiency Scenario	Governor's Delta Vision Blue Ribbon Task Force	August 2007
52.	Facilitating Water Markets To Induce Improvements in the Productivity of Water Use in California Agriculture	Natural Heritage Institute	
53.	Comments on Climate Change Adaptation White Paper	NRDC	July 2010
54.	Central Valley Recovery Plan	NOAA Fisheries	October 2009
55.	Northern Sacramento Valley Conjunctive Water Management Investigation	Glenn-Colusa Irrigation District, NHI	Website Updated December 2010
56.	2010 Climate Action Team Report	Cal EPA	Website Updated December 2010
57.	Climate Change Downscaling Workshop	USFWS/CDFG	November 2010
58.	2009 California Climate Change Adaptation Strategy	California Natural Resources Agency	Website Updated November 2010
59.	Projections of Potential Flood Regime Changes in California	CEC/Cal EPA	Draft Paper March 2009
60.	Delta Protection Commission Land Use and Resources Management Plan	Delta Protection Commission	Draft for the Primary Zone of the Delta Adopted February 2010
61.	Habitat Management, Preservation and Restoration Plan for Suisun Marsh	Reclamation	Draft EIS/EIR October 2010
62.	Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta	CDFG	November 2010
63.	Envisioning Futures for the Sacramento-San Joaquin Delta	Public Policy Institute of California (Jay Lund, Ellen Hanak, William Fleenor, Richard Howitt, Jeffrey Mount, and Peter Moyle)	February 2007
64.	Comparing Futures for the Sacramento-San Joaquin Delta	Public Policy Institute of California (Jay Lund, Ellen Hanak, William Fleenor, William Bennett, Richard Howitt, Jeffrey Mount, and Peter Moyle)	July 2008
65.	Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Overview	CALFED	
66.	Planning for a Better Future - California 2025 - 2011 Update	PPIC	2011
67.	Sacramento Valley Conjunctive Use Project - Final Phase	Glenn Colusa Irrigation District/USBR; DWR/Western Canal Water District/Richvale Irrigation District Current contact person:	

SRP Literature Inventory

Title		Preparer	Date
68.	Central Valley Systemwide Conjunctive Water Management framework plan	NHI	
69.	Decision Rules for Water Resources Management under Uncertainty	Yue-Ping Xu and Yeou-Koung Tung	May/June 2009
70.	Water System Management through a Mixed Optimization-Simulation Approach	Giovanni M. Sechi and Andrea Sulis	May/June 2009
71.	Predictors of Chinook salmon extirpation in California's Central Valley	S.C. Zeug et. al.	2011
72.	Ecosystem level assessment of environmentally based flow restrictions for maintaining ecosystem integrity: a comparison of a modified peaking versus unaltered river	K. E. Smokorowski et. al.	
73.	CalLite: California Central Valley Water Management Screening Model	Nazrul Islam et. al.	January/February 2011
74.	Decision Support System for Optimizing Reservoir Operations Using Ensemble Streamflow Predictions	E.T. Alemu et. al.	January/February 2011
75.	Sacramento River Sediment Study Sediment Transport Modeling and Channel Shift Analysis	Northwest Hydraulic Consultants; Mobile Boundary Hydraulics; USACE Sac District	
76.	Priorities for the Central Valley Flood Protection Plan		
77.	Ecologically Functional Floodplains: Connectivity, Flow Regime, and Scale	Jeffrey J. Opperman, Ryan Luster, Bruce A. McKenney, Michael Roberts, and Amanda Wrona Meadows	
78.	Quantifying activated floodplains on a lowland regulated river: its application to floodplain restoration in the Sacramento Valley	Philip B. Williams, Elizabeth Andrews, Jeff J. Opperman,Setenay Bozkurt, and Peter B. Moyle	
79.	Facilitating Water Markets to Induce Improvements in the Productivity of Water Use in California Agriculture	Gregory Thomas	
80.	Optimization of Multireservoir Systems Operation Using Modified Direct Search Genetic Algorithm	Alireza B. Darianeand Shervin Momtahen, Ph.D.	
81.	Improved Drought Management of Falls Lake Reservoir: Role of Multimodel Streamflow Forecasts in Setting up Restrictions	Kurt Golembesky1; A. Sankarasubramanian; and Naresh Devineni	
82.	Water System Management through a Mixed Optimization-Simulation Approach	Giovanni M. Sechi and Andrea Sulis	

	Title	Preparer	Date
83.	CALFED Surface Storage Investigations Progress Report	State of California, Natural Resources Agency, Department of Water Resources	December 23, 1999
84.	North-of-the-Delta Offstream Storage Investigation Plan Formulation Report	Reclamation Mid-Pacific Region Sacramento, California and Department of Water Resources	September 2008
85.	Upper San Joaquin River Basin Storage Investigation Plan Formulation Report	Reclamation Mid-Pacific Region Sacramento, California and DWR	May 2009
86.	Draft Sacramento Valley Technical Investigation Conjunctive Water Management Modeling Report	CH2M Hill & MBK	
87.	Estimating Ecologically Based Flow Targets for the Sacramento and Feather Rivers	John Cain and Carrie Monohan / NHI	

Appendix B – Existing and Proposed Programs

Local Programs

Integrated Regional Water Management Plans

With integrated regional water management (IRWM), regions have been able to take advantage of opportunities that are not always available to individual water suppliers such as reducing dependence on imported water and making better use of local supplies, enhancing the use of groundwater with greater ability to limit groundwater overdraft, increasing reliability and security, and improving water quality. The extent to which regions have carried these out has been driven by considerations like economics, environment, engineering, and institutional feasibility. The SRP has drawn a variety of potential system reoperation measures from Integrated Regional Water Management Plans and will coordinate with IRWM activities where system reoperation strategies could influence regional conditions.

State Programs

California Water Plan

The California Water Plan provides a framework for water managers, legislators, and the public to consider options and make decisions regarding California's water future. The Plan, which is updated every five years, presents basic data and information on California's water resources including water supply evaluations and assessments of agricultural, urban, and environmental water uses to quantify the gap between water supplies and uses. The Plan also identifies and evaluates existing and proposed statewide demand management and water supply augmentation programs and projects to address the State's water needs. The SRP has already initiated coordination with the California Water Plan through participation in the May 2011 SWAN workshop, and will continue to coordinate closely with this program as major SRP milestones are completed.

Delta Plan

The Delta Stewardship Council must adopt and implement a comprehensive management plan for the Sacramento-San Joaquin Delta by January 1, 2012. This Delta Plan will guide state and local agencies to help achieve the coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The Delta Plan will also guide protection and enhancement of the unique resources, culture, and values of the Delta as an evolving place. The SRP will track the progress of the Delta Plan and coordinate aspects of system reoperation strategies with Delta-specific components.

Bay Delta Conservation Plan

The Bay Delta Conservation Plan (BDCP) is being prepared through a collaboration of state, federal, and local water agencies, state and federal fish agencies, environmental organizations, and other interested parties. These organizations have formed the BDCP Steering Committee with the goal of identifying water flow and habitat restoration actions to recover endangered and sensitive species and their habitats in California's Sacramento-San Joaquin River Delta.

A range of alternatives for providing species/habitat protection and improving water supply reliability will be evaluated through the development of an Environmental Impact Report (EIR)/Environmental Impact Statement (EIS). One goal of the BDCP is to provide a reliable water supply to the Delta through isolated conveyance of water, and a major feature of BDCP is the Isolated Delta Conveyance (IDC). An IDC facility would increase the reliability of conveying Sacramento River water to the Central Valley Project (CVP), State Water Project (SWP), and other projects south of the Delta. The BDCP would also restore aquatic and terrestrial habitat in the Delta; some of these habitats would benefit from changes in flow regime. The major system changes under consideration in the BDCP clearly have significant potential to influence the performance of system reoperation strategies. Therefore, the SRP will closely coordinate with the BDCP process, and in fact, this Study Plan includes IDC as a modification to baseline conditions that will be considered in the evaluation of system reoperation strategies.

FloodSAFE

In 2005, the State of California launched FloodSAFE California (FloodSAFE), a multifaceted initiative to improve integrated flood management. The Central Valley Flood Management Planning (CVFMP) Program, one of several programs managed by DWR under FloodSAFE, addresses flood-related planning activities within the Central Valley that require State leadership and participation.

Three documents are being prepared under the CVFMP to collectively meet requirements of the Central Valley Flood Protection Act of 2008, and related flood legislation passed in 2007: the 2012 Central Valley Flood Protection Plan (CVFPP), the State Plan of Flood Control (SPFC) Descriptive Document, and the Flood Control System Status Report. A history of the planning, development, and operation of the flood management system in the Central Valley will also be prepared to complement these documents. The SRP has already begun coordination with FloodSAFE and will continue to do so as both programs progress. It is anticipated that modeling and analysis tools under development and being applied within FloodSAFE will be adapted and used in the SRP to evaluate improvements in flood hazard reduction achieved through system reoperation strategies.

Surface Storage Investigations Program

DWR and Reclamation are currently investigating three surface storage projects (Shasta Lake Water Resources Investigation, North-of-the-Delta Offstream Storage, or NODOS, and Upper San Joaquin River Basin Storage Investigation). Each of these projects is described in more detail below.

Shasta Lake Water Resources Investigation

Reclamation is leading the investigation in consultation with DWR and local water interests and stakeholders. Shasta Lake Water Resources Investigation (SLWRI) Mission Statement: To develop an implementable plan primarily involving the enlargement of Shasta Dam and Reservoir to promote increased survival of anadromous fish populations in the upper Sacramento River; increased water supply reliability; and to the extent possible through meeting these objectives, include features to benefit other identified ecosystem, flood control, and water resources needs.

NODOS

DWR and Reclamation are working in partnership with local, regional, State, and Federal agencies, and stakeholders to study North-of-the-Delta Offstream Storage (NODOS) opportunities. The proposed Sites Reservoir, one of the major elements of NODOS, would be located in Glenn and Colusa counties and could store up to 1.8 million acre-feet of water. Sites Reservoir would be a multi-purpose facility with the primary objectives of increasing water supply reliability, improving health and survivability of aquatic species, including anadromous fish, providing flexible hydropower generation, and improving Delta water quality. NODOS also has two secondary objectives: 1) providing additional recreational opportunities and 2) creating incremental flood-damage reduction opportunities to support the northern California flood management system. Sites Reservoir is in the planning phase. The NODOS environmental document and feasibility report are anticipated to be completed at the end of 2012. The additional storage provided by Sites Reservoir could significantly expand the potential of proposed system reoperation strategies to improve water supply reliability, flood hazard reduction, and ecosystem protection and restoration. The SRP shares lead staff with the NODOS program and it is anticipated that these staff will ensure that relevant aspects of NODOS are incorporated into the SRP.

Upper San Joaquin River Basin Storage Investigation

The Upper San Joaquin River Basin Storage Investigation is a feasibility study being performed by Reclamation and DWR. The investigation is evaluating alternatives to develop water supplies from the San Joaquin River that could contribute to restoration of, and improve water quality in, the San Joaquin River and enhance conjunctive management and exchanges to provide high-quality water to urban areas. This investigation is one of five surface water storage studies recommended in the CALFED Bay-Delta Program Programmatic Environmental Impact Statement/Report Record of Decision of August 2000.

Federal Programs

San Joaquin River Restoration Program

The San Joaquin River Restoration Program (SJRRP) has two goals: 1) to restore and maintain fish populations in "good condition" in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish; and 2) to reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the interim flows and restoration. Because this program will alter future flow regimes in the San Joaquin Basin, the SRP will coordinate all aspects of system reoperation strategies that influence or are dependent on the hydrology of the basin.

Folsom Dam Joint Federal Project

The Folsom Dam Joint Federal Project is a collaborative effort by Reclamation and the United States Army Corps of Engineers (USACE) to address the dam safety hydrologic risk at the Folsom facility and improve flood protection. Under the Dam Safety Program, Reclamation identified the requirement for expedited action to reduce hydrologic (overtopping), seismic (earthquake), and static (seepage) events. These events have a low probability of occurrence in a given year; however, due to the large population downstream of Folsom Dam, modifying the facilities is necessary to improve public safety. The USACE, in partnership with the Central Valley Flood Protection Board (formally The State Reclamation Board) and the Sacramento Area Flood Control Agency (SAFCA), is working to implement Congressional direction to reduce the risk of flooding in the Sacramento area. The SRP will coordinate with this effort when considering system reoperation strategies that could be influenced by or dependent on Folsom operations.

Central Valley Integrated Flood Management Study

This watershed study, lead by the USACE, is a revitalization of the Sacramento-San Joaquin River Basins Comprehensive Study completed in 2002, and is designed to complement the work currently being done by the DWR through the CVFPP. The timeline for study development is concurrent with the CVFPP, which expects a final plan by January 2012. The SRP will also coordinate the development and evaluation of flood-related aspects of system reoperation strategies with this program.

Central Valley Project Integrated Resource Plan

The Central Valley Project Integrated Resource Plan (CVP-IRP), lead by Reclamation, developed in partnership with stakeholders, will chart a path forward for the CVP to anticipate and adapt to the numerous water resources management challenges of the 21st century, including water supply reliability, infrastructure and operations, socio-economic and environmental conditions, and climate change. The SRP and CVP-IRP share similar missions and will therefore be closely coordinated as both programs progress.

Integrated Water Resources Science and Service Program

The Integrated Water Resources Science and Service (IWRSS) is a collaborative activity of the National Oceanic and Atmospheric Administration (NOAA), USACE, the US Geological Survey (USGS), and Reclamation to address data collection and operational activities of federal projects and services that support water management. The SRP will coordinate with this program to ensure that data and tools applied in the development and evaluation of system reoperation strategies are consistent with best available approaches.

National Integrated Drought Information System

The National Integrated Drought Information System (NIDIS) is being developed to consolidate data on drought's physical, hydrological and socio-economic impacts on an ongoing basis, to develop drought decision support and simulation tools for critical, drought-sensitive areas, and to enable proactive planning by those affected by drought. Where applicable, data and tools developed under NIDIS will be adopted by the SRP.

Habitat Conservation Plans

There are a number of Habitat Conservation Plans (HCPs) in place or under development in California that could influence system reoperation strategies. HCPs are typically site-specific, therefore individual HCPs will be reviewed within the SRP where relevant to a system reoperation strategy.

Appendix C - Inventory and Assessment of Existing Analytical Tools

Analytical Tools Inventory and Assessment Department of Water Resources, System Reoperation Program

PREPARED FOR: State of California, Department of Water Resources (DWR)

PREPARED BY: Brian Delemos, P.E. – HDR, Inc.
Lee Frederiksen, P.E. – HDR, Inc.
Buzz Link, P.E. – HDR, Inc.

DATE: June 16, 2011

Purpose and Organization

The purpose of this appendix is to provide an inventory and assessment of available analytic tools that could be used to prepare the System Reoperation Program for the State of California's water supply and flood control system. HDR Engineering, Inc. and its subconsultants (together, referred to as the HDR Team) prepared this appendix for the California Department of Water Resources in fulfillment of Task Order 1, Task 7 of contract 4600008997. The following major topics are discussed in this appendix:

- Purpose and Organization
- Scope of Work
- Inventory of Available Analytical Tools
- Assessment of Available Analytical Tools
- Recommended Analytical Tools
- Recommended Tool Improvements

Scope of Work

The Task 7 scope of work includes the following main activities for the HDR Team:

1. Review an inventory of existing analytical tools associated with the System Reoperation Program that was provided by DWR
2. Summarize discussions with DWR about the existing tools, including their appropriate uses and limitations, and document the inventory and assessment of the tools
3. Identify which analytical tools will be the appropriate for the study
4. Identify improvements to existing tools needed (if any) for the study

Inventory of Existing Analytical Tools

Table C-1 contains an inventory of the available analytical tools that may be useful for the System Reoperation Program. The inventory was originally provided by DWR, but was augmented by the HDR Team. The tools in the table are grouped by resource topic, as follows: Water Supply, Flood Management, Water Quality, Groundwater, Ecosystem, Economics, and Miscellaneous. Some tools appear under multiple categories. The table includes descriptions of the key features of the tools. The developer of each tool is also provided. Finally, miscellaneous comments about the tools are included in the table. The information about the tools provided in Table C-1 can be referenced and updated during the study.

Assessment of Available Analytical Tools

Key analytical tools from Table C-1 were assessed for their usefulness in conducting the System Reoperation Program. Ultimately, the usefulness of each tool will be determined for each proposed reoperation strategy based on the specific details of the strategy. Thus, the assessment of tools in this appendix can only be discussed generally.

Due to the relatively short schedule and limited budget of the study, analytical tools that have been applied to the study area on recent studies will likely be deemed most useful in the SRP phases. Also, the usefulness of each tool may vary based on the phase of the study. In the reconnaissance phase of the SRP, only approximate analyses are needed to screen reoperation strategies.

During the feasibility phase of the SRP, more detailed analyses will be conducted for the study. More time will be available for modifying existing inputs, utilizing analytical tools, developing post-processing tools, creating linkages between different analytical tools, and analyzing results. These activities will be done as necessary for gaining the appropriate level of certainty in selecting strategies at a feasibility-analysis level, and as time and budget allow.

The assessment of the tools is discussed in the following sections: Water Supply, Flood Management, Ecosystem, Water Quality, Groundwater, Weather and Runoff Forecasting, and Climate Change.

Water Supply

Table C-2 summarizes an assessment of relevant water supply models/tools (also described in Table C-1): CalSim III, CalLite/WEAP PA, CalSim II/USRDOM, and INFORM. Model information is compared side by side for the four models. Model information (in the first column heading) is grouped under several categories (along the rows). General modeling capabilities are presented first. Modeling features that are pertinent to the representation of the study area and potential study measures (building blocks) are presented next. Shown last are the advantages and desired improvements of the tools in relation to the study.

CalSim II provides a representation of reservoirs and streams in the watersheds of the Sacramento and San Joaquin Rivers, Delta channels, and water deliveries to water users in the central valley, bay area, and southern California. It has been used extensively in recent water supply planning studies within the study area. As a result, many pre- and post-processing tools have been developed to aid with data input, analysis of results, and to prepare CalSim II results for use in other analysis tools. It has been used in conjunction and linked with many analysis tools, in particular, many ecosystem tools. CalSim II is not appropriate for flood management analysis because it runs on monthly time steps and does not represent peak flows, which are used for flood analyses. Calsim II has not been directly linked to groundwater analysis tools—although, it has been used in conjunction with a recently developed USGS groundwater model. CalSim has been applied recently on the Bay Delta Conservation Plan (BDCP) for water supply and ecosystem analysis. On the FloodSafe Supplemental Reservoir Operations Analysis, CalSim II was used in conjunction with existing flood analysis tools.

USRDOM is used in conjunction with CalSim II. Unlike CalSim II, though, USRDOM calculates flows on a daily time step (giving better hydrologic resolution) and only models a portion of the Sacramento River (and not the rest of the Central Valley streams modeled by CalSim II). Using the shorter time step allows improved representation of flood conditions in the analysis tool, but is still not appropriate for flood management analysis. The main advantage of the shorter time step is that USRDOM is more appropriate for ecosystem and water quality analysis. USRDOM has been used for the NODOS study.

CalSim III is currently under development as an improvement of CalSim II. Improvements include, among several others, increased spatial hydrologic resolution and dynamic linking to an associated groundwater model called California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM). This improvement would be very useful for the System Reoperation Program. Of course, CalSim III has not been applied to any studies, and may lack pre- and post-processing tools, but these tools could be adapted from the CalSim II tools. The time step for flow calculations is, like CalSim II, monthly, so CalSim III is still not appropriate for direct flood management analysis—it would need to be used in conjunction with flood analysis tools.

CalLite is a simplified version of CalSim II and is used as screening tool because of its faster execution times than CalSim II. WEAP PA, which has been used in 2009 California Water Plan Update, has improved hydrology and water demand inputs. Table C-2 recommends CalLite/WEAP PA as a good choice for the reconnaissance phase of the study. As mentioned above, this tool was designed as a screening tool, which is most appropriate for a feasibility phase. It also has the advantage over CalSim II and III of incorporating an ecosystem flow index to optimize its solutions based on ecosystem constraints. This feature reduces the number of analysis iterations needed for optimizing reoperation strategies. CalLite/WEAP PA is being developed for the Central Valley Project (CVP) Integrated Resource Plan.

INFORM has had limited application to the central valley water supply system. Representation of the water system would need to be improved, but this tool may be useful in analyzing forecast-based operations and in assisting with reservoir decision support (adaptive and risk-based management).

Table C-2 also lists several analysis tool improvements that are desirable for improving the efficiency of water supply analysis. First, except as mentioned above for CalLite and its ecosystem index function, the water supply tools do not optimize their solutions based on ecosystem, flood management, and groundwater constraints. This limitation requires iterative water supply analyses, which increases time and budget required for studies. Efficiency would be improved by developing and adding ecosystem and flood indices to the optimization routines and by fully integrating the surface water calculations with the calculations of a detailed groundwater analysis tool (as is being done for CalSim III . Second, the analysis tools do not include a built-in function for analyzing water supply reliability, which would greatly aid with analysis of results. Third, analysis efficiency could be improved by developing an automation/optimization tool to speed up the analysis effort, and to help make optimal management decisions. Adding water supply reliability analysis capability to the tools would also increase efficiency. Finally, adding capabilities for analyzing forecast related operations would be useful in modeling forecast based or coordinated operation scenario

Flood Management

Flood management analysis tools analyze different aspects of the same system than do water supply tools. Flood analysis is focused on peak flows, whereas water supply analysis is typically focused on flows over longer periods. Also, flood analysis is focused on seasons and events of heavy precipitation, whereas water supply analysis is based on all types of hydrologic conditions (wet, normal, and dry). Thus, flood management tools are typically not the same tools used for water supply.

A few analysis tools for flood management are commonly applied to the study area. HEC-HMS analyzes watershed hydrology. HEC-RAS is a one-dimensional model that analyzes stream and floodplain hydraulics. Flo2D is a two-dimensional (primarily) model that analyzes floodplain hydraulics. HEC ResSim models reservoir flood operations. Applications of these models are currently being developed for the central valley by the US Corps of Engineers (USACE). However, applications using predecessors of these models were developed for previous studies: HEC-1(for HEC-HMS), UNET (for HEC-RAS), and HEC-5 (for HEC ResSim). These predecessor models were recently used on the FloodSafe Supplemental Reservoir Operations Analysis, and as mentioned above, were used in conjunction with the CalSim II water supply tool.

RMA2 is a two-dimensional model (primarily) that has been applied to the Delta. It has also been applied to the Yolo Bypass.

DSM2 is a one-dimensional hydrodynamic model that has been applied extensively to the Delta. It is not recommended as a flood management tool because it was not developed to represent flooding conditions such as levee overtopping or breaks.

Ecosystem

The usefulness of existing ecosystem analysis tools can, at this point, only be assessed in a very limited way. First, the usefulness of the tools will be highly dependent on the details of each strategy to be proposed and on the evaluation metrics to be developed. Second, the ecosystem topics analyzed are numerous, and oftentimes not directly comparable. Further assessment of the ecosystem tools in Table C-1 will need to be done in the next phases of the study to determine which analysis tools are most useful for each proposed strategy. At this point, the usefulness of the existing ecosystem analysis tools can only be based on whether they have been applied to the study area and how reliable they are.

Extensive ecosystem analysis using several ecosystem tools has been conducted for recent studies in the study area, such as for the BDCP. CALSIM II, although designed as a water supply analysis tool, has been used extensively for ecosystem analysis, for example, in analyzing changes in environmental flows for fisheries. CALSIM II output also provides the basis (boundary conditions) for multiple other hydrologic, hydrodynamic, and biological models and analyses for many planning projects. CALSIM II results are being used as input into the detailed model of the Delta, DSM2, which is used to determine water quality, hydrodynamics, and particle tracking in Delta channels. The CALSIM II outputs also feed into temperature models including the Sacramento River Water Quality Model (SRWQM), the Reclamation Temperature Model, as well as biological models such as SALMOD. These analyses and associated tools used for BDCP could be very useful for both the reconnaissance and feasibility phases of the study.

Tools for some of the more complex aspects of the ecosystem have not been applied extensively in the study area, or have only been applied to a limited extent. For example, tools for analyzing ecosystem components and processes such as complex flow regime changes, nutrient cycling, and sediment transport have not been developed for all or substantial parts of the study area. Development of these types of analysis tools are extremely labor intensive, and the SRP budget and schedule are limited, the SRP may be limited to using only the few existing tools or the tools that are currently being developed by other parties.

Such tools (refer to Table C-1) have been recently developed or are being developed for the three ecosystem components and processes mentioned above (complex flow regime changes, nutrient cycling, and sediment transport), for at least some portions of the SRP study area. First, the FloodSAFE Environmental Stewardship and Statewide Resources Office (FESSRO) is developing an HEC-EFM analysis tool that relates complex changes in flow regimes with ecosystem effects. Second, as used for BDCP, nutrient cycling analysis tools have been developed for the Delta (specifically, DSM2) but not upstream of the Delta. Third, sediment transport system tools have not yet been developed for any substantial portions of the study area, but as a part of NODOS are being developed (specifically, SRH) for the some parts of the Sacramento River watershed. These tools may be very useful for analyzing ecosystem strategies of the SRP.

Other ecosystem analysis tools in Table C-1 have also not been applied extensively to the study area. If these models are selected for the System Reoperation Program, they should be reviewed thoroughly for quality control purposes. Due to time and budget constraints for the SRP, the use of these models may be limited.

Groundwater

The USGS has recently developed a comprehensive application of a groundwater analysis tool for the central valley called the Central Valley Hydrologic Model (CVHM). It represents surface water-groundwater interactions. For BDCP, CALSIM II output (along with DSM2 output) was prepared for input into CVHM. The analysis tool was used to evaluate the effects on groundwater conditions that would be caused by proposed water supply strategies. However, it was not fully integrated with CalSim II, and optimization of the CalSim II calculations could not account for groundwater flow and aquifer water table constraints.

As discussed above, the CalSim III water supply tool will include full integration with a groundwater model called C2VSIM. C2VSIM and CalSim III will cover the areas of interest for the System Reoperations Program, and the integration of the two tools will allow CalSim III to optimize its solutions considering groundwater constraints. This integration of tools could greatly increase the efficiency of the analyses of strategies involving the integration of surface water and groundwater supplies, as compared to using CVHM and CalSim II. Another advantage of C2VSIM over CVHM is that DWR maintains support of C2VSIM, which would likely make it easier to get technical support for the study.

Water Quality

Water quality concerns, and therefore the analysis tools used, are generally different for the Delta waterways than for upstream of the Delta. In the Delta, DSM2 (refer to Table C-1) has been applied extensively to analyze changes in Delta hydrodynamics and water quality constituents such as salinity. This tool will likely be most useful for analyzing water quality changes in the Delta.

Upstream of the Delta, one of the main water quality concerns with changes in water supply operations is effects on water temperature. Water temperature has been analyzed for the Trinity, Sacramento, Feather, American, and Stanislaus Rivers based on output from the SRWQM tool and for other rivers using the Reclamation Temperature Model. Sediment content is also a concern upstream of the Delta. The SRH sediment transport analysis tool is being developed for NODOS to analyze suspended sediment changes. This tool, and the temperature analysis tools, could be the most useful tools for analyzing water quality changes upstream of the Delta.

The water quality parameters to be analyzed may depend on the details of each proposed strategy. Only some parameters can be analyzed with the tools mentioned above. Many other parameters could be analyzed qualitatively or semi-quantitatively based on the results of the tools above. It is anticipated that this approach will be taken for such parameters, and that no water quality analysis tools will need to be developed for the SRP.

Weather and Runoff Forecasting

Several models have been developed for weather and storm runoff forecasting (refer to Table C-1) that could be used for analyzing forecast based operations. QPF is a tool that was developed and is used extensively in the study area. This tool may be the most useful for the study, but other tools may be used as determined by the details of each proposed strategy.

Climate Change

Analyses for the Systems Reoperation Program are required to consider the effects of predicted climate change. The climate change scenarios and hydrology recommended from DWR Climate Change Matrix Team will be considered.

Recommended Analytical Tools

Table C-3 and Table C-4 include subsets of the existing analytical tools in Table C-1, and are the existing tools that are expected to be most useful and that are recommended for use in the SRP. Table C-3 is a more comprehensive list of existing tools. Table C-4 below is a short list of tools that are anticipated to be used most extensively in the SRP. Any combination of tools will be selected from these tables for each reoperation strategy based on the following three general factors:

- The match between study areas of the proposed strategy and of the tools
- The match between (1) the details of the strategy and (2) the analysis functions of the tools
- The relationship between (1) the time and budget needed to make any needed improvements to the analysis tools and (2) the available time and budget allotted for the associated proposed strategies

In Table C-3, the tools are grouped in sets by the associated applications, or studies, for ease of reference, and also because it gives an indication of which tools have been linked and/or used in conjunction. That is, typically, pre- and post-processing tools are developed to integrate analysis tools to some degree, as well as to aid with data input and analysis.

In Table C-4, the short list of analysis tools are a subset of tools in Table C-3that are, again, anticipated to be the most heavily used for the study. The list is organized by the relevant resource topics.

The tools in Tables C-3 and C-4 may not be the only tools that are used during the System Reoperation Study. Other existing tools may need to be used, and new tools may need to be developed, as determined during further refinement of the study plan.

Recommended Tool Improvements

No significant improvements to the analytical tools are anticipated for the reconnaissance phase, but improvements discussed above could be needed for the feasibility phase. Potential needed improvements have been identified for water supply and ecosystem analysis tools. Other needed improvements may be identified as the study plan is further refined in later phases of the SRP.

Potentially needed water supply tool improvements that have been identified include:

- Developing and adding ecosystem and flood indices to the optimization routines (it should be noted that CalLite does already include an ecosystem flow index in its calculations)

- Adding water supply reliability analysis capability or using reliability analysis tool
- Adding or using existing automation/optimization capabilities to speed up strategy analysis
- Adding capabilities for analyzing forecast related operations
- Implementing surface water and groundwater interaction in CalSim II or CalLite if CalSim III is not available.

Potentially needed improvements to ecosystem tools will be highly dependent on the details of each strategy to be proposed and on the evaluation metrics to be developed. In general, new tools, in particular, those for analyzing ecosystem components and processes such as complex flow regime changes, nutrient cycling, and sediment transport, could be needed for the SRP. Due to schedule and budget constraints, the SRP may be limited to using only existing ecosystem tools and the tools that are currently being developed by other parties.

Table C-1. Inventory of Existing Analytical Tool Potentially Useful for the System Reoperation Study

Category	Name	Description	Developer/Contact	Comment
Water Supply	CalSim	California water resources Simulation model (CalSim) is developed by DWR and Bureau of Reclamation covering the water supply operation of SWP and CVP. CalSim was recently renamed by DWR and Reclamation to WRIMS (Water Resources Integrated Modeling System). However, it has been expanded to cover some area beyond SWP or CVP service area. the current version is CalSim II. CalSim III is currently under development and is to be released in March 2011. CalSim III will have better resolution in hydrology representation and better groundwater modeling capability. It is a monthly model with 82 years hydrology data.	DWR and USBR	this tool is believed to be the primary tool in California for analyzing water supply of SWP and CVP. It is believed to be used again in the system reoperation study due to its unique status. The BDCP application of the model incorporates predicted climate change effects.
	CalLite	California Central Valley Water Management Screening Tool (CalLite) is a simplified version of CalSim aiming for easy use and faster execution. CalLite was developed using the GoldSim system dynamics software that enables simulation of complex process through a buildup of simple object relationships, incorporates Monte Carlo stochastic methods, and includes dynamic, interactive user interfaces.	DWR	CalLite is being redeveloped using WRESL language. The stochastic analysis is currently not in the WRESL developed CalLite but will be added later. It can be used for screening and rank potential candidate strategies.
	HEC-PRM	HEC-PRM is a generalized network model. It uses optimization technique to distribute water for desired operation.	Army Corp of Engineers	No HEC-PRM model has been developed for SWP or CVP found. CALVIN used HEC-PRM as engine but it is not designed for modeling reservoir operation.
	HFAM II	HFAM II is based on the Stanford, HSP, HSPF, SRFM family of models. It is a continuous simulation model that does historical or forecast analysis and it includes probabilistic or ensemble forecasts of stream flows, reservoir levels and releases or power production. It has four running modes: Forecast, Analysis, Probabilistic and Optimization.	HydroComp, http://www.hydrocomp.com/HFAMSoftware/HFAM%20II%20Description.htm	Currently it lacks capabilities of setting complex downstream constraints such as salinity constraints in Delta
	USRDOM	Upper Sacramento River Daily Operations Model (USRDOM) is designed to model the flows and related operations of the Sacramento River and existing and proposed facilities related to the operation of proposed NODOS alternatives. USRDOM also can assess temperature and flow regime impacts and benefits. The model includes the streams and facilities in the upper portion of Sacramento River from Shasta Reservoir to Knights Landing and the Trinity River section of the Central Valley Project (CVP). It allows the user to establish bounds on availability and operating criteria for diversion of excess flows to NODOS. It simulates realistic daily flow conditions in the Sacramento River based on the operations specified by CalSim II under projected conditions (future) or historical operations for use in river morphology and fisheries analyses for NODOS. It also can be used to evaluate NODOS performance for ecosystem restoration objectives. Finally, it can be used to demonstrate incremental environmental impacts of various NODOS scenarios.	USBR and DWR	USRDOM is currently the only daily simulation model for SWP and CVP. However, the daily operation simulation only covers certain area of Sacramento Valley and no operation decision will be made based on daily time step modeling. The operation decision is made by CalSim II. The advantage of USRDOM includes be better water quality and temperature modeling due to daily modeling, unregulated flow assessment.
	CAM	CalSim Allocation Module (CAM) is a tool included in CalSim, which is being developed by DWR in collaboration with Reclamation. CAM was developed to mimic the procedure used by operations staff so it is more towards real time operation		this tool should be used in evaluating short term (1 year) effective system reoperation strategies.
	WEAP	Water Evaluation and Planning System (WEAP) is a water resources planning model with a generic, object-oriented, programmable, integrated water resources management modeling platform. It uses LP solver to optimize the distribution of water at each time step. WEAP is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand side of the equation--water use patterns, equipment efficiencies, re-use, prices, hydropower energy demand, and allocation--on an equal footing with the supply side--stream flow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies. WEAP has been linked with QUAL2K, MODFLOW2000, MODPATH DWR Delta salinity model and East-Bay reservoir operation model. It can use daily, weekly, monthly, or annual time-steps to characterize the system's water supplies and demands. It can be called through API interface and currently has been used by PEST, CARS and VBscripts.	Stockholm Environment Institute	This model is one of the few models integrating water supply/reservoir modeling with stream routing built-in. It also has built-in tools for water demand, water quality analysis and financial analysis. Currently It is used as the tool for California water plan update. It use linear solver to distribute water throughout the water system just like CalSim with better integration with other models. However, for system reoperation, the application is depend on how much the Central Valley hydrology and SWP/CVP are represented in the model. Need to check the progress of existing model application to Central Valley.
	Integrated Forecast and Reservoir Management (INFORM)	INFORM consist of stream flow forecasting module and reservoir decision module. The reservoir decision module provides short range decision support (hourly resolution and a horizon of one day), mid range reservoir management (daily resolution and a horizon of several months) and long range planning (monthly solution and a horizon of one to two years). Forecasted information and optimization are used in decision support module.	Hydrologic Research Center, Georgia Water Resources Institute	This model is one of the few models integrating water supply/reservoir modeling with stream routing built-in. This model is capable of simulating reservoir operation during flood event. However, this model need implementation of more detailed State's water system (including CVP) and salinity control.
	MIKE BASIN	Typical MIKE BASIN applications: Solve multi-sector water allocation problems Improve reservoir and hydropower operations Conduct transparent water resources assessments Evaluate irrigation scheme performance and crop yield Assess nutrient loads from non-point and point sources Compare measures for water quality compliance Store, analyze and visualize temporal data in GIS	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/WaterResources/MIKEBASIN.aspx	

Category	Name	Description	Developer/Contact	Comment
	OASIS	OASIS is a unique software program that realistically simulates the routing of water through a water resources system. OCL™ (Operations Control Language) is a computer language that allows the water system operator to express any condition or rule, and enter it into the software. Users can express all operating rules as operating goals or operating constraints, and can account for both human control and physical constraints on the system. To model any system, one simply needs to approach the problem as a set of goals and constraints. The software then solves for the best means of moving water through the system to meet these goals and constraints.	HydoLogics: http://hydrologics.net/oasis_ocl.html	
Flood Management	HEC-ResSim	HEC-ResSim has been developed by the Hydrologic Engineering Center of the US Army Corps of Engineers to aid engineers and planners performing water resources studies in predicting the behavior of reservoirs and to help reservoir operators plan releases in real-time during day-to-day and emergency (flood management) operations.	US Army Corps of Engineers	Lacks the capability of setting downstream constraints such as water salinity control in Delta
	CWMS	The Corps Water Management System (CWMS) is the automated information system used by the U.S. Army Corps of Engineers to support its water control management mission. CWMS is an integrated system of hardware and software that begins with the receipt of hydromet, watershed, and project status data. This data is then processed, stored, and made available through a user friendly interface to the water manager to evaluate and model the watershed. Both model and processed data can be displayed and disseminated in tabular, graphical, and/or geo-spatially resulting in an effective decision support system. CWMS allows evaluation of any number of operation alternatives before a final forecast scenario and release decision are adopted. For example, various alternative future precipitation amounts may be considered, hydrologic response may be altered, reservoir release rules may be investigated, and alternative bridge obstruction, levee integrity, or other river conditions may be evaluated.	Army Corp of Engineers	It is a great water resource/reservoir operation planning and real time operation model. It is main program to utilize other HEC models such as HEC-ResSim, HEC-RAS, etc.. Due to the difficulty of implementation Delta constraints in HEC-ResSim its use is limited. another concern is that HEC-ResSim has not been applied to cover all SWP and CVP operations.
	USRDOM	Upper Sacramento River Daily Operations Model (USRDOM) is designed to model the flows and related operations of the Sacramento River and existing and proposed facilities related to the operation of proposed NODOS alternatives. USRDOM also can assess temperature and flow regime impacts and benefits. The model includes the streams and facilities in the upper portion of Sacramento River from Shasta Reservoir to Knights Landing and the Trinity River section of the Central Valley Project (CVP). It allows the user to establish bounds on availability and operating criteria for diversion of excess flows to NODOS. It simulates realistic daily flow conditions in the Sacramento River based on the operations specified by CalSim II under projected conditions (future) or historical operations for use in river morphology and fisheries analyses for NODOS. It also can be used to evaluate NODOS performance for ecosystem restoration objectives. Finally, it can be used to demonstrate incremental environmental impacts of various NODOS scenarios.	USBR and DWR	USRDOM is currently the only daily simulation model for SWP and CVP. However, the daily operation simulation only covers certain area of Sacramento Valley and no operation decision will be made based on daily time step modeling. The operation decision is made by CalSim II. The advantage of USRDOM includes be better water quality and temperature modeling due to daily modeling, unregulated flow assessment.
	INFORM	INFORM consist of stream flow forecasting module and reservoir decision module. The reservoir decision module provides short range decision support (hourly resolution and a horizon of one day), mid range reservoir management (daily resolution and a horizon of several months) and long range planning (monthly solution and a horizon of one to two years). Forecasted information and multiple periods optimization are used in decision support module.	Hydrologic Research Center, Georgia Water Resources Institute	This model is one of the few models integrating water supply/reservoir modeling with stream routing built-in. This model is capable of simulating reservoir operation during flood event. However, this model need implementation of more detailed State's water system (including CVP) and salinity control.
	HEC-RAS	HEC-RAS allows you to perform one-dimensional steady flow, unsteady flow, sediment transport/mobile bed computations, and water temperature modeling.	Army Corp of Engineers	A HEC-RAS model developed for Central Valley will be available in the Summer of 2011 in the effort of CVFED (Central Valley Floodplain Evaluation and Delineation Program). This new model should be used for any flood related assessment. It is the first flood model developed covering the whole Central Valley.
	UNET			
	Jflow-GPU	JFlow is a raster GIS based 2D hydrodynamic model. Since 2009 update it is able to handle almost full set of hydrodynamic equations.	Developer: JBA Consulting Contact: 1. Chris Bowles: c.bowles@cbecoeng.com 2. http://www.jbaconsulting.co.uk/	Very fast model setup and much faster computing are the advantage of Jflow. It is claimed to be 50-80 times faster than conventional hydrodynamic models such as flow-2D, RMA, etc. The faster computing is due to its capability of utilizing 480 CPU cores in GPU parallel programming. Because of these two advantage JFlow is a practical tool in flood planning/forecasting and river eco analysis. A presentation by Chris Bowles of CBEC shows a Jflow model setup for Sacramento Valley was done in one day (without refinement/correction of bridges) and the simulation time of a flood event (4-5 days) only took about 18 hours with the grid resolution of 30 feet square feet cell (total 123,594,240 cells).
	MIKE 11	Application areas: Flooding and hydraulics Forecasting Hydrology Sediments Water Quality	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/WaterResources/MIKE11.aspx	
	MIKE 21C	Typical MIKE 21C applications: Design protection schemes against bank erosion Evaluate measures to reduce or manage shoaling Analyze alignments and dimensions of navigation channels for minimizing maintenance dredging Predict sedimentation of water intakes, outlets, locks, harbors and reservoirs Forecast the impact of bridge, tunnel and pipeline crossings on river channel hydraulics and morphology Optimize restoration plans for habitat environment in channel floodplain systems	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/WaterResources/MIKE21C.aspx	

Category	Name	Description	Developer/Contact	Comment
	MIKE FLOOD	Application areas: Coastal flooding Urban Flooding Riverine flooding	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/WaterResources/MIKEFLOOD.aspx	
	MIKE BASIN	Typical MIKE BASIN applications: Solve multi-sector water allocation problems Improve reservoir and hydropower operations Conduct transparent water resources assessments Evaluate irrigation scheme performance and crop yield Assess nutrient loads from non-point and point sources Compare measures for water quality compliance Store, analyze and visualize temporal data in GIS	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/WaterResources/MIKEBASIN.aspx	
	RMA2	The RMA2 model (King 1986) is a generalized free surface hydrodynamic model that is used to compute two-dimensional depth-averaged velocity and water surface elevation. RMA11 (King 1995) is a generalized two-dimensional depth-averaged water quality model which computes a temporal and spatial description of conservative and non-conservative water quality parameters. RMA11 uses the results from RMA2 for its description of the flow field. The model uses a depth-averaged approximation in the western Delta and Suisun Bay where significant vertical gradients in salinity are often present. The model uses CALSIM outputs as well as existing bathymetry and topography as inputs. The RMA model produces results at a 15 minute time step.		
Water Quality	DSM2	DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta (DWR, 13 2002). DSM2 represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by facilities and operations. DSM2 uses flow data generated from CALSIM II outputs. DSM2 is a simulated on a 15-minute time step to address the changing tidal dynamics of the Delta system. However, the boundary flows are typically provided from monthly CALSIM II results. In all previous planning-level evaluations to the BDCP effects analysis, the DSM2 boundary flow inputs were applied on a daily time step but used constant flows equivalent to the monthly average CALSIM II flows. In an effort to better represent the sub-monthly flow variability, particularly in early winter, a monthly-to-daily flow mapping technique identical to that described for CALSIM II (Section 2.1.1) is applied to the boundary flow inputs to DSM2. All river flows are mapped according to the "borrowed" observed patterns. CALSIM II simulated daily flows from the Fremont Weir and Sacramento Weir are directly incorporated in DSM2. North Delta exports are patterned based on the actual monthly diversion and potential daily diversion from CALSIM II operations. As with CALSIM II, in all cases the monthly flows and diversions are maintained as daily mapping is implemented.	DWR	DSM2 does not represent well flood-flow conditions because it is not intended to represent overtopping or failure of levees. Also, Calsim II provides riverine flow inputs (into DSM2) as average monthly flows, which do not approximate flood-flow (peak) conditions closely. The BDCP application of the model incorporates predicted climate change effects.
	MIKE 11	See description above.		
	MIKE BASIN	See description above.		
	RMA2	See description above under the Category column and the heading Water Supply System.		
	SRWQM	The Sacramento River Water Quality Model (SRWQM) was used in the effects analysis to predict the effects of operations to water temperature in the Sacramento River and Shasta and Keswick reservoirs. The SRWQM was developed using the HEC-5Q model to simulate mean daily (using 6-hour meteorology) reservoir and river temperatures at key locations on the Sacramento River (Table 1). The time step of the model is daily and provides water temperature each day for the 82 year hydrologic period used in CALSIM II. The model has been used in the previous CVP and SWP system operational performance evaluation (Reclamation 2008). Monthly flows from CALSIM II for an 82 year period (1 WY 1922-2003) are used as input into the SRWQM after being temporally downsized to daily average flows. Temporal downscaling is performed on the CALSIM II monthly average tributary flows to convert them to daily average flows for HEC5Q input. Monthly average flows are converted to daily tributary inflows based on 1921 through 1994 daily historical record for the following aggregated inflows: 1. Trinity River above Lewiston; 2. Sacramento River above Keswick; and 3. Incremental inflow between Keswick and Bend Bridge (Seven day trailing average for inflows below Butte City). Each of the total monthly inflows specified by CALSIM II is scaled proportionally to one of these three historical records. Reservoir inflows were proportioned as defined above. Outflows and diversions are smoothed for a better transition at the end of the month without regard for reservoir volume constraints or downstream minimum flows. As flows are redistributed within the month, the minimum flow constraint at Keswick, Red Bluff and Knights Landing may be violated. In such cases, operation modifications are required for daily flow simulation to satisfy minimum flow requirements. A utility program is included in SRWQM to convert the monthly CALSIM II flows and releases into daily operations. More detailed description SRWQM and the temporal downscaling process is included in an RMA calibration report (RMA 2003). Output from the SRWQM was used as an input to a number of biological models for upstream life stages of salmonids and sturgeon.		
	Reclamation Temperature Model	The Reclamation Temperature Model was used to predict the effects of operations on water temperatures in the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs. The model is a reservoir and stream temperature model, which simulates monthly reservoir and stream temperatures used for evaluating the effects of CVP/SWP project operations on mean monthly water temperatures in the basin based on hydrologic and climatic input data. It has been applied to past CVP and SWP system operational performance evaluations (Reclamation 1994, 2004, 2008). The model uses CALSIM II output to simulate mean monthly vertical temperature profiles and release temperatures for seven major reservoirs (Trinity, Whiskeytown, Shasta, Oroville, Folsom, New Melones, and Tulloch), four downstream regulating reservoirs (Lewiston, Keswick, Goodwin and Natoma), and five main river systems (Sacramento, Trinity, Feather, American, and Stanislaus), although the model was not applied to the Sacramento River in this analysis because the SRWQM was deemed superior as a result of its daily time step.	USBR	
	SRH-2D	Two-dimensional (2D) hydraulic, sediment, temperature, and vegetation model for river systems.	USBR: http://www.usbr.gov/pmts/sediment/model/srh2d/index.html	
Groundwater	MODFLOW	MODFLOW is a finite-difference flow model and is the most widely use in the country. The water must have a constant density, dynamic viscosity (and consequently temperature) throughout the modeling domain.	USGS	

Category	Name	Description	Developer/Contact	Comment
	Central Valley Hydrologic Model (CVHM)	Central Valley Hydrologic Model (CVHM) is MODFLOW 2000 groundwater model covering the whole Central Valley. The active modeled area is 20,334 mi2 on a finite-difference grid comprising 441 rows, 98 columns, and 10 layers (1 mile. It simulates groundwater flow from April 1961 through September 2003 in monthly stress period.	USGS: http://pubs.usgs.gov/pp/1766/	CVHM is discretized into 1-mile model cells and features smaller cells that are not simulated. the model is likely only to represent features accurately at a scale of approximately 5 square miles.
	IGSM2/IWFM	IWFM (Integrated Water Flow Model) is a integrated groundwater and surface water finite element model that simulates groundwater, surface water, stream-groundwater interaction, and other components of the hydrologic system. It models groundwater flow as a quasi three-dimensional system and solves the governing flow equation using the Galerkin finite element method. A unique feature of IWFM is the land use based approach of calculating water demand. IWFM simulates stream flow, soil moisture accounting in the root zone, flow in the vadose zone, groundwater flow, and stream-aquifer interaction. Agricultural and urban water demands can be pre-specified, or calculated internally based on different land use types. Water re-use is also modeled as well as tile drains and lakes or open water areas.	DWR	IWFM is linked with CalSim III. It has been developed to cover the whole Central Valley. It is a candidate for modeling groundwater in Central Valley, especially if CalSim III is used.
	SacFEM	It is finite element groundwater model developed for Sacramento Valley using Micro-FEM. It is a 125-meter node pacing, 7 layers model. It does not have wells of less than 100 feet deep or pumping less than 100 gpm.	CH2M Hill	This model has been used in Stony Creek Fan Conjunctive Use study.
	HydroGeoShpere	Fully integrated surface water and groundwater finite element model. Both surface water and groundwater governing equation were solved simultaneously. Water Resources Planning and Management capability will be developed. It is a 3-D model.	Matanga, George B [GMatanga@usbr.gov], USBR	under development
Ecosystem	CalSim	See description above under the Category column and the heading "Water Supply System." Although CalSim was developed for water supply analysis, it is used extensively for ecosystem analysis.		
	DSM2	See description above under the Category column and the heading "Water Quality".		
	SacEFT	Sacramento River Ecological Flows Tool (SacEFT) is designed to improve water decision on the Sacramento River through the inclusion of ecological targets. It incorporates the hydrologic modeling (flow, temperature, sediment transport and river channel migration) and biophysical habitat models for five local species (Chinook Salmon, Steelhead Trout, Green Sturgeon, Bank Swallow and Fremont Cottonwood). It can work with some water planning models such as CalSim output, physical process oriented models such as the meander migration model developed UC Davis, and a gravel augmentation and sediment transportation developed by Stillwater Sciences.	Client Alexander: Calexander@essa.com Ryan Luster: Rluster@tnc.org	It is recently developed with new approach. It is a model connecting flows to environmental habitats.
	DPM	The Delta Passage Model (DPM) was used in the effects analysis to predict relative reach specific survival estimates for winter, spring, and fall-run juvenile Chinook salmon passing through the Delta. The model simulates migration and mortality of juvenile Chinook salmon entering the Delta from the Sacramento River, the Mokelumne River, and the San Joaquin River through a simplified Delta channel network similar to that depicted in Perry et al. (2010), and provides quantitative estimates of relative juvenile Chinook salmon survival through the Delta to Chipps Island. The DPM is based on a detailed accounting of migratory pathways and reach specific mortality as smolts travel through a network of Delta channels. The biological functionality of the DPM is based upon the foundation provided by Perry et al. (2010), as well as other acoustic tag-based studies and earlier coded wire tag (CWT) analyses provided by Newman (2003) and Kimmerer (2008), among others. Consistent with the findings of Perry et al. (2010), salmon smolts arriving at distributaries enter downstream reaches in approximate proportion to the flow diverted. Reach-specific survival rate and associated error estimates were obtained from three separate Delta acoustic tagging studies (Bureau et al. 2007, SJRGA 2007, Perry et al. 2010). Similar to the analyses of Newman (2003) and Newman and Rice (2002), reach-specific survival in river discharge driven reaches is calculated as a logarithmic function of reach-specific flow. Smolt movement in the DPM occurs daily and is a function of reach specific length and migration speed informed by acoustic tagging studies. Smolt migration speed is calculated as a reach-specific logarithmic function of flow. Indirect mortality for migrating smolts associated with South Delta exports is modeled as based on the relationship described by Newman and Brandes (2009). Though the DPM is primarily based on studies of winter-run Chinook surrogates (late fall-run Chinook), the emigration timing in the model is modified to reflect differences between Chinook races.		
	Interactive Object-Oriented Salmon Simulation Model (IOS)	IOS is a life-cycle model for Sacramento River Winter Run Chinook Salmon. It was developed for NODOS.	Cramer Fisher Science DWR	
	SALMOD	SALMOD is a computer model that simulates the dynamics of freshwater salmonid populations, both anadromous and resident. The model's premise is that egg and fish mortality are directly related to spatially and temporally variable micro- and macrohabitat limitations, which themselves are related to the timing and amount of stream flow and other meteorological variables. Habitat quality and capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which were used as spatial "computation units" in the model.	http://www.fort.usgs.gov/Products/Software/SALMOD/	
	Reclamation Salmon Mortality Model	The Reclamation Salmon Mortality Model was used in the effects analysis to predict temperature-related proportional losses of eggs and fry for each race of Chinook salmon as a result of changes in operations in the Trinity, Sacramento, Feather, American, and Stanislaus rivers. This model estimates proportional salmon mortality for pre-spawned eggs, fertilized eggs, and pre-emergent fry of all Chinook salmon races in the Trinity, Sacramento, Feather, American, and Stanislaus Rivers based on water temperature output from the SRWQM for the Sacramento River and the Reclamation Temperature Model for other rivers. The daily time step from the SRWQM may underestimate mortality in the Sacramento River (J. Hannon pers. comm.). The model provides output on an annual time step. The model uses temperature exposure mortality criteria for the three life stages, spawning distribution data, and output from the river temperature models to estimate percentages of egg and fry losses of a given brood of eggs for each run of Chinook salmon.		
	SRWQM	See description under Water Quality section above.		

Category	Name	Description	Developer/Contact	Comment
	Reclamation Temperature Model	See description under Water Quality section above.		
	MIKE 21 Flexible Mesh Model	MIKE 21 is used to analyze ecosystem components such as hydrology and hydraulics. The MIKE 21 flexible mesh model was used to estimate the areal extent of inundation in the Yolo Bypass under CM2 Yolo Bypass Fisheries Enhancements for 1,000 to 6,000 cfs at 1,000 cfs intervals. The model is a two-dimensional hydrodynamic model that predicts water surface elevation, flow, and average velocity at each computational grid cell. The model incorporates existing LiDAR and Toe Drain/Tule Canal bathymetry as well as estimated west-side tributary flows. Outputs of the model were used to predict the potential benefits to species that use the Yolo Bypass as habitat when inundated (e.g., splittail, Chinook salmon, etc.) and to food production.		
	MIKE 21C	Typical MIKE 21C applications: Design protection schemes against bank erosion Evaluate measures to reduce or manage shoaling Analyze alignments and dimensions of navigation channels for minimizing maintenance dredging Predict sedimentation of water intakes, outlets, locks, harbors and reservoirs Forecast the impact of bridge, tunnel and pipeline crossings on river channel hydraulics and morphology Optimize restoration plans for habitat environment in channel floodplain systems	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/WaterResources/MIKE21C.aspx	
	HEC-EFM	The Ecosystem Functions Model (HEC-EFM) is designed to help study teams determine ecosystem responses to changes in the flow regime of a river or connected wetland. HEC-EFM analyses involve: 1) statistical analyses of relationships between hydrology and ecology, 2) hydraulic modeling, and 3) use of Geographic Information Systems (GIS) to display results and other relevant spatial data. Through this process, study teams will be able to visualize and define existing ecologic conditions, highlight promising restoration sites, and assess and rank alternatives according to predicted changes in different aspects of the ecosystem.	USACE, HEC	HEC-EFM has many strengths, most notably 1) it is capable of testing ecological change for any number of relationships and flow regimes, 2) it links ecology with established hydrologic, hydraulic, and GIS tools, and 3) it can be applied quickly, inexpensively, and can incorporate expert knowledge. HEC-EFM is also a generic software tool, applicable to a wide range of riverine and wetland ecosystems.
	ECO Lab	Typical ECO Lab applications: Water quality and ecological studies related to rivers, wetlands, lakes, reservoirs, estuaries, coastal waters and the sea Spatial predictions of any ecosystem response Simple and complex water quality studies Impact and remediation studies Planning and permitting studies Water quality forecast	Danish Hydraulic Institute (DHI) http://mikebydhi.com/Products/ECOLab.aspx	
	Jflow-GPU	See description in the Flood Management section.		
	IHA (Indicators of Hydrologic Alteration)	Used to translate periods of hydrologic data into a series of ecologically relevant hydrologic parameters.	TNC: http://www.nature.org/initiatives/freshwater/files/ihav7.pdf	
	Sacramento River Meander Model	It was developed to predict and represent river meander possibilities in rivers. An application in Sacramento River in 2007. Details was described in "Sacramento River Ecological Flows Study: Meander Migration Modeling", published by The Natural Conservancy. This report describes the current version of a meander migration model developed by Eric Larsen, data used as model input, management scenarios used for the model runs, application of the meander migration model to the study reaches used for this study, and model results. The significant difference between the application of the model in this project compared to previous applications is the integration of a variable flow regime. Previous applications of the model assumed a single representative flow. This report interprets model results by showing area of land reworked and migration rates, and explores implications of the model results for management of the Sacramento River. This report documents work done to accomplish the modeling tasks and the results of those tasks.	Eric Larson, UCD Stacy Cepello DWR	It was developed for Sac River from Red Bluff to Colusa. Could be incorporated into the HEC EFM; HEC/UCD interested in doing this work.
	SRH-2D	See description under Water Quality section above.		
	Habitat Suitability Index Models (HSI)	Habitat Suitability Index (HSI) models describe habitat quality for selected fish and wildlife species and were initially developed by the U.S. Fish and Wildlife Service (FWS) in conjunction with other Federal agencies, including the Corps of Engineers. The FWS Ecological Services Manual (ESM) 103 describes more about the models. Although they were developed for assessing impacts of large water resource projects, their utility and flexibility in other areas has been proven. See the list of Habitat Suitability Index (HSI) models (sometimes referred to as the Blue Books) and click to view any of those indicated by a pdf. The models can also be accessed from the U.S. Geologic Survey National Wetlands Research Center page: http://www.nwrc.gov/wdb/pub/hsi/hsiindex.html.		
	Hydrogeomorphic Approach to Assessing Wetland Functions (HGM)	The Hydrogeomorphic Approach (HGM Approach) is a method to assess the functional condition of a specific wetland referenced to data collected from wetlands across a range of physical conditions. The approach utilizes a wetland classification system based on geomorphic position and hydrologic characteristics to group wetlands into seven different wetland classes. Regional Guidebooks are developed to assess specific subclasses of the seven HGM classes of wetlands. HGM at the Subclass Level can be used to assess an array of relevant matter, such as current wetland conditions, mitigation ratios, post-project impacts, and restoration success.		
	Index of Biotic Integrity (IBI)	To quantitatively assess changes in the composition of biologic communities, IBIs are developed to accurately reflect the ecological complexity from statistical descriptions of sample species counts. There is no one universal IBI, and developing metrics that consistently give accurate assessment of the monitored population requires rigorous testing to confirm its validity for a given subject. Often IBIs are region-specific and require experienced professionals to provide sufficient quality data to correctly asses a score. Because communities naturally vary as do samples collected from a larger population, identifying robust statistics with acceptable variance is an area of active research.		

Category	Name	Description	Developer/Contact	Comment
	Macroinvertebrate IBI (MIBI)	Same as above but focused on macroinvertebrates.		
	Floristic Quality Assessment (FQA)	A tool to assist environmental consultants, scientists, natural resource managers, land stewards, environmental decision-makers, and restorationists in assessing the floristic, and implicitly, natural significance of a given area. This assessment system is not intended for use as a stand-alone method, but it can be applied to complement and corroborate other methods of evaluating the natural quality of a site.		
	Conceptual	A tentative description of a system or sub-system that serves as the basis for intellectual organization and represents the modeler's current understanding of the relevant system processes and characteristics.		
	PHABSIM / Habitat Suitability Curves	This extensive set of programs is designed to predict the micro-habitat (depth, velocities, channel indices) conditions in rivers as a function of stream flow, and the relative suitability of those conditions to aquatic life		
	Custom spreadsheet / GIS based models	Varies		
	Habitat Equivalency Analysis	Habitat Equivalency Analysis (HEA) is a procedure developed to scale compensation for habitat damage (National Oceanic and Atmospheric Administration (NOAA) 1997) with potential application to environmental benefits analysis.		
Economic	CALVIN	CALVIN is a hydro-economic optimization model of California's intertied water system. It is the only model representing the extensive statewide system in terms of supplies, demands, and physical and economic adaptability in California. The CALVIN model uses a 72-year monthly time series of hydrology (1921-1993) to represent system variability. CALVIN manages water infrastructure and demands throughout California's intertied water network to minimize net scarcity and operating costs statewide. The model employs HEC-PRM with a network flow optimization solver developed by the US Army Corps of Engineers.	UC Davis	this model does not do much hydrological modeling. This model takes inputs from other model such as CalSim. This model can be used to evaluate economic benefit resulting from water supply.
	LCPSIM	Least-Cost Planning SIMulation model (LCPSIM) is an economically efficient regional water management planning model based on the principle of least-cost planning.	Ray Hoagland, DWR	This model has been linked with CalSim.
Miscellaneous	IWRIS	Integrated Water Resources Information System (IWRIS) is a data management tool for water resources data. It is a web based GIS application that allows you to access, integrate, query, and visualize multiple sets of data. Some of the databases include DWR Water Data Library, California Data Exchange Center (CDEC), USGS stream flow, Local Groundwater Assistance Grants (AB303), and data from local agencies. It also keep track of areas with modeling studies performed.	DWR: http://www.water.ca.gov/iwris/	It is a tool can be used for review groundwater aquifer data and studies performed.
Forecast-Based/Forecast-Coordinated Operations	GFS	The Global Forecast System is a global numerical weather prediction computer model run by NOAA. It is run 4 times a day utilizing synoptic base times of 00Z, 06Z, 12Z and 18Z to initialize the model. The model is run in two parts: the first part has a much higher resolution and is used for the 180 time frame, while the second part is more coarse and is utilized for medium range forecasts up to 384 hours (16 days). It divides the atmosphere into 64 layers, while producing a forecast that is temporally divided into 3 hr increments. The GFS is the basis for an additional model, the Medium Range Forecast (MRF) that runs concurrent (same time scales) as the GFS.	National Oceanic and Atmospheric Administration (NOAA)	This model gives an excellent global, synoptic scale, look at forecast weather that provides the ability to perform a trend analysis on the entire earth's atmospheric patterns. Thus, a better understanding of potential precipitation events may be tracked for several days prior to the near term forecast analysis.
	ECMWF	The European Centre for Medium Range Weather Forecasts provides an atmospheric forecasting model produced by a consortium of European states. It is an alternative to the GFS model as it provides a similar, synoptic scale, medium range (up to 15 days) forecast. The long range forecasting component of the ECMWF model have made significant contributions to a better understanding of climate variability.	European Centre for Medium Range Weather Forecasts	This model is used in concert with the GFS to help verify initialization of these models, while providing a slightly different analysis/forecasting numerical scheme. The vagaries and variables involved in atmospheric modeling are extremely complex and often provide varied results. The application of this model to operational weather forecasting provides a secondary level of analysis that inevitably increases forecast accuracy.
	MM5	The PSU/NCAR mesoscale atmospheric model is a limited-area, nonhydrostatic, terrain following, sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation.	Penn State Univ./National Center of Atmospheric Research	This model provides a regional outlook for meteorological parameters that are used as the basis for precipitation/runoff forecasts. This model is quite adaptable to varying meteorological situations, which makes it quite popular among the University and Federal meteorological research communities.
	WRF-NAM	The Weather Research and Forecast – North American Mesoscale Model provides a more localized numerical model for precipitation forecasting, as well as numerous other meteorological parameters. Recent upgrades and improved physics have increased this model's capabilities, and have made this model extremely important to the accuracy of near-term precipitation forecasting. This model primarily provides forecast information out to 48 hours in 12 hour increments with individual forecast times provided in 6 hour increments out 60 hours.	National Center for Environmental Prediction (NCEP)	Although this model is not used exclusively for near-term precipitation forecasting, it has proven extremely adept and adaptable to California. This model is geared for the real-time operational forecasting. It does contain certain forecasting biases that may or may not produce more accurate results in varying synoptic situations, but is an extremely good forecasting tool.
	NOAA's Hydrometeorology Testbed (HMT)	NOAA's Hydrometeorology Testbed (HMT) is a demonstration program that focuses the use of advanced observational and modeling tools on quantitative precipitation estimation (QPE) and quantitative precipitation forecasting (QPF) for the purpose of improving hydrologic forecasts and warnings.	NOAA http://www.esrl.noaa.gov/psd/programs/hmt/2010/	

Category	Name	Description	Developer/Contact	Comment
Climate Change/Variability	GCMs	General Circulation Models are key components of Global Climate Models, which are used for projecting future climate change. They utilize the interaction between the atmosphere and the oceans to model the earth's systems. There are many different GCMs including: HadCM2, CCC, BMRC,CCSR,CERF,CSIRO,ECHAM3,ECHAM4,GFDL,GISS,IAP LMD, MRI, NCAR CSM, NCAR WM, PCM, HadCM3, etc. In a typical climate change analysis anywhere from 2-6 different GCMs are considered.	Intergovernmental Panel on Climate Change, Hadley Centre, NCAR, etc.	GCMs are regularly changed, updated or adjusted to accommodate new findings in the science of climate change/variability. An example of this would be the latest attempt by climate modelers to incorporate climate trends (see Climate Variability adjustment below) such as the El Nino Southern Oscillation (ENSO) into the global climate modeling effort.
	Downscaled Climate Modeling	GCM climate simulations/projections are performed on a global scale that encompasses the entire earth. To better understand climate change occurring on a local or regional scale, a technique called "spatial downscaling" was used for analysis of climate change. Downscaled global climate projections were used to better understand how global climate change will affect the Project Area on a regional scale. While multiple approaches exist for deriving regional climate data from coarse resolution model output, downscaling of the data set can be performed using a statistical method called Bias Correction and Spatial Downscaling (BCSD) as applied by Wood et al. (2004).	IPCC, USDOI, BOR, Lawrence Livermore National Lab, Santa Clara Univ. Civil Engineering Dept., Climate Central, Institute for Research on Climate Change and Societal Impacts	There are many options for downscaling of GCM output, but, fortunately much of this work was completed as part of the BDCP in accordance with the latest methodological advances.
	Climate Variability	Climate variability can be modeled as a component/combination of cyclical trends, historical climate or directly from downscaled climate projections that reflect monthly sequences and variability. As mentioned in the GCM comments above, cyclical Ocean-atmosphere trends such as the ENSO, Pacific Decadal Oscillation (PDO) or North Atlantic Oscillation (NAO) have a significant impact on the future climate conditions. These index values are used to adjust GCM output to allow it to account for variability within a specific climate regime.	ESRL	The value of the incorporation of climate variability into the broader projection of future climate is extremely acute during the next 30-40 years, when climate variability is seen as a more heavily weighted factor than anthropogenic change.
	Climate Emissions Scenarios	Climate emissions scenarios are GCM input for future Greenhouse Gas concentration scenarios. These scenarios labeled A1, A2, A1FI, A1T, A1B, B1, B2, etc. are based varying levels of economic and population growth, new technologies, and use and reliance on fossil fuels. These scenarios enable a better understanding of the potential for future climate change.	Special Report on Emissions Scenarios -IPCC	Originally the BDCP used 16 different emissions scenarios combined with GCMs to produce 112 different climate projections. This modeling was eventually pared down to fewer scenarios, but this data is still available for consideration on the re-op project.
	VIC	The Variable Infiltration Capacity model is a semi-distributed grid –based macroscale hydrology model which enables the user to solve for full water and energy balances within a system. It has been applied to the Sacramento-San Joaquin, Arkansas-Red, and Mississippi River basins among others. Its inputs are time series of daily or hourly meteorological parameters (e.g. precipitation, air temperature, wind speed), which allows this model to incorporate GCM output for use in climate change assessment. Land-atmosphere fluxes, and the water and energy balances at the land surface, are also simulated at a daily or sub-daily time step.	Univ. of Washington and Princeton University	This valuable tool was used as a front-end of sorts for the incorporation of climate change information from the GCM/emissions scenarios into the CALSIM II and DSM2 modeling effort on the BDCP. The VIC's most valuable asset was the ability to incorporate future snowmelt/snowpack changes based on GCM input into its geographic grid.

Table C-2. Summary of Assessment of Existing Water Supply Analysis Tools

Model Information		Water Supply Models			
		CalSim III	CalLite/WEAP PA	CalSim II/USRDOM (BDCP/NODOS)	INFORM
Model capabilities	*time step*	monthly	CalLite: monthly WEAP: various	monthly (CalSim II) daily (USRDOM)	various
	representation of hydrology in Central Valley	SWP/CVP service area and beyond	SWP/CVP service area and beyond with WEAP PA	SWP/CVP service area (CalSim II) upper Sacramento River (USRDOM)	Northern California only
	stream routing	no	no	USRDOM only (upper Sacramento River)	yes
	surface water and groundwater interaction	linked with C2VSIM	simple representation	simple representation	simple representation
	Watershed runoff modeling	Yes, through CalSim Hydrology	yes, through WEAP, to be completed	no	yes
	multiple time step optimization in water allocation	no	no	no	yes
	Linkage to models / tools	no, but similar linkage as CalSim II can be implemented	SWAP	USRWQM, Reclamation Temperature & Mortality models, SALMOD, WRCLCM (IOS), LTGEN SWP Power, SWAP, LCPSIM/SUPEM, LCRBWQM/SBWQM	no
	reliability analysis	no built-in tool	no built-in tool	no built-in tool	some
	Optimization/management tool	no built-in tool	no built-in tool	no built-in tool	limited/unknown
System Reoperation building blocks	*cooperate among SWP, CVP and other local projects*	limited with COA agreement	limited with COA agreement	limited with COA agreement	limited with COA agreement
	reoperate reservoirs (Forecast based or cooperated operation and rule curve revision)	limited with monthly time step, no FBO	limited with monthly time step, no FBO	monthly operation decision with daily stream rooting, no FBO	yes
	integrate management of groundwater and surface water	yes	limited	limited	limited
	facilitate water transfer	yes	yes, but limited in evaluating surface water and groundwater impact	yes, but limited in evaluating surface water and groundwater impact	yes, but limited in evaluating surface water and groundwater impact
	change stream flow patterns	no	no	yes. But limited to upper Sacramento River	yes
	change points, timing and/or volume diversion	yes	yes	yes	yes
System Reoperation Objectives	*water supply representation*	yes	yes	yes	yes
	flood protection representation	representation of flood protection operations is not appropriate for flood protection analysis	representation of flood protection operations is not appropriate for flood protection analysis	USRDOM has improved (daily) stream routing at Upper Sacramento River only, but representation of flood protection operations is not appropriate for flood protection analysis.	limited, need better representation of water system
	ecosystem representation	limited can be implemented as CalSim II	limited can be implemented as Calsim II	limited linked, but not dynamically linked with some ecosystem models. USRDOM (with daily time step) allows for better representation of ecosystem hydrology	no
Model analysis	*issues*	not released yet, no stream routing	integration not completed, simple representation of SWP and CVP, SJR region to be added, some features still under development	newer model (USRDOM), need experienced modeler	lack of details for representing SWP and CVP, need implementation of Delta salinity control in addition to X2 requirement
	advantage	better hydrology resolution, linked to C2VSIM	water demand calculation, watershed runoff module, easier use and faster execution	stream routing at Upper Sacramento River (USRDOM only), linked with some other ecosystem and water quality models	runoff module, stream routing, forecast based operation, reservoir decision support system (current policy and Adaptive, Risk-based Policy up to nine months), energy consumption in reservoir operation
	Model Improvement	for candidate models: (1) without stream routing capability or linked flood hydraulic model, implementing flood measures and controls index in the models is needed; (2) if not linked with ecosystem models, implementing ecosystem measures and controls in the models is needed. Use the model linking techniques developed in BDCP and NODOS efforts. (3) developing an automation/optimization tool to speed up modeling effort, perform reliability analysis and help make optimal management decision. (4) Model improvement to simulate forecast related operations			implement water system in more detail as CalLite, improve delivery logic
			if CalSim III is not available, implementing surface water and groundwater interaction		

Table C-3. Recommended Sets of Existing Analysis Tools

Application of Tool(s)	Lead Agency	Resource Analyzed	Sub-Resource Analyzed	Tools Used/Produced	Tool Coverage/Extents
Bay Delta Conservation Plan (BDCP)	DWR/USBR	Water Supply		CalSim II	Central Valley terminal reservoirs and downstream streams, including Delta
		Flood Hazard Reduction	Reservoir operations and stream flows	CalSim II, DSM2 (only limited semi-quantitative/qualitative analysis possible)	Central Valley terminal reservoirs and downstream streams, including Delta
		Ecosystem	Biological, Fish and Aquatic	CALSIM II, DSM2 (HYDRO, QUAL, PTM, Nutrient Module), SRWQM, Reclamation Temperature Model, IOS, DPM, SALMOD, Sat Sac Mortality, SAC EFT, many other manual analyses	Central Valley streams (not including flood plains), DSM2 is limited to the Delta, some models are limited to portions of the Sacramento River
			Biological, Terrestrial (within existing stream levees)	CALSIM II	Central Valley terminal reservoirs and downstream streams, including Delta
		Water Quality		DSM2 (HYDRO, QUAL, PTM)	Delta
				Reclamation Temperature Model, SRWQM	Upstream of the Delta on the Sacramento River
		Groundwater		CALSIM II CVHM CVHM-D	Central Valley, including Delta
		Power Generation		CALSIM II LT-GEN SWP Power	Central Valley reservoir dams

Application of Tool(s)	Lead Agency	Resource Analyzed	Sub-Resource Analyzed	Tools Used/Produced	Tool Coverage/Extents
		Socioeconomics, Agriculture, Recreation		CALSIM II CVPM, LCPSIM, LCRBWQM, IMPLAN	
North-of-Delta Off-Stream Storage Study	DWR/USBR	Water Supply		USRDOM, and other models similar to those used for BDCP	Similar to BDCP, except USRDOM only covers upper Sacramento River
		Ecosystem	Sediment Transport	SRH	Parts of the Sacramento River
		Water Quality	Sediment Transport	SRH	Parts of the Sacramento River
CVP Integrated Resource Plan	USBR	Water Supply		CalLite/WEAP PA	Central Valley terminal reservoirs and downstream streams, including Delta
Sacramento-San Joaquin Comprehensive Study (Comp Study)	USACE	Flood Hazard Reduction	Reservoir Operations	HEC-1 HEC-5	Central Valley watersheds Central Valley terminal reservoirs
			Flood Hydrology and Hydraulics	HEC-1 UNET, FLO-2D	Central Valley watersheds Central Valley streams and floodplains downstream of terminal reservoirs (not including downstream areas of Delta)
			Flood Damage Assessment	Discharge-frequency stage-discharge, stage-damage, and damage-frequency curves	Various index points along subject streams

Application of Tool(s)	Lead Agency	Resource Analyzed	Sub-Resource Analyzed	Tools Used/Produced	Tool Coverage/Extents
Various	USACE	Flood Hazard Reduction	Reservoir Operations	HEC ResSim (Conversion of Comp Study HEC-5 models)	Central Valley watersheds Central valley terminal reservoirs
			Floodplain Hydraulics	HEC-RAS (Conversion of Comp Study UNET models)	Central Valley watersheds Central Valley streams and floodplains downstream of terminal reservoirs (not including downstream areas of Delta)
Folsom Dam Permanent Operations Study	USACE	Flood Hazard Reduction	Reservoir Operations	HEC ResSim	Folsom Lake
		Water Supply		CalSim II, DSM2	Central Valley terminal reservoirs and downstream streams, including Delta
		Forecast Based Operations		TBD	
		Ecosystem	Temperature	CalSim, Reclamation Temperature Model, HEC-RAS	Sacramento River
		Ecosystem	Fish Mortality	Reclamation Mortality Model	Sacramento River
		Water Quality	Dissolved and Particulate Water Quality Constituents	DSM2	Delta
		Geomorphology	Sediment Transport	HEC-RAS	American River
		Power Generation		LTGEN	Folsom Dam

Application of Tool(s)	Lead Agency	Resource Analyzed	Sub-Resource Analyzed	Tools Used/Produced	Tool Coverage/Extents
FloodSAFE Central Valley Hydrology Study	DWR/USACE	Flood Hazard Reduction	Flood Hydrology	HEC-HMS HEC ResSim HEC-RAS (for routing) (models under development)	Central Valley watersheds
FloodSAFE Central Valley Flood Evaluation and Delineation Program	DWR	Flood Hazard Reduction	Floodplain Hydraulics	HEC-RAS, FLO-2D (under development)	Central Valley streams and floodplains downstream of terminal reservoirs (not including downstream areas of delta)
FloodSAFE Supplemental Reservoir Operations Analysis	DWR	Flood Hazard Reduction	Reservoir Operations	HEC 5	Central Valley terminal reservoirs
			Flood Hydrology and Hydraulics	HEC-1 UNET, FLO-2D	Central Valley watersheds Central valley streams and floodplains downstream of terminal reservoirs (not including downstream areas of delta)
FloodSAFE (FESSRO)	DWR	Ecosystem	Flow Regime Change	HEC-EFM	Central Valley
Feather and Yuba River Forecast Coordinated Operations Program	Yuba County Water Agency/DWR/USACE/NOA	Flood Hazard Reduction	Reservoir Operations	HEC-ResSim	Feather and Yuba Rivers and Associated Reservoirs
Various	Various	Water Supply (primarily, but includes ecosystem flow index)		CalLite (errors being corrected)	Central valley terminal reservoirs and downstream streams, including Delta

Application of Tool(s)	Lead Agency	Resource Analyzed	Sub-Resource Analyzed	Tools Used/Produced	Tool Coverage/Extents
Various	DWR	Weather and storm runoff forecasting		QPF	
Groundwater Availability of the Central Valley Aquifer, California	USGS	Groundwater		CVHM (was applied in BDCP)	Central Valley

Table C-4. Short List of Recommended Existing Analysis Tools

Resource Topic	System Reoperation Study Phase	Main Analysis Tool	Applicable Recent Study
Water Supply	Reconnaissance	CalSim II/USRDOM	Flood Safe Supplemental Reservoir Operations Analysis BDCP NODOS
		CalLite/WEAP PA	CVP Integrated Resource Plan
	Feasibility	CalSim III[a]	N/A
Flood Hazard Reduction	Reconnaissance	HEC-5/UNET	Flood Safe Supplemental Reservoir Operations Analysis
		Discharge-frequency stage-discharge, stage-damage, and damage-frequency curves	Sacramento-San Joaquin Comprehensive Study (Comp Study)
	Feasibility	HEC ResSim/HEC-RAS	Flood Safe Central Valley Hydrology Study
Ecosystem	Reconnaissance/ Feasibility	To be determined based on selected metrics and proposed concepts	BDCP and others
		HEC-EFM	Flood Safe
		DSM2 (Nutrients)	BDCP
		SRH	NODOS
Groundwater	Reconnaissance	Historical hydrogeology studies/data CVHM	Various BDCP
	Feasibility	C2MSIM	N/A

a. If available. Otherwise, CalSim II/USRDOM would be recommended.
b. If integration with CalSim III has been completed, otherwise, CVHM would be recommended.