Draft

Modeling Appendix

Upper San Joaquin River Basin Storage Investigation

Prepared by:

United States Department of the Interior
Bureau of Reclamation
Mid-Pacific Region

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Bureau of Reclamation

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation’s natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Contents

Tables

Figures

Attachments

CalSim II Modeling Attachment
CE-Qual-W2 Modeling Attachment
SJR5Q Modeling Attachment
DSM2 Modeling Attachment
Hydropower Modeling Attachment
Climate Change Modeling Attachment
Modeling Results Supporting Chapter 5 – Fisheries and Aquatic Ecosystems Attachment

Abbreviations and Acronyms

°C	degree Celsius
μS/cm	microsiemens per centimeter
AIC	Agricultural Issues Center
Bay Area	San Francisco Bay Area
BO	Biological Opinion
BST	Benchmark Study Team
CACMP	Common Assumptions Common Model Package
CBOD	carbonaceous biochemical oxygen demand
CCWD	Contra Costa Water District
CES	Constant Elasticity of Substitution
cfs	cubic feet per second
CGE	Computable General Equilibrium
CNP	current normalized price
CONV	conveyance
CVP	Central Valley Project
Delta	Sacramento-San Joaquin River Delta
DICU	Delta Island Consumptive Use
DMC	Delta-Mendota Canal
DSM2	Delta Simulation Model Version II
DWR	California Department of Water Resources
E/I	Export/Inflow
EBMUD	East Bay Municipal Utility District
EC	electroconductivity
EDT	Ecosystem Diagnosis and Treatment
EIS	Environmental Impact Statement
EOD	end-of-day
FERC	Federal Energy Regulatory Commission
GWh	gigawatt-hour
IMPLAN	IMpact analysis for PLANning
Investigation	Upper San Joaquin River Basin Storage Investigation
I-O	input-output
Kerckhoff Project	PG&E Kerckhoff Hydroelectric Project
kWh	kilowatt-hour
LLIS	low level intake structure
LOD	level of development

LTGen	LongTermGen
M&I	municipal and industrial
NED	National Economic Development
Neq	equilibrium abundance
NMFS	National Marine Fisheries Service
O&M	operations and maintenance
OMR	Old and Middle River
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PEIS/R	Programmatic Environmental Impact Statement/Report
PG&E	Pacific Gas and Electric Company
PMP	Positive Mathematical Programming
ppt	past per thousand
R&D	research and development
RCC	roller compacted concrete
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RED	regional economic development
RM	River Mile
SAR	smolt-to-adult return rate
Settlement	Stipulation of Settlement in NRDC et al. vs. Kirk Rodgers et al.
SJR5Q	San Joaquin River HEC-5Q temperature model
SJRRP	San Joaquin River Restoration Program
SLIS	selective level intake structure
SLWRI	Shasta Lake Water Resources Investigation
SOD	South-of-Delta
SRA	State Recreation Area
State	State of California
SWAP	State Wide Agricultural Production
SWP	State Water Project
TAF	thousand acre-feet
TS	time series
TXFR	transfer
UCCE	University of California Cooperative Extension
USACE	U.S. Army Corps of Engineers

USAN	Upper San Joaquin Basin Model
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
Western	Western Area Power Authority
WQCP	Water Quality Control Plan
WRESL	Water Resources Simulation Language
WRIMS	Water Resources Integrated Modeling System

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Chapter 1
Introduction

This document presents information on modeling and analysis processes and results performed in support of the Draft Environmental Impact Statement (EIS) prepared for the Upper San Joaquin River Basin Storage Investigation (Investigation). The Investigation is led by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation), in cooperation with the California Department of Water Resources (DWR). The purpose of the Investigation is to determine the type and extent of Federal, State of California (State), and regional interest in a potential project to expand water storage capacity in the upper San Joaquin River watershed to (1) improve water supply reliability and flexibility of the water management system for agricultural, municipal and industrial (M&I), and environmental uses; and (2) enhance water temperature and flow conditions in the San Joaquin River downstream from Friant Dam for salmon and other fish.

Appendix Purpose

A suite of models and other tools was used to develop information needed to analyze the effects of the final Investigation alternatives on different resource areas in the EIS. This Modeling Appendix documents the models, tools, assumptions, and associated analysis procedures used to develop this information. It also presents detailed results and discussion to assist in interpreting the results. The overall analysis process encompasses reservoir operations, water temperature, fish habitat, water quality, hydroelectric power generation, and economic benefits.

This Modeling Appendix is organized as follows:

Chapter 1 provides background on the Investigation and a description of the study area and alternative plans considered.

Chapter 2 provides an overview of the modeling and analysis processes and tools described in this appendix.

Chapter 3 discusses operations modeling tools, assumptions, application, and results.

Chapter 4 describes reservoir and river water temperature modeling.

Chapter 5 describes analysis of improvements and impacts to fisheries habitat under the alternative plans.

Chapter 6 describes hydrodynamic and salinity modeling in the Sacramento-San Joaquin River Delta (Delta).

Chapter 7 describes hydroelectric power generation modeling.

Chapter 8 describes tools and analyses used to describe effects of the Investigation alternatives on recreation.

Chapter 9 describes models and analyses used to evaluate changes in regional groundwater conditions under the alternative plans.

Chapter 10 describes economic agricultural water supply reliability benefits analysis.

Chapter 11 describes regional economic impact modeling.

Chapter 12 describes climate change modeling.

Chapter 13 contains sources of information used to prepare the appendix.

CalSim II Modeling Attachment contains summary tables and raw output from the routed CalSim II model that are relevant to the Investigation.

CE-Qual-W2 Modeling Attachment contains summary tables and raw output from the CE-Qual-W2 model for Temperance Flat River Mile (RM) 274 Reservoir and Millerton Lake.

SJR5Q Modeling Attachment contains summary tables and raw output from the SJR5Q model for select locations along the San Joaquin River.

DSM2 Modeling Attachment contains water quality modeling summary tables and raw output from the DSM2 model.

LTGen and SWP Power Modeling Attachment contains raw output from the LTGen and SWP Power models.

Climate Change Modeling Attachment contains in depth further details regarding the climate change modeling methodology and additional results in support of Chapter 8, “Climate Change,” of the EIS.

Modeling Results in Support of Chapter 5 - Fisheries and Aquatic Ecosystems Attachment contains tables and figures of Millerton Lake and Temperance Flat RM 274 Reservoir temperature; San Joaquin River temperature and flow; and San Joaquin River tributaries’ flow in support of Chapter 5, “Biological Resources – Fisheries and Aquatic Ecosystems,” of the EIS.

Investigation Background

During previous phases of the Investigation, several potential surface water storage sites in the upper San Joaquin River Basin were identified and evaluated for potential inclusion in action alternatives (Reclamation and DWR 2003, 2005, and 2008). Multiple sizes and configurations were considered at several sites. These initial evaluations considered water supply operations, general environmental consequences, construction costs, and energy generation and use.

Evaluations conducted during the Plan Formulation Phase of the Investigation led to selection of a new dam and reservoir at RM 274 (the Temperance Flat RM 274 Reservoir) as the preferred surface water storage measure for further development and inclusion in action alternatives in the Feasibility Report and EIS. Temperance Flat RM 274 Reservoir would include construction of a dam in the upstream portion of Millerton Lake at RM 274, approximately 6.8 miles upstream from Friant Dam and 1 mile upstream from the confluence of Fine Gold Creek and Millerton Lake. Additional details regarding the development of the Investigation are available in Chapter 2 of the EIS and in the Plan Formulation Appendix.

Study Area

The San Joaquin River is California’s second longest river and discharges to the Delta and, ultimately, to the Pacific Ocean through San Francisco Bay. Originating high in the Sierra Nevada Mountains, the San Joaquin River carries snowmelt and rainfall runoff from mountain meadows south of Yosemite National Park to the valley floor near Fresno, then northwest through the valley to the Delta. Tributaries to the San Joaquin River from the east include the Merced, Tuolumne, and Stanislaus rivers; small streams, sloughs, wetlands, and agricultural drainage form the inflow from the west. The upper San Joaquin River Basin encompasses the San Joaquin River and tributary lands from its source high in the Sierra Nevada to its confluence with the Merced River. Friant Dam and Millerton Lake are located on the upper San Joaquin River about 20 miles northeast of Fresno.

The study area evaluated in this EIS includes both a primary and an extended study area to reflect the localized effects of a potential new major dam and reservoir upstream from Friant Dam in the upstream portion of Millerton Lake, and the effects of subsequent water deliveries over a larger geographic area. The primary study area was refined as the Investigation progressed and the number and location of feasible storage sites was narrowed. The primary study area presented in this Draft EIS includes the following (Figure 1-1):

- San Joaquin River upstream from Friant Dam to Kerckhoff Dam, including Millerton Lake and the area that would be inundated by the proposed Temperance Flat RM 274 Reservoir (Temperance Flat Reservoir Area)
- Areas that could be directly affected by construction-related activities, including the footprint of proposed temporary and permanent facilities upstream from Friant Dam

The extended study area encompasses the following (Figure 1-2):

- San Joaquin River downstream from Friant Dam, including the Delta
- Lands served by San Joaquin River water rights
- Friant Division of the Central Valley Project (CVP), including underlying groundwater basins in the eastern San Joaquin Valley
- South-of-Delta (SOD) water service areas of the CVP and State Water Project (SWP)

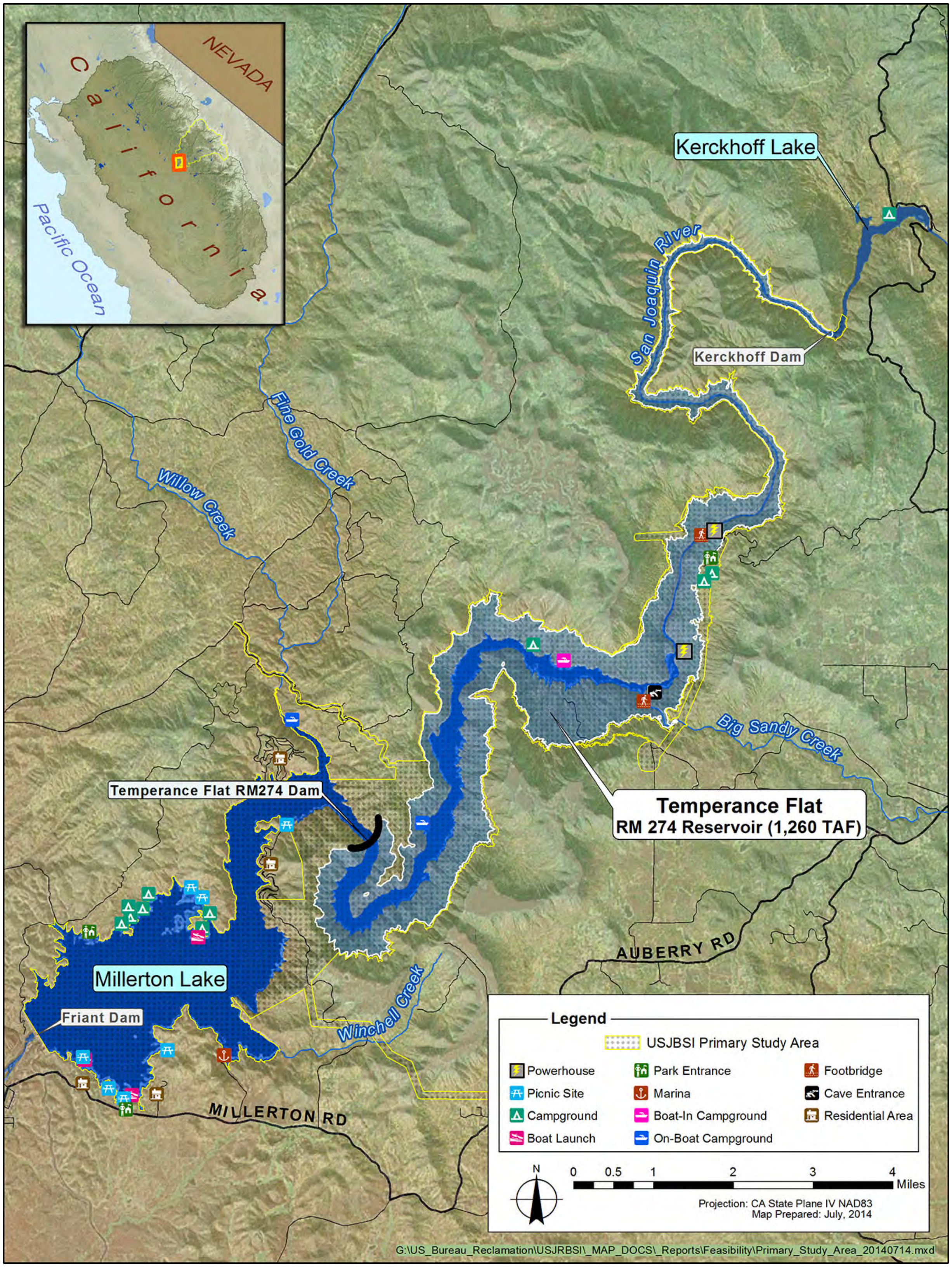


Figure 1-1. Primary Study Area Including Proposed Temperance Flat RM 274 Reservoir and Dam

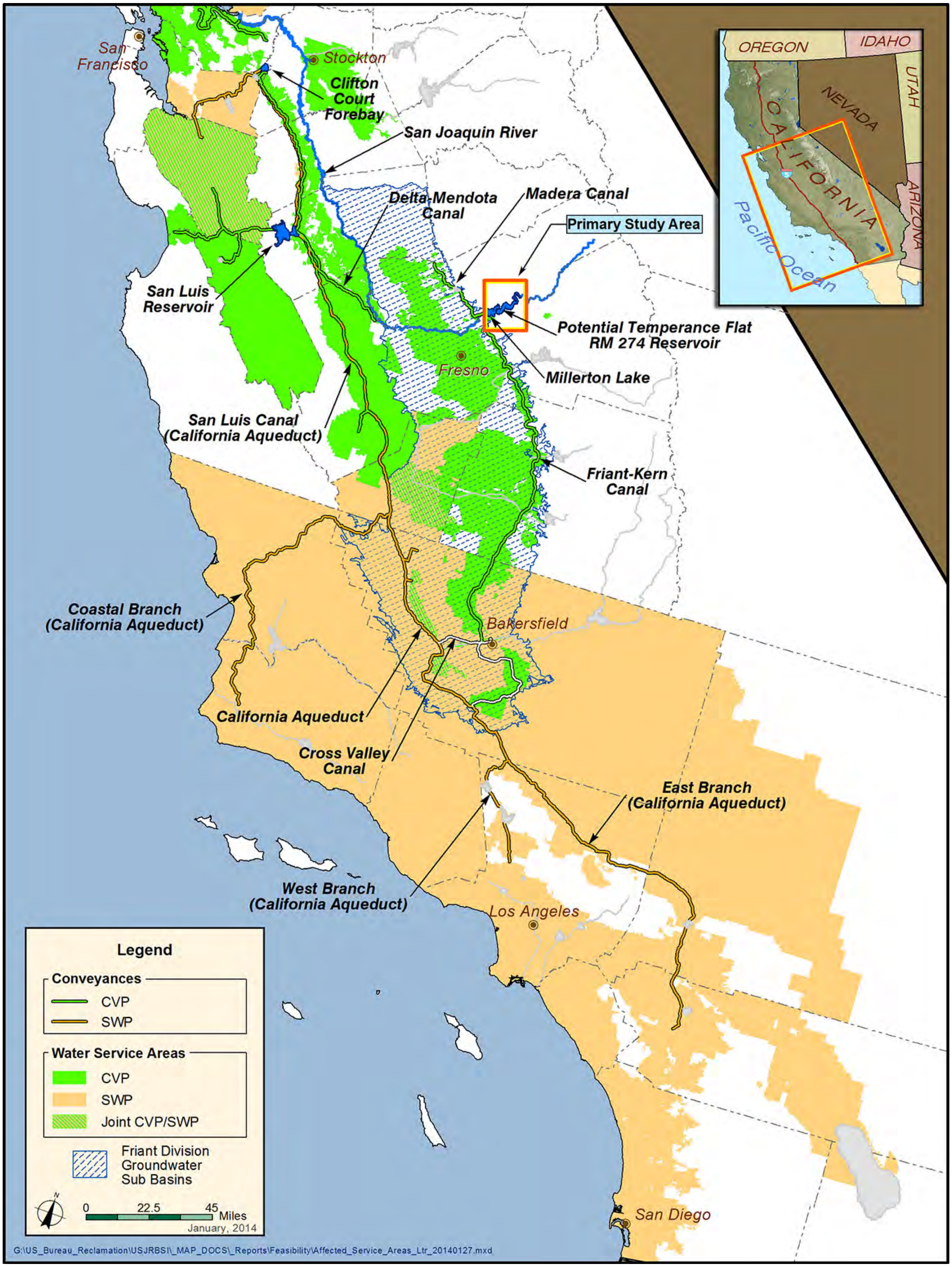


Figure 1-2. Extended Study Area

Temperance Flat RM 274 Reservoir Overview

Temperance Flat RM 274 would be created through construction of a dam in the upstream portion of Millerton Lake at RM 274 (Figure 1-1). The dam would create a reservoir with 1,260 thousand acre-feet (TAF) of new storage. The dam site is located approximately 6.8 miles upstream from Friant Dam and 1 mile upstream from the confluence of Fine Gold Creek and Millerton Lake. Permanent features that would be constructed as part of the action alternatives include a main dam with an uncontrolled spillway to pass flood flows, a powerhouse to generate electricity, and outlet works for other controlled releases.

At the top of active storage capacity (985 feet above mean sea level [elevation 985]), Temperance Flat RM 274 Reservoir would provide about 1,260 TAF of additional storage (1,331 TAF total storage, 75 TAF of which overlaps with Millerton Lake), and would have a surface area of about 5,700 acres. The reservoir would extend about 18.5 miles upstream from RM 274 to Kerckhoff Dam. Temperance Flat Dam would be roller compacted concrete (RCC) arch gravity dam. The dam would be about 665 feet high, from base elevation 340 in the bottom of Millerton Lake (San Joaquin River channel) at the upstream face to the dam crest at elevation 1,005.

Alternatives

Five action alternatives were formulated and evaluated to assess the potential range of impacts for each plan. The action alternatives vary according to the operation of Temperance Flat RM 274 Reservoir and Millerton Lake carryover storage, potential beneficiaries receiving new water supply, delivery routing of new water supply, and intake configuration.

- Carryover storage is the volume of water reserved in the reservoirs and is assumed to be unavailable for diversion or release to the San Joaquin River. The magnitude of this reservation impacts water supply, recreation, hydropower, and cold water pool management operations.

- Potential beneficiaries receiving new water supply include existing Friant contractors, CVP SOD contractors, and SWP M&I water users. The term SWP M&I water users is used to identify to potential beneficiaries of new water supply developed from this project and has no impact on their existing SWP M&I water supplies.

- Delivery of any new water supply to the potential beneficiaries could be accomplished through multiple routes. The San Joaquin River, Friant-Kern Canal, Delta-Mendota Canal, Cross Valley Canal and California Aqueduct are all potential conveyance options for deliveries and water exchanges depending on the beneficiary of the new water supply.

- The intake configuration may include a selective level intake structure (SLIS) on Temperance Flat RM 274 for cold water pool management.

The alternatives evaluated are as follows:

- **No Action Alternative –** Under the No Action Alternative, the project would not be implemented. The No Action Alternative reflects projected conditions under a 2030 level of development if the project is not implemented.

- **Alternative Plan 1 –**Alternative Plan 1 would construct a dam in the upstream portion of Millerton Lake at RM 274 and provide new water supplies to the Friant Division via the Friant-Kern and Madera Canals; and SWP SOD M&I contractors via the San Joaquin River through exchange at Mendota Pool and the California Aqueduct. This action alternative includes a low level intake structure (LLIS) and a 200 TAF minimum carryover storage target (water that is kept in the reservoir rather than delivered) in Temperance Flat RM 274 Reservoir. Millerton Lake would maintain a 340 TAF minimum carryover storage target, with a preference to store water in Temperance Flat RM 274 Reservoir before increasing Millerton Lake storage above the target.

- **Alternative Plan 2 –**Alternative Plan 2 would construct a dam in the upstream portion of Millerton Lake at RM 274 and provide new water supplies to the Friant Division via the Friant-Kern Canal and Madera Canals; and SWP SOD M&I contractors and CVP SOD contractors via the San Joaquin River through exchange at Mendota Pool and the California Aqueduct. This action alternative includes an LLIS and a 200 TAF minimum carryover storage target in Temperance Flat RM 274 Reservoir. Millerton Lake would maintain a 340 TAF minimum carryover storage target, with a preference to store water in Temperance Flat RM 274 Reservoir before increasing Millerton Lake storage above the target.

- **Alternative Plan 3 –** Alternative Plan 3 would construct a dam in the upstream portion of Millerton Lake at RM 274 and provide new water supplies to: the Friant Division via the Friant-Kern and Madera Canals; SWP SOD M&I contractors via existing cross-valley conveyance and the California Aqueduct; and CVP SOD contractors via the San Joaquin River through exchange at Mendota Pool and the California Aqueduct. This action alternative includes an LLIS and a 200 TAF minimum carryover storage target in Temperance Flat RM 274 Reservoir. Millerton Lake would maintain a 340 TAF minimum carryover storage target, with a preference to store water in Temperance Flat RM 274 Reservoir before increasing Millerton Lake storage above the target.

- **Alternative Plan 4 –** Alternative Plan 4 would construct a dam in the upstream portion of Millerton Lake at RM 274 and provide new water supplies to the Friant Division via the Friant-Kern and Madera Canals; and SWP SOD M&I contractors and CVP SOD contractors via the San Joaquin River through exchange at Mendota Pool and the California Aqueduct. This action alternative includes the SLIS and a 325 TAF minimum carryover storage target in Temperance Flat RM 274 Reservoir. Millerton Lake would maintain a 340 TAF minimum carryover storage target, with a preference to store water in Temperance Flat RM 274 Reservoir before increasing Millerton Lake storage above the target.

- **Alternative Plan 5 –** Alternative Plan 5 would construct a dam in the upstream portion of Millerton Lake at RM 274 and provide new water supplies to the Friant Division via the Friant-Kern and Madera Canals; and CVP SOD contractors via the San Joaquin River through exchange at Mendota Pool and the California Aqueduct. This action alternative includes a LLIS and a 100 TAF minimum carryover storage target in Temperance Flat RM 274 Reservoir. Millerton Lake would maintain a 130 TAF minimum carryover storage target, with preferences to store water in Millerton Lake up to 340 TAF and store water in Temperance Flat RM

274 Reservoir before increasing Millerton Lake storage above 340 TAF. Alternative Plan 5 also includes modification of the water supply allocation operational rules to increase drier year water supply reliability with minimal impact to long term average annual water supply reliability.

Table 1-1 summarizes the operational variables associated with the action alternatives.

Table 1-1. Summary of Action Alternatives Evaluated in EIS

	New Water Supply Beneficiaries/Deliveries					
Alternative Plan	**CVP Friant Division**	**CVP South-of-Delta**	**SWP Municipal & Industrial**	**Millerton Lake Minimum Carryover Storage (TAF)**	**Temperance Flat Minimum Carryover Storage (TAF)**	**Intake Structure Type [1]**
	Conveyance Route					
1	Friant-Kern / Madera Canals	N/A	San Joaquin River [2]	340	200	LLIS
2	Friant-Kern / Madera Canals	San Joaquin River [2, 3]	San Joaquin River [2]	340	200	LLIS
3	Friant-Kern / Madera Canals	San Joaquin River [2, 3]	Friant-Kern Canal	340	200	LLIS
4	Friant-Kern / Madera Canals	San Joaquin River [2, 3]	San Joaquin River [2]	340	325	SLIS
5	Friant-Kern / Madera Canals	San Joaquin River [2, 3]	N/A	130[4]	100	LLIS

Notes:

[1] Selective Level Intake Structure may be used for water temperature management.

[2] Water supply delivered from via the San Joaquin River to Mendota Pool would be available for exchange with CVP SOD contractors, CVPIA Level 2 refuge supplies, or San Joaquin River Exchange Contractor supplies.

[3] Alternative Plans would exchange Temperance Flat RM 274 Reservoir water supply for Level 2 refuges supplies delivered from the Delta, diversifying the CVPIA Level 2 water supply, and freeing up Delta supplies to be delivered to CVP SOD contractors.

[4] Millerton Lake would be operated with a preference for maintaining minimum storage at 340 TAF (when Temperance Flat is not full), but allows for Millerton Lake to be drawn down to 130 TAF when needed for water supply delivery.

Key:
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
LLIS = low level intake structure
N/A = not applicable
SLIS = selective level intake structure
SWP = State Water Project
TAF = thousand acre-feet

Chapter 2
Modeling and Analysis Process Overview

The Investigation implemented a multi-objective modeling process for comprehensive analysis of the alternative plans. Beginning with water operations at the new reservoir, modeling efforts were carried through reservoir and river temperature models, hydropower operations, fish habitat modeling, simulated emergency water supply, M&I water quality, and flood damage reduction, to characterize the physical accomplishments of the action alternatives. Each modeling process component of evaluating the operations and effects of the project is described in this Modeling Appendix and shown in Figure 2-1.

Modeling tools used for evaluations in the EIS include suite of models and other tools to evaluate the range of alternatives and the wide range of potential impacts of project implementation. These models and tools include the following:

- **CalSim II –** This model is a specific application of the Water Resources Integrated Modeling System (WRIMS) to simulate Central Valley water operations. The CalSim II model simulates CVP and SWP operations, including reservoir storages, river and canal flows, and project deliveries. Output from CalSim II is to supply project operation data to all other models and analysis processes in this evaluation.

- **Temperance Flat-Millerton Daily Operations Model –** This model reads in CalSim II operational data for the Temperance Flat and Millerton Reservoirs, converts the boundary conditions from the CalSim II monthly values to daily values using a modified linear interpolation process, and simulates the local reservoir operations on a daily basis within the monthly operational constraints obtained from the CalSim II model.

- **Temperance Flat-Millerton Reservoir Temperature Model –** This model, based on the CE-QUAL-W2 water quality modeling tool, uses the daily operations from the Temperance Flat-Millerton to simlate reservoir temperature profiles and San Joaquin River release temperatures.

- **San Joaquin River HEC-5Q Temperature Model (SJR5Q) –** This model, based on the HEC-5Q model, uses operational data from the Temperance Flat – Millerton Daily Operations model and temperature data from the Temperance Flat-Millerton Reservoir Temperature Model to simulate water temperature in the San Joaquin River from Friant Dam to the confluence with the Merced River.

- **SWAP –** SWAP, Version 6, uses CalSim II water supply deliveries to agricultural contractors to simulate the decisions of agricultural producers (farmers) in California. The model selects crops, water supplies, and irrigation technology to maximize profit.

- **Delta Simulation Model –** DSM2, Version 8.0.6, uses CalSim II Delta inflows, outflows, and exports to determine Delta water quality and water levels.

- **LTGen and SWPPower –** LTGen, Version 1.18, and SWPPower, Benchmark Study Team (BST) April 6, 2010 version, use CalSim II reservoir storages, releases, and project pumping to determine the energy generation and usage of the CVP and SWP.

- **Local Hydropower Generation –** This model uses operations data from the Temperance Flat-Millerton Daily Operations Model to simulate existing local hydropower energy generation from the Kerckhoff Power Project and Friant Power Plant.

- **Plexus PLEXOS® –** This model simulates hourly hydropower generation and capacity at Temperance Flat RM 274 Reservoir powerhouse and Kerckhoff Hydroelectric Project dispatch in an optimized manner to maximize the value of energy and ancillary services on an hourly basis. Ancillary services are provided by generating resources with specific attributes to quickly ramp up or down generation production. Ancillary services respond to fluctuations in variable energy resources generation to meet load in a reliable manner.

- **Ecosystem Diagnosis and Treatment (EDT) –** This model is a life-cycle and habitat model that has been applied to the San Joaquin River between Friant Dam and the Merced River for the San Joaquin River Restoration Program (SJRRP), herein referred to as the SJRRP EDT, to test potential spring-run Chinook salmon habitat improvements that could be provided by various restoration actions and changes in flow and temperature. The model uses temperature and flow data from the San Joaquin River Temperature Model.

- **Reservoir Fishery Model –** This model uses operations data from the Temperance Flat-Millerton Daily Operations Model and habitat and life history information to simulate spawning production for largemouth and spotted bass in the Temperance Flat and Millerton Reservoirs.

- **Schmidt Tool –** This model uses operational data from CalSim II to simulate changes in groundwater elevation due to changes in surface water delivery to selected Friant contractors.

- **IMPLAN** model, Version 3.0.17.2, uses construction cost estimates to simulate the effect of construction-related expenditures on the regional economy in terms of changes in industry output, employment, and income.

- **Central Valley Project Improvement Act Climate Change Modeling Suite –** This modeling suite of climate, hydrology, operations, and performance assessment models was modified specifically for the Investigation; however, it does not include the capacity to quantitatively evaluate all the resources categories associated with potential climate impacts on the Investigation. These limitations mean that some of the details of the various Investigation alternatives could not be represented in the quantitative modeling of climate change assessments. The results are not directly comparable to the results of other modeling tools used in the Investigation and were not used to support specific impact evaluations.

Figure 2-1 shows the interaction between the major modeling tools and the outputs and information used to support the EIS.

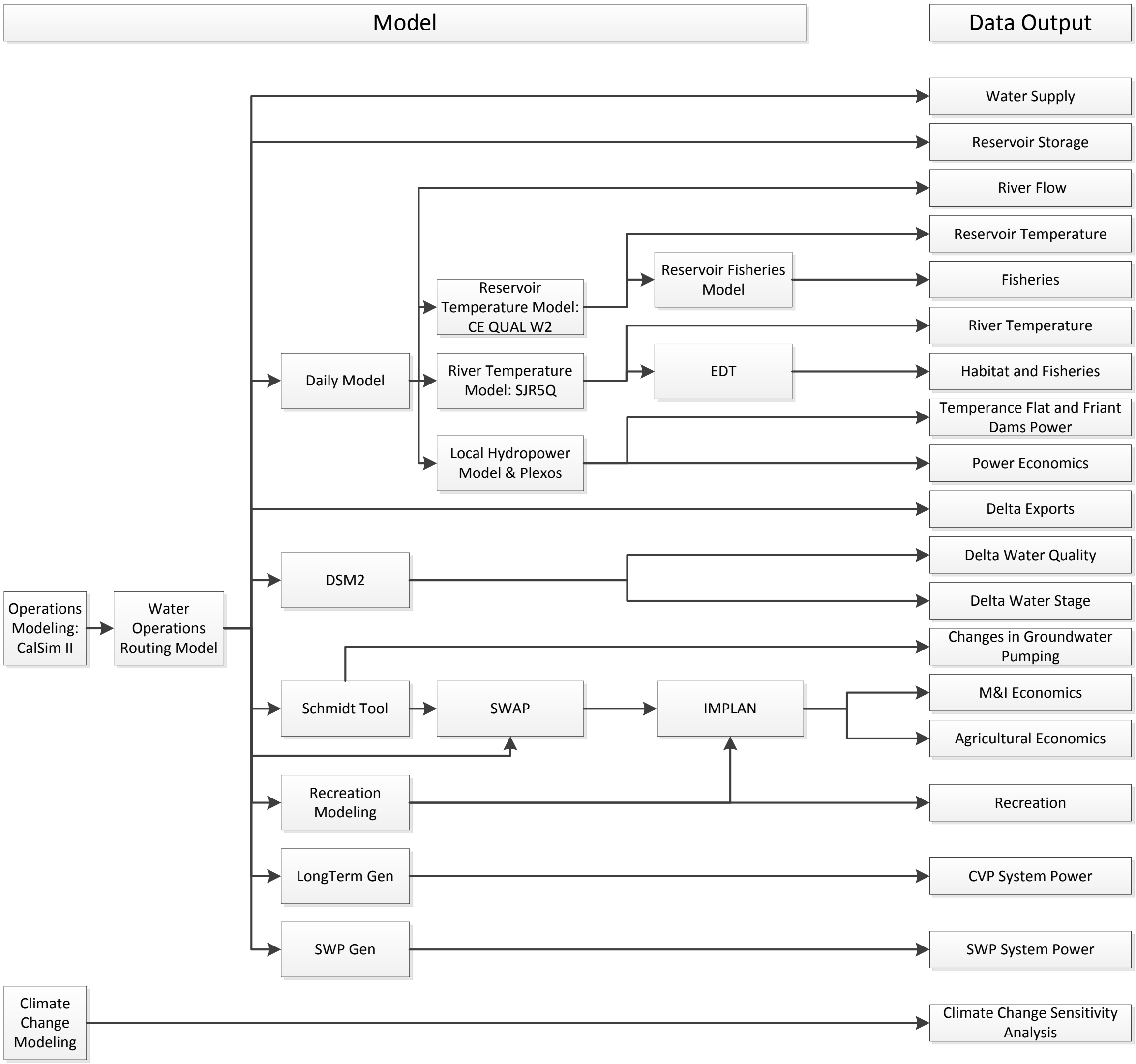


Figure 2-1. Modeling Processes Used to Characterize Environmental Impacts of the Alternative Plans

Subsequent chapters of this appendix describe and document each of these tools, associated utilities required to apply the tools, analysis assumptions, and application to this Investigation in greater detail. Selected results from the application of the tools are also presented.

Chapter 3
Operations Modeling

Several models were used to simulate CVP and SWP system operations. The CalSim II model and a post-processing routing model were used to develop the overall operational parameters for the entire CVP/SWP system, including Millerton Lake and Temperance Flat RM 274 Reservoir. Further, a daily operations model of Millerton and Temperance Flat was used to define a set of daily operations for these two reservoirs for use in temperature analysis. The river temperature model included a daily flow model component for the San Joaquin River based on the HEC5 reservoir modeling tool. This chapter describes the modeling tools (with the exception of the San Joaquin River daily operations, which is described in Chapter 4), operational assumptions, and modeling process carried out to simulate the operational data required to support the EIS.

Terms and Definitions

The following definitions are used in the Investigation operations analysis.

- The following periods are defined for different year definitions:
    - "Water Year" starts October 1 of the preceding calendar year and ends September 30 of the current calendar year. For example Water Year 1922 starts October 1, 1921, and ends September 30, 1922.
    - "Delivery Year" starts March 1 of the current calendar year and ends February 28 of the following year. For example Delivery Year 1922 starts March 1, 1922.
    - "Restoration Year" starts March 1 of the current calendar year and ends February 28 of the following year. For example Restoration Year 1922 starts March 1, 1922.
- There are three different year-type classification systems used in the analysis:

    - **Sacramento Valley Year Type –** This classification system is based on the historical and forecasted unimpaired inflows to the Sacramento River Basin of the Sacramento, Feather, Yuba, and American river basins as defined in State Water Board Resources Control Decision D-1641. The classification consists of five year types: wet, above normal, below normal, dry, and critical.
    - **San Joaquin Year Type or 60-20-20 Year Type –** This classification system is based on the historical and forecasted unimpaired inflows of the Stanislaus, Tuolumne, Merced, and San Joaquin rivers to the San Joaquin River Basin, as defined in State Water Board Resources Control Decision D-1641. The classification consists of five year types: wet, above normal, below normal, dry, and critical.
    - **San Joaquin Restoration Year Type –** This classification system is based on the unimpaired inflow to Millerton Lake, or Temperance Flat RM 274 Reservoir for the with-project conditions, as defined in the San Joaquin River Restoration Settlement (Settlement). The classification consists of six year types: wet, normal-wet, normal-dry, dry, critical high and critical low.
- Monthly means the average condition for a particular month, except storage, which is the end of the month.

CalSim II

CalSim II, an operations planning model for the CVP and SWP systems, is used in the Investigation to evaluate the operational strategies and changes resulting from each Investigation alternative. This chapter describes CalSim II and its application in reservoir operations studies for the Investigation.

Model Description

This section summarizes the modeling platform, development, and overall capabilities of CalSim II.

WRIMS

CalSim II is an application of the WRIMS. WRIMS is a generalized water resources modeling software platform developed by the DWR Bay-Delta Office. WRIMS is entirely data driven and can be applied to most reservoir-river basin systems. WRIMS represents the physical system (reservoirs, streams, canals, pumping stations) by a network of nodes and arcs. The model user describes the system connectivity and a set of system operation priorities (weights) and constraints using a modeling language known as Water Resources Simulation Language (WRESL). WRIMS subsequently translates this into an appropriate format and, using a mixed integer programming solver, determines an optimal flow routing and system operation decisions for each time step. The model is described by DWR (2000) and Draper et al. (2004).

CalSim II

CalSim II was jointly developed by Reclamation and DWR for performing planning studies related to CVP and SWP operations. The primary purpose of CalSim II is to evaluate the water supply reliability of the CVP and SWP at current or future levels of development (e.g., 2005, 2030), with and without various assumed future facilities, and with different modes of facility operations. Geographically, the model covers the drainage basin of the Delta, CVP and SWP deliveries to the Tulare Lake Basin, and SWP deliveries to the San Francisco Bay Area (Bay Area), Central Coast, and Southern California.

CalSim II typically simulates system operations for an 82-year period using a monthly time step. The model assumes that facilities, land-use, water supply contracts, and regulatory requirements are constant over this period, representing a fixed level of development. The historical flow record of October 1921 to September 2003, adjusted for the influence of land-use change and upstream flow regulation, is used to represent the possible range of hydrologic conditions. Results from a single simulation may not necessarily correspond to actual system operations for a specific month or year, but are representative of general water supply conditions. Model results are best interpreted using various statistical measures, such as long-term or year-type averages.

A general external review of the methodology, software, and applications of CalSim II was conducted in 2003 (Close et al. 2003) and an external review of the San Joaquin River Valley CalSim II model was conducted in 2006 (Ford et al. 2006). Several limitations of the CalSim II models were identified in these external reviews, as follows:

- Model uses a monthly time step

- Accuracy of the inflow hydrology is uncertain
- Model lacks a fully explicit groundwater representation

In addition, Reclamation, DWR, and external reviewers identified the need for a comprehensive error and uncertainty analysis for various aspects of the CalSim II model. DWR issued the CalSim II Model Sensitivity Analysis Study (DWR 2005), and Reclamation completed a similar sensitivity and uncertainty analysis for the San Joaquin River Basin (Reclamation and DWR 2006). This information is intended to improve understanding of model results.

Despite these limitations, monthly CalSim II model results remain useful for comparative purposes. It is important to differentiate between "absolute" or "predictive" modeling applications and "comparative" applications. The comparative mode consists of comparing two model runs: one containing modifications representing an action alternative, and one that does not. Differences in certain factors, such as deliveries or reservoir storage levels, are analyzed to determine the impacts of the action alternatives. In the absolute mode, results of a single model run, such as the amount of delivery or reservoir levels, are considered directly. Model assumptions are generally believed to be more reliable in a comparative study than an absolute study. All of the assumptions are the same for baseline and alternative model runs, except the action itself, and the focus of the analysis is the differences in the results. For the purposes of the Shasta Lake Water Resources Investigation (SLWRI), the CalSim II modeling output is used in the comparative mode rather than the absolute mode.

Model Assumptions

This analysis started with the Existing and Future condition SLWRI 2012 Benchmark Version of the CalSim II models. These versions were selected for consistency with the SLWRI and other Reclamation planning efforts, and because they included the most recent set of updates to the CalSim II model.

The model was changed from a two-step model into a one-step model. In a two-step model, CalSim II models the first step, CONV (conveyance), for 12 months, then models the next step, TXFR (transfer), for the same 12 months using initial conditions from the CONV step. The CONV step implements all CVP and SWP operations and regulatory requirements (except transfers), including operation of any new or enlarged reservoir storage. The TXFR step then adds transfer operations (including Cross Valley Canal wheeling and Joint Point of Diversion) into the model simulation, creating the final model results. The single-step model uses approximations of expected results if a separate CONV step had been simulated, to perform the entire simulation in a single step. This was done to maintain consistency with anticipated CalSim II simulations with Temperance Flat RM 274 Reservoir fully integrated with CVP/SWP system operations. Full system integration requires that CalSim II operates in single step mode. Two step and single step simulation provide slightly different results, and use of both methods would have complicated alternative plan comparisons, impact analysis, and benefit computations.

Table 3-1 summarizes the CalSim II assumptions for the Existing and No Action alternatives including assumed levels of development, demands, facilities, regulatory standards, operations, and water management actions.

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions

Assumption	Existing Condition[1]	Future Condition[1]
Planning Horizon	2005	2020
Period of Simulation	82 years (1922–2003)	Same
HYDROLOGY		
Level of Development (land-use)	2005 Level[2]	2030 Level[3]
DEMANDS		
North of Delta (excluding the American River)		
CVP	Land-use based, limited by contract amounts[4]	Land-use based, full build-out of contract amounts
SWP (FRSA)	Land-use based, limited by contract amounts[5]	Same
Nonproject	Land-use based, limited by water rights and State Water Board Decisions for Existing Facilities	Same
Antioch Water Works	Pre-1914 water right	Same
Federal refuges	Recent historical Level 2 water needs[6]	Firm Level 2 water needs[6]
American River Basin		
Water rights	Year 2005[7]	Year 2025, full water rights[7]
CVP	Year 2005[7]	Year 2025, full contracts, including FRWP[7]
San Joaquin River Basin[8]		
Friant Unit	Limited by contract amounts, based on current allocation policy	Same
Lower basin	Land-use based, based on district level operations and constraints	Same
Stanislaus River Basin[9, 10]	Land-use based, based on New Melones Interim Operations Plan, up to full SEWD deliveries (155 TAF/year) depending on New Melones Index	Same
In-Delta		
CCWD	195 TAF/year CVP contract supply and water rights[11]	Same[11]
South of Delta		
CVP	Demand based on contract amounts[4]	Same
Federal refuges	Recent historical Level 2 water needs[6]	Firm Level 2 water needs[6]
SWP [5, 12]	Variable demand, of 3.0-4.1 MAF/year, up to Table A amounts including all Table A transfers through 2008	Demand based on full Table A amounts
Article 56	Based on 2001–2008 contractor requests	Same
Article 21	MWD demand up to 200 TAF/month from December to March subject to conveyance capacity, KCWA demand up to 180 TAF/month and other contractor demands up to 34 TAF/month in all months, subject to conveyance capacity.	Same
North Bay Aqueduct	71 TAF/year demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville, and Benicia Settlement Agreement	Same

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions (contd.)

Assumption	Existing Condition[1]	Future Condition[1]
FACILITIES		
Systemwide	Existing facilities	Same
Sacramento Valley		
Shasta Lake	Existing, 4,552 TAF capacity	Same
Red Bluff Diversion Dam	Diversion dam operated with gates out all year, NMFS BO (June 2009) Action I.3.1[10]; assume permanent facilities in place	Same
Colusa Basin	Existing conveyance and storage facilities	Same
Upper American River	PCWA American River pump station	Same
Lower Sacramento River	None	FRWP
In-Delta		
Los Vaqueros Reservoir	Enlarged storage capacity, 160 TAF, existing pump location. Alternate Intake Project included[15]	Same
Delta Export Conveyance		
SWP Banks Pumping Plant (South Delta)	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months up to 8,500 cfs during December 15–March 15, depending on Vernalis flow conditions[13]; additional capacity of 500 cfs (up to 7,180 cfs) allowed for reducing impact of NMFS BO (June 2009) Action IV.2.1[10] on SWP[14]	Same
CVP C.W. “Bill” Jones Pumping Plant (formerly Tracy PP)	Permit capacity is 4,600 cfs in all months (allowed for by the DMC–California Aqueduct Intertie)	Same
Upper DMC	Existing (exports limited to 4,200 cfs plus diversion upstream from DMC constriction) plus 400 cfs Delta-Mendota Canal-California Aqueduct Intertie	Same
San Joaquin River		
Millerton Lake (Friant Dam)	Existing, 520 TAF capacity	Same
Lower San Joaquin River	None	City of Stockton Delta Water Supply Project, 30 mgd capacity
South of Delta (CVP/SWP project facilities)		
South Bay Aqueduct	Existing capacity	SBA rehabilitation, 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 point
California Aqueduct East Branch	Existing capacity	Same

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions (contd.)

Assumptions	Existing Condition[1]	Future Condition[1]
REGULATORY STANDARDS		
Trinity River		
Minimum Flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/year)	Same
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same
Clear Creek		
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 Reclamation proposal to USFWS and NPS, and USFWS predetermined CVPIA 3406(b)(2) flows[16], and NMFS BO (June 2009) Action I.1.1[10]	Same
Upper Sacramento River		
Shasta Lake end-of-September minimum storage	NMFS 2004 Winter-run BO (1900 TAF in non-critical dry years), and NMFS BO (June 2009) Action I.2.1[10]	Same
Minimum flow below Keswick Dam	State Water Board WR 90-5, predetermined CVPIA 3406(b)(2) flows, and NMFS BO (June 2009) Action I.2.2[10]	Same
Feather River		
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700/800 cfs).	Same
Minimum flow below Thermalito Afterbay outlet	1983 DWR and CDFW agreement (750 –1,700 cfs)	Same
Yuba River		
Minimum flow below Daguerre Point Dam	State Water Board D-1644 Operations (Lower Yuba River Accord)[17]	Same
American River		
Minimum flow below Nimbus Dam	American River Flow Management as required by NMFS BO (Jun 2009) Action II.1[10]	Same
Minimum flow at H Street Bridge	State Water Board D-893	Same
Lower Sacramento River		
Minimum flow near Rio Vista	State Water Board D-1641	Same
Mokelumne River		
Minimum flow below Camanche Dam	FERC 2916-029[18], 1996 (Joint Settlement Agreement) (100–325 cfs)	Same
Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25–300 cfs)	Same
Stanislaus River		
Minimum flow below Goodwin Dam	1987 Reclamation, CDFW agreement, and flows required for NMFS BO (June 2009) Action III.1.2 and III.1.3[10]	Same
Minimum dissolved oxygen	State Water Board D-1422	Same

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions (contd.)

Assumptions	Existing Condition[1]	Future Condition[1]
Merced River		
Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180–220 cfs, November–March), and Cowell Agreement	Same
Minimum flow at Shaffer Bridge	FERC 2179 (25–100 cfs)	Same
Tuolumne River		
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94–301 TAF/year)	Same
San Joaquin River		
San Joaquin River below Friant Dam/Mendota Pool	Interim San Joaquin River Restoration flows	Full San Joaquin River Restoration flows
Maximum salinity near Vernalis	State Water Board D-1641	Same
Minimum flow near Vernalis	State Water Board D-1641 and single-step VAMP with water from Merced Irrigation District.[19] NMFS BO (June 2009) Action IV.2.1 Phase II flows not provided due to lack of agreement for purchasing water.	State Water Board D-1641 and VAMP San Joaquin River Agreement.[19] NMFS BO (June 2009) Action IV.2.1 Phase II flows not provided due to lack of agreement for purchasing water.
Sacramento-San Joaquin Delta		
Delta Outflow Index (flow and salinity)	State Water Board D-1641 and USFWS BO (December 2008) Action 4[10]	Same
Delta Cross Channel gate operation	State Water Board D-1641 with additional days closed from October 1–January 31 based on NMFS BO (June 2009) Action IV.1.2[10] (closed during flushing flows from October 1–December 14 unless adverse water quality conditions)	Same
South Delta exports (Jones PP and Banks PP)	State Water Board D-1641 export limits, not including VAMP period export cap under the San Joaquin River Agreement; Vernalis flow-based export limits in April–May as required by NMFS BO (June 2009) Action IV.2.1 Phase II[10] (additional 500 cfs allowed for July–September for reducing impact on SWP)[14]	Same
Combined Flow in Old and Middle River (OMR)	USFWS BO (December 2008) Actions 1, 2, and 3 and NMFS BO (June 2009) Action IV.2.3[10]	Same
OPERATIONS CRITERIA: River-Specific		
Upper Sacramento River		
Flow objective for navigation (Wilkins Slough)	NMFS BO (June 2009) Action I.4[10]; 3,500 – 5,000 cfs based on CVP water supply condition	Same
American River		
Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)	Same
Feather River		
Flow at mouth of Feather River (above Verona)	Maintain CDFW/DWR flow target of 2,800 cfs for April–September dependent on Oroville inflow and FRSA allocation	Same

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions (contd.)

Assumptions	Existing Condition[1]	Future Condition[1]
Stanislaus River		
Flow below Goodwin Dam	Revised Operations Plan and NMFS BO (June 2009) Action III.1.2 and III.1.3[10]	Same
San Joaquin River		
Salinity at Vernalis	Grassland Bypass Project (partial implementation)	Grassland Bypass Project (full implementation)
OPERATIONS CRITERIA: Systemwide		
CVP Water Allocation		
CVP settlement and exchange	100% (75% in Shasta critical years)	Same
CVP refuges	100% (75% in Shasta critical years)	Same
CVP agriculture	100%–0% based on supply. South-of-Delta allocations are additionally limited due to State Water Board D-1641, USFWS BO (December 2008), and NMFS BO (June 2009)[10]	Same
CVP municipal & industrial	100%–50% based on supply. South-of-Delta allocations are additionally limited due to State Water Board D-1641, USFWS BO (December 2008), and NMFS BO (June 2009)[10]	Same
SWP Water Allocation		
North of Delta (FRSA)	Contract specific	Same
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement; allocations are limited due to State Water Board D-1641, USFWS BO (December 2008), and NMFS BO (June 2009)[10]	Same
CVP/SWP Coordinated Operations		
Sharing of responsibility for in-basin use	1986 Coordinated Operations Agreement (FRWP, EBMUD, and 2/3 of the North Bay Aqueduct diversions are considered as Delta export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin use)	Same
Sharing of surplus flows	1986 Coordinated Operations Agreement	Same
Sharing of restricted export capacity for project-specific priority pumping	Equal sharing of export capacity under State Water Board D-1641, USFWS BO (December 2008), and NMFS BO (June 2009) export restrictions[10]	Same
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks PP over non-SWP users; LYRA included for SWP contractors[14]	
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/year), CALFED ROD defined Joint Point of Diversion (JPOD)	Same
San Luis Reservoir	San Luis Reservoir is allowed to operate to a minimum storage of 100 TAF	Same

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions (contd.)

Assumptions	Existing Condition[1]	Future Condition[1]
CVPIA 3406(b)(2)		
Policy decision	May 2003 Department of Interior decision	Same
Allocation	800 TAF/year, 700 TAF/year in 40-30-30 dry years, and 600 TAF/year in 40-30-30 critical years	Same
Actions	Pre-determined non-discretionary USFWS BO (December 2008) upstream fish flow objectives (October-January) for Clear Creek and Keswick Dam, non-discretionary NMFS BO (June 2009) actions for the American and Stanislaus Rivers, and USFWS BO (December 2008) and NMFS BO (June 2009) actions leading to export restrictions[10]	Same
Accounting adjustments	No discretion assumed under USFWS BO (December 2008) and NMFS BO (June 2009)[10], no accounting	Same
WATER MANAGEMENT ACTIONS:		
Water Transfer Supplies (long term programs)		
LYRA[14]	Yuba River acquisitions for reducing impact of NMFS BO export restrictions[10] on SWP	Same
Phase 8	None	None
Water Transfers (short term or temporary programs)		
Sacramento Valley acquisitions conveyed through Banks PP	Post-analysis of available capacity[20]	Same

Notes:

[1] These assumptions were initially developed under the direction of the DWR and Reclamation management team for the BDCP HCP and EIR/EIS. Additional modifications were made by Reclamation for SLWRI baselines and other 2012 Reclamation study baselines.

[2] The Sacramento Valley hydrology used in the Future Condition CalSim II model reflects 2020 land-use assumptions associated with Bulletin 160-98 (DWR 1998). The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation to support Reclamation studies (Reclamation 2008a).

[3] CVP contract amounts have been reviewed and updated according to existing and amended contracts, as appropriate.

[4] SWP contract amounts have been updated as appropriate, based on recent Table A transfers/agreements.

[5] Water needs for Federal refuges have been reviewed and updated, as appropriate. Refuge Level 4 (and incremental Level 4) water is not included; only firm Level 2 water deliveries were included. Annual acquisitions of Incremental Level 4 (IL4) water vary from year to year, depending on annual hydrology, water availability, water market pricing, and funding. Therefore, it would be speculative to predict or assume quantities and locations of annual acquisitions from willing sellers. Without that information, it could not be incorporated into the CalSim II modeling assumptions or other analyses. It would not be possible to quantitatively assess effects of the action alternatives on deliveries of IL4 water.

[6] The Sacramento Area Water Forum agreement, its dry year diversion reductions, Middle Fork Project operations and “mitigation” water is not included.

[7] The new CalSim II representation of the San Joaquin River has been included in this model package (CalSim II San Joaquin River Model, Reclamation, 2005). The model reflects the difficulties of ongoing groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to groundwater overdraft problems. In addition, a dynamic groundwater simulation is not yet developed for the San Joaquin River Valley. Groundwater extraction/recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions.

Table 3-1. Investigation 2012 Benchmark Version CalSim II Assumptions (contd.)

Notes (contd.):

[8] The CalSim II model representation for the Stanislaus River does not necessarily represent Reclamation's current or future operational policies. A suitable plan for supporting flows has not been developed for NMFS BO (June 2009) Action III.1.3.

[9] In cooperation with NMFS, USFWS, and CDFW, the Reclamation and DWR have developed assumptions for implementation of the USFWS BO (December 15, 2008) and NMFS BO (June 4, 2009) in CalSim II.

[10] The actual amount diverted is reduced because of supplies from the Los Vaqueros project. Los Vaqueros storage capacity is 160 TAF for both the existing and future conditions. Associated water rights for Delta excess flows are included.

[11] Under existing conditions it is assumed that SWP Contractors demand for Table A allocations vary from 3.0 to 4.1 MAF/year. Under the Future No Action Alternative, it is assumed that SWP Contractors can take delivery of all Table A allocations and Article 21 supplies. Article 56 provisions are assumed and allow for SWP Contractors to manage storage and delivery conditions such that full Table A allocations can be delivered. Article 21 deliveries are limited in wet years under the assumption that demand is decreased in these conditions. Article 21 deliveries for the NBA are dependent on excess conditions only, all other Article 21 deliveries also require that San Luis Reservoir be at capacity and that Banks PP and the California Aqueduct have available capacity to divert from the Delta for direct delivery.

[12] Current USACE permit for Banks PP allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during December 15–March up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.

[13] Acquisitions of Component 1 water under the LYRA, and use of 500 cfs dedicated capacity at Banks PP during July–September, are assumed to be used to reduce as much of the impact of the April–May Delta export actions on SWP Contractors as possible.

[14] The CCWD Alternate Intake Project (also known as Middle River Intake Project), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir. Construction was completed in fall 2010.

[15] Delta actions, under USFWS discretionary use of CVPIA 3406(b)(2) allocations, are no longer dynamically operated and accounted for in the CalSim II model. The Combined OMR flow and Delta export restrictions under the USFWS BO (December 15, 2008) and the NMFS BO (June 4, 2009) severely limit any discretion that would have been otherwise assumed in selecting Delta actions under the CVPIA 3406(b)(2) accounting criteria. Therefore, it is anticipated that CVPIA 3406(b)(2) account availability for upstream river flows below Whiskeytown, Keswick, and Nimbus dams would be very limited. It appears the integration of BO RPA actions will likely exceed the 3406(b)(2) allocation in all water year types. For these baseline simulations, upstream flows on the Clear Creek and Sacramento River are predetermined, based on CVPIA 3406(b)(2) based operations from the August 2008 BA Study 7.0 and Study 8.0 for Existing and Future No-Action baselines, respectively. The procedures for dynamic operation and accounting of CVPIA 3406(b)(2) are not included in the CalSim II model.

[16] State Water Board D-1644 and the LYRA are assumed to be implemented for Existing and Future No-Action baselines. The Yuba River is not dynamically modeled in CalSim II. Yuba River hydrology and availability of water acquisitions under the LYRA are based on modeling performed and provided by the LYRA EIS/EIR study team.

[17] It is assumed that VAMP, a functional equivalent, or State Water Board D-1641 requirements would be in place in 2020. CVP and SWP VAMP export restrictions during the April 15 to May 15 pulse period were not included in CalSim II modeling.

[19] Only acquisitions of LYRA Component 1 water are included.

Key:

Ag = agricultural
BA = Biological Assessment
BDCP = Bay-Delta Conservation Plan
BO = Biological Opinion
CALFED = CALFED Bay-Delta Plan
CCWD = Contra Costa Water District
CDFW = California Department of Fish and Wildlife
cfs = cubic feet per second
CVP = Central Valley Project
CVPIA = Central Valley Project Improvement Act
Delta = Sacramento-San Joaquin Delta
DMC = Delta-Mendota canal
DWR = California Department of Water Resources
EBMUD = East Bay Municipal Utility District
EIR = Environmental Impact Report
EIS = Environmental Impact Statement
FC&WSD = Flood Control and Water Service District
FERC = Federal Energy Regulatory Commission
FRSA = Feather River Service Area
FRWP = Freeport Regional Water Project
HCP = Habitat Conservation Plan
JPOD = joint point of Diversion
KCWA = Kern County Water Agency
LYRA = Lower Yuba River Accord
M&I = municipal and industrial
MAF = million acre-feet
mgd = million gallons per day
MWD = Metropolitan Water District
NBA = North Bay Aqueduct
NMFS = National Marine Fisheries Service
NPS = National Park Service
OMR = Old and Middle River
PCWA = Placer County Water Agency
PP = Pumping Plant
Reclamation = U.S. Department of the Interior, Bureau of Reclamation
ROD = Record of Decision
RPA = Reasonable and Prudent Alternative
SBA = South Bay Aqueduct
SEWD = Stockton East Water District
SLWRI = Shasta Lake Water Resources Investigation
SWP = State Water Project
State Water Board = State Water Resources Control Board
TAF = thousand acre-feet
USACE = U.S. Army Corps of Engineers
USFWS = U.S. Fish and Wildlife Service
VAMP = Vernalis Adaptive Management Plan
WR = water right

Highlights of operational rules in the CalSim II studies for the Investigation include the following:

- Regulatory conditions include Reclamation’s 2008 *Biological Assessment on the Continued Long-Term Operations of the CVP and SWP* (Reclamation 2008b), the 2008 U.S. Fish and Wildlife Services (USFWS) Biological Opinion (BO) and the 2009 National Marine Fisheries Services (NMFS) BO and associated reasonable and prudent alternatives.

- In action alternatives, Temperance Flat RM 274 Reservoir is modeled upstream from Millerton Lake at RM 274, with a maximum storage capacity of 1,331 TAF. The active storage, or the volume available for use, varies by alternative. Millerton storage is reduced by 75 TAF to account for the physical overlap with Temperance Flat RM 274 Reservoir.

- Flood control space can be reserved in either Millerton Lake or Temperance Flat RM 274 Reservoir or both, as long as the total available flood control space is greater than or equal to the required Millerton Lake flood control space under the current flood control rule curve. The flood control rule curve takes upstream storage at Mammoth Pool reservoir into consideration.

- Implementation of SJRRP Restoration Flows is assumed in all simulations for all alternatives. The existing conditions simulations include the Capacity Constrained flow, and the future conditions include the full Exhibit B flows. These flows are fully met before any delivery is made to existing and potential future beneficiaries.

- The CalSim II Friant allocation algorithm was modified to include the new storage available at Temperance Flat RM 274 Reservoir and to allocate the new delivery to one of the three potential beneficiaries, as desired in each action alternative. For Action Alternatives 1 through 4, the allocation algorithm was not modified to change the relative priority of maximizing delivery in the current year over storing water for subsequent, potentially drier years. In Action Alternative 5, the allocation algorithm was modified to attempt to maintain delivery levels in the wetter years while reserving water in storage for subsequent, potentially drier years. Each scenario required multiple CalSim simulations to maintain the Existing and No Action Friant deliveries from the baseline studies and to split the new delivery between the potential beneficiaries.

- New delivery to CVP SOD or SWP M&I beneficiaries was routed down the San Joaquin River and exchanged at Mendota Pool or, for the SWP M&I beneficiary, routed down the Friant Kern Canal and through available cross valley conveyance capacity. Performing this routing in CalSim would have been difficult without impacting other project operations because of complex interactions at Mendota Pool, in the Delta-Mendota Canal, in San Luis Reservoir, and Delta exports. To avoid these implementation issues in the CalSim II modeling, all new supply deliveries were routed through a new diversion at Friant out of the system. A separate Routing Model was developed to post-process the CalSim results and route the water to the desired delivery locations for each beneficiary. The routing model is described later in this chapter of the Modeling Appendix.

- The CalSim II modeling shows some infrequent, minor changes to CVP/SWP water operations north of the Delta. These changes are a result of the model response to the reductions in San Joaquin River inflow to the Delta and the implementation of the complex web of Delta inflows, exports, regulations, hydrodynamic and salinity interaction rules and their interactions with the Coordinating Operating Agreement on how water supply and regulatory responsibility are shared by the CVP/SWP North of the Delta in the model.

Routing Model

Action alternatives were formulated such that the delivery of new supplies from Temperance Flat RM 274 Reservoir would not have an impact on SWP or CVP Delta exports, San Luis Reservoir operation, or conveyance operations. Implementation of the routing of new supplies directly into CalSim II would have been difficult because of the interconnected representation of these features in the CalSim II model and the variety of potential delivery locations for new water supplies.

In the CalSim II model, additional delivery to the Friant Division was routed through the Friant-Kern and Madera canals using the existing logic, and additional delivery to all other potential users was imposed as a diversion out of the system from Millerton Lake to maintain a reservoir storage water balance (the rules for each action alternative that constrain the carryover storage in Millerton Lake and Temperance Flat RM 274 Reservoir).

A new, post-processing routing tool was developed using Microsoft Excel to read the new water supply and the existing flows along the selected path to each customer from the "raw" CalSim II output, and modify the CalSim II-simulated flows to include the new water supply delivery to the appropriate customer. All physical and operational limits from the CalSim model were checked during the routing process to assure that the final routing was feasible. Because the tool is a post-processor, it has no impact on any internal CalSim computation or solution techniques. The tool was reviewed to ensure that the routing and mass balance at each node were correct, and included outputs to verify the results of each application.

This routing tool was used to read in the CalSim II-simulated operations from the "raw" CalSim II output, modify flows as required to deliver the water to the appropriate point(s) of use, and then write the modified operations data into a copy of the "raw" CalSim II output to produce a "routed" version of the output data files for each CalSim II simulation. The resulting "routed" output has the same internal structure as any other CalSim II output file and can be used with other preexisting tools with only minor, project-specific modifications. This process allowed enhanced routing flexibility over modifying the CalSim II model directly, and produced a "routed" output that was compatible with existing output post-processing tools.

Daily Model

A transparent, consistent, repeatable process to estimate a reasonable set of daily water operations that maintain the overall monthly operational constraints from CalSim II was required to perform more detailed analysis of certain conditions and resource areas, such as local hydropower production and water temperature. The Investigation developed an Excel-based spreadsheet to disaggregate monthly CalSim II water operations into a daily set of water operations for use in further analyses. The initial development of this tool is fully described in the Reservoir Operations Technical Appendix to the Plan Formulation Report (Reclamation and DWR 2008). This tool was modified to include balancing between Temperance Flat RM 274 Reservoir and Millerton Lake to maximize power generation opportunity.

The tool generates a daily set of water operations using a two-step process:

1. Monthly-to-daily interpolation to convert CalSim II-generated monthly time step boundary conditions (CalSim reservoir diversions and non-rain-flood releases to the San Joaquin River) to a daily time step.
2. Simplified daily rain-flood operation to generate daily operational data for Temperance Flat RM 274 Reservoir and Millerton Lake to be used in further analysis.

Monthly to Daily Interpolation Process

The daily model requires boundary or input data on a daily basis. These data include the following:

- San Joaquin River inflow to Millerton Lake
- Mammoth Pool storage
- Friant-Kern Canal diversion
- Madera Canal diversion
- Snowmelt (flood control) release
- SJRRP minimum flow release
- Millerton Lake and Temperance Flat evaporation

San Joaquin River Inflow to Millerton Lake

The daily model used Millerton Lake inflows from the Upper San Joaquin Basin (USAN). USAN is an operations model of the upper San Joaquin River Basin typically used to predict inflows to Millerton Lake. These daily inflows were summed and used to generate monthly inflows for use in CalSim II. Since daily inflows are available, no interpolation from monthly to daily values is required.

Mammoth Pool Storage

Flood control operations at Millerton Lake can take credit for up to 85 TAF of available upstream storage capacity in the Mammoth Pool reservoir. Daily Mammoth Pool storage is obtained from USAN and input into the spreadsheet tool as a data time series to allow the spreadsheet tool to compute the available credit space at Mammoth Pool in the original version of the tool. Because this project has no effect on Mammoth Pool storage, the final computed flood control space from the original tool was used directly to avoid the overhead of repeatedly re-computing the same values.

The remaining daily boundary condition values were computed from monthly CalSim II output values using a modified linear interpolation process. The interpolation process attempts to maintain a long-term mass balance by adjusting the process for interpolation between months with different numbers of days. This process is documented in further detail in the SJRRP Programmatic Environmental Impact Statement/Report (PEIS/R) Modeling Appendix (SJRRP 21012).

Friant-Kern Canal Diversion

The Friant-Kern Canal diversion was converted using a monthly to daily interpolation as discussed above.

Madera Canal Diversion

The Madera Canal diversion in CalSim II includes both the actual diversion for delivery, and diversion of flood control releases to protect the San Joaquin River. The interpolation process is only performed on the Madera Canal diversion for delivery. All flood control releases are recomputed in the simplified daily rain-flood operations and assumed to be made to the San Joaquin River.

Snowmelt Release

The snowmelt release in CalSim II is determined by predicting the expected inflows to Millerton Lake from February 1 to June 30, subtracting the expected diversions for the same period, and releasing the difference over the period in an attempt to minimize spills from the reservoir. These CalSim II monthly values were disaggregated using the modified interpolation process.

San Joaquin River Restoration Program Minimum Flow Release

San Joaquin River Restoration minimum flow requirements are specified as mean monthly values for use by CalSim II. The actual SJRRP flow requirements are volumes in certain time periods, with considerable flexibility on daily flows to allow real-time adaptive management to meet changing operations and biological needs. This means that a single SJRRP flow schedule cannot be developed to be applicable under all conditions. Because of this uncertainty, and because the simulations were used in comparison mode in this analysis, use of a modified interpolation procedure was deemed appropriate for the Investigation.

Millerton Lake and Temperance Flat RM 274 Reservoir Evaporation

Millerton Lake and Temperance Flat RM 274 Reservoir evaporation is computed in CalSim II based on an assumed evaporation rate and mean monthly surface area. These CalSim II monthly values are disaggregated using the modified interpolation procedure.

Simplified Daily Rain-Flood Operation

The operation simulation was rewritten to implement an efficient process to balance reservoir storage between Temperance Flat RM 274 Reservoir and Millerton Lake to achieve the desired operation goals for each alternative. The new balancing procedure is based on a user-specified curve that defines the desired storage levels in Millerton Lake for any total combined storage. The original operation simulation routed flood flows into both the San Joaquin River and the Friant-Kern and Madera canals under specific circumstances; because of the anticipated reduction in flood release requirements expected with the additional storage available in Temperance Flat RM 274 Reservoir, all flood releases are made to the San Joaquin River under the revised operation.

Daily operations are simulated as follows:

- Obtain desired end-of-day (EOD) Millerton Lake storage from the reservoir balance curve based on the combined start of day storage.

- Compute initial estimate of Millerton Lake EOD storage from start-of-day storage, and the daily boundary values from the interpolation process, assuming no inflow from Temperance Flat RM 274 Reservoir.

- Compute required Temperance Flat RM 274 Reservoir release to change initial Millerton Lake EOD storage to desired EOD storage.

- Compute Temperance Flat RM 274 Reservoir daily operations with desired release. The release was modified in some instances due to storage and/or physical facility limits; for example, if the desired release is zero and Temperance Flat RM 274 Reservoir is full, a flood release may be required from Temperance Flat RM 274 Reservoir even though that would leave Millerton Lake at a higher-than-desired storage.

- Compute final Millerton Lake operations with the actual release from Temperance Flat RM 274 Reservoir. This may change the initial Millerton Lake operations to meet storage and/or physical facility limits. The flood control operation assumes that the maximum non-flood release to the San Joaquin River is 8,000 cubic feet per second (cfs).

The process yields a daily system operation that meets all operational requirements within physical and regulatory limits, while maintaining the desired operational characteristics of each alternative.

Model Output

The primary output from the daily model is daily Millerton Lake and Temperance Flat RM 274 Reservoir storages, Temperance Flat RM 274 Reservoir release, Friant-Kern and Madera canals diversions, and San Joaquin River release values for use in other models and analysis. Output ranges from October 1, 1921 to September 30, 2003, the same period included in the CalSim II model.

Operations Modeling Results Summary and Discussion

This section presents selected water supply, storage, releases to the San Joaquin River, peak flow analysis, and X2 results, from the routing model previously described in this chapter. Detailed operations modeling output tables are included in the CalSim II Modeling Attachment.

Water Supply Results

Water supply results of the Investigation operations modeling for alternative plans are presented as the change in deliveries by water year type in Table 3-2 for existing conditions and Table 3-3 for future conditions.

Table 3-2. Long-Term Average Annual Change in Deliveries for Temperance Flat RM 274 Reservoir Alternative Plans Under Existing Conditions (in TAF)

Alternative Plan	WY Type San Joaquin Index [1]	Change in System-wide Delivery[2,3]	Total Friant Ag[2,3]	Class 1[2,3]	Class 2[2,3]	Section 215[2,3]	Total SWP SOD[2,3]	SWP Ag SOD[2,3]	SWP M&I SOD[2,3]	Total CVP SOD[2,3]	CVP Ag SOD[2,3]	CVP M&I SOD[2,3]
1	Wet	171	123	(1)	292	(168)	66	(2)	69	(19)	(18)	(1)
	Above Normal	191	104	2	205	(103)	91	1	90	(4)	(4)	(0)
	Below Normal	(31)	(41)	(2)	2	(42)	22	(8)	30	(11)	(12)	(0)
	Dry and Critical	44	22	4	38	(20)	28	4	24	(6)	(5)	(1)
	All Years[4]	**99**	**59**	**1**	**141**	**(83)**	**51**	**(0)**	**51**	**(10)**	**(10)**	**(1)**
2	Wet	170	111	(2)	282	(170)	40	(2)	42	20	17	(0)
	Above Normal	183	67	1	170	(104)	58	(0)	59	57	58	(0)
	Below Normal	(39)	(74)	(2)	(31)	(42)	8	(9)	18	27	26	(0)
	Dry and Critical	43	15	5	30	(20)	19	2	17	10	10	(1)
	All Years[4]	**96**	**40**	**1**	**123**	**(84)**	**31**	**(1)**	**33**	**25**	**24**	**(0)**
3	Wet	190	102	(2)	272	(169)	65	(1)	66	23	21	0
	Above Normal	197	56	(2)	162	(104)	80	3	77	61	61	(0)
	Below Normal	(28)	(43)	(2)	1	(42)	(13)	(7)	(6)	28	26	(0)
	Dry and Critical	44	22	6	36	(20)	15	6	9	7	8	(1)
	All Years[4]	**107**	**43**	**1**	**126**	**(84)**	**38**	**1**	**37**	**25**	**25**	**(0)**
4	Wet	176	124	(3)	274	(148)	36	(2)	38	16	16	(1)
	Above Normal	158	51	(0)	152	(101)	56	0	56	51	51	(0)
	Below Normal	(41)	(71)	(2)	(27)	(42)	6	(9)	15	24	22	(0)
	Dry and Critical	28	3	4	19	(20)	20	2	17	5	6	(1)
	All Years[4]	**87**	**37**	**0**	**114**	**(77)**	**30**	**(1)**	**31**	**20**	**20**	**(1)**
5	Wet	63	55	(1)	228	(172)	(22)	(8)	(14)	30	28	(0)
	Above Normal	133	50	1	153	(104)	0	(1)	1	82	82	(0)
	Below Normal	108	35	(16)	92	(42)	2	1	1	71	69	(0)
	Dry and Critical	138	94	22	93	(20)	(3)	(1)	(2)	46	46	(0)
	All Years[4]	**110**	**65**	**5**	**145**	**(85)**	**(7)**	**(3)**	**(5)**	**52**	**51**	**(0)**

Notes:

[1] The San Joaquin Year Type, or 60-20-20 Year Type, classification system is based on the historical and forecasted unimpaired inflows of the Stanislaus, Tuolumne, Merced, and San Joaquin rivers to the San Joaquin River Basin, as defined in State Water Board Decision D-1641. The classification consists of five year types: wet, above normal, below normal, dry, and critical.

[2] Changes in deliveries as simulated with CalSim II with existing level of development and 82 year hydrologic period of record from October 1921 to September 2003.

[3] Action Alternatives are compared to Existing Conditions.

[4] Average for all years is weighted average based on proportion of each year type out of 82-year period of record.

Key:

Ag = agricultural	CVP = Central Valley Project	RM = river mile	SWP = State Water Project
TAF = thousand acre-feet	M&I = municipal and industrial	SOD = south-of-Delta	WY = water year

Table 3-3. Long-Term Average Annual Change in Deliveries for Temperance Flat RM 274 Reservoir Alternative Plans Under Future Conditions (in TAF)

Alternative Plan	WY Type San Joaquin Index [1]	Change in System-wide Delivery[2,3]	Total Friant Ag[2,3]	Class 1[2,3]	Class 2[2,3]	Section 215[2,3]	Total SWP SOD[2,3]	SWP Ag SOD[2,3]	SWP M&I SOD[2,3]	Total CVP SOD[2,3]	CVP Ag SOD[2,3]	CVP M&I SOD[2,3]
1	Wet	112	102	(1)	239	(137)	33	(10)	44	(23)	(22)	(1)
	Above Normal	152	82	2	133	(53)	79	(3)	82	(9)	(9)	0
	Below Normal	1	(49)	(3)	(14)	(32)	53	7	46	(3)	(3)	0
	Dry and Critical	19	12	4	23	(15)	13	0	13	(5)	(5)	(1)
	All Years[4]	**70**	**43**	**1**	**103**	**(61)**	**38**	**(3)**	**40**	**(11)**	**(10)**	**0**
2	Wet	115	99	(1)	237	(137)	0	(10)	10	16	17	(1)
	Above Normal	145	65	1	117	(53)	43	(3)	46	36	37	0
	Below Normal	(4)	(65)	(3)	(30)	(32)	42	7	35	19	19	0
	Dry and Critical	24	8	6	18	(15)	15	1	13	1	1	(1)
	All Years[4]	**71**	**36**	**1**	**95**	**(61)**	**20**	**(2)**	**22**	**16**	**16**	**0**
3	Wet	116	86	(1)	224	(138)	22	(10)	33	9	10	0
	Above Normal	152	62	1	113	(53)	48	(3)	51	42	43	0
	Below Normal	7	(38)	(3)	(2)	(32)	21	6	15	23	23	0
	Dry and Critical	30	18	7	27	(15)	8	1	7	3	3	(1)
	All Years[4]	**76**	**38**	**2**	**98**	**(62)**	**22**	**(2)**	**25**	**15**	**16**	**0**
4	Wet	99	91	(1)	220	(128)	(2)	(10)	8	10	11	0
	Above Normal	122	39	2	90	(53)	40	(3)	43	42	42	0
	Below Normal	2	(62)	(3)	(27)	(32)	40	6	34	23	23	0
	Dry and Critical	21	6	6	15	(15)	14	1	12	2	3	0
	All Years[4]	**61**	**27**	**2**	**85**	**(59)**	**18**	**(2)**	**21**	**16**	**16**	**0**
5	Wet	(0)	20	(1)	158	(137)	(45)	(11)	(35)	26	27	(0)
	Above Normal	152	84	(1)	138	(53)	(8)	(3)	(4)	76	76	(0)
	Below Normal	89	(6)	(29)	55	(32)	18	7	11	78	78	0
	Dry and Critical	121	75	25	66	(15)	8	1	6	39	39	(1)
	All Years[4]	**87**	**48**	**4**	**106**	**(61)**	**(10)**	**(2)**	**(7)**	**48**	**48**	**(0)**

Notes:

[1] The San Joaquin Year Type, or 60-20-20 Year Type, classification system is based on the historical and forecasted unimpaired inflows of the Stanislaus, Tuolumne, Merced, and San Joaquin rivers to the San Joaquin River Basin, as defined in State Water Board Decision D-1641. The classification consists of five year types: wet, above normal, below normal, dry, and critical.

[2] Changes in deliveries as simulated with CalSim II with existing level of development and 82 year hydrologic period of record from October 1921 to September 2003.

[3] Action Alternatives are compared to Existing Conditions.

[4] Average for all years is weighted average based on proportion of each year type out of 82-year period of record.

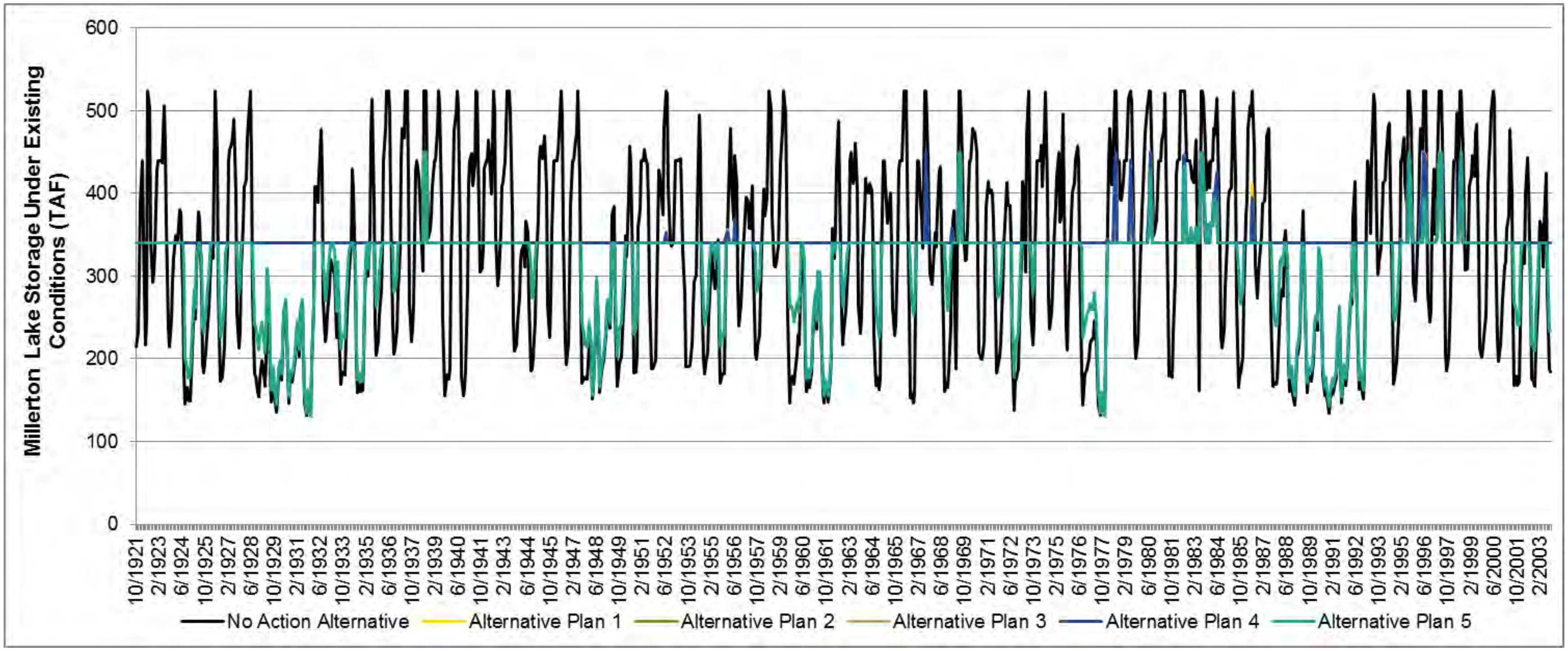
Key:

Ag = agricultural	CVP = Central Valley Project	RM = river mile	SWP = State Water Project
TAF = thousand acre-feet	M&I = municipal and industrial	SOD = south-of-Delta	WY = water year

There are some negative values for CVP SOD and SWP SOD deliveries in Table 3-2 and Table 3-3. Temperance Flat RM 274 is operated to capture, store, and deliver water that is currently released down the San Joaquin River over downstream requirements. These San Joaquin River flow reductions result in reduced San Joaquin River inflow to the Delta during the spring months. Delta operation requirement, notably the Old and Middle (OMR) standards and the San Joaquin Export/Inflow (E/I) ratio are both strongly influenced by changes in San Joaquin River inflow and can limit allowable exports. These export reductions occur in all action alternatives. The negative values represent the results of action alternatives that did not receive enough of the new supply to replace the export reduction.

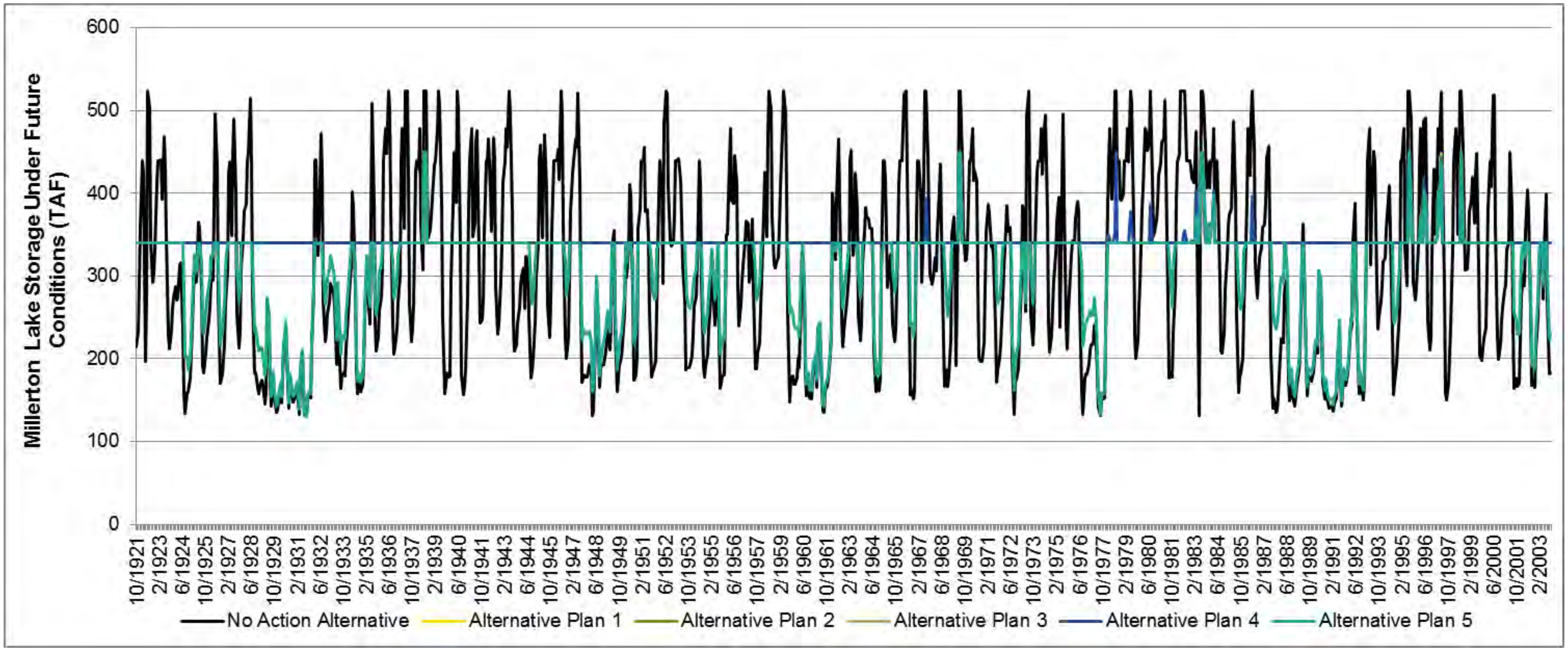
Storage Results

Figure 3-1 and Figure 3-2 show existing and future condition monthly storage in Millerton Lake and Figure 3-3 and Figure 3-4 show existing and future condition monthly storage in Temperance Flat RM 274 Reservoir. Action Alternatives 1 – 4 maintains Millerton Lake storage at 340 TAF, unless Temperance Flat Rm 274 Reservoir is full, in which case Millerton Lake storage is allowed to increase to the maximum to avoid spills and maximize yield. Alternative Plan 5 attempts to maintain Millerton Lake storage at 340 TAF, except if Temperance Flat RM 274 storage falls to 100 TAF; Millerton Lake will allow storage reductions to maintain releases and diversions, and allow storage increases above 340 TAF if Temperance Flat RM 274 is full. This allows for maximum potential project yield at the cost of reductions in Millerton Lake storage below 340 TAF.



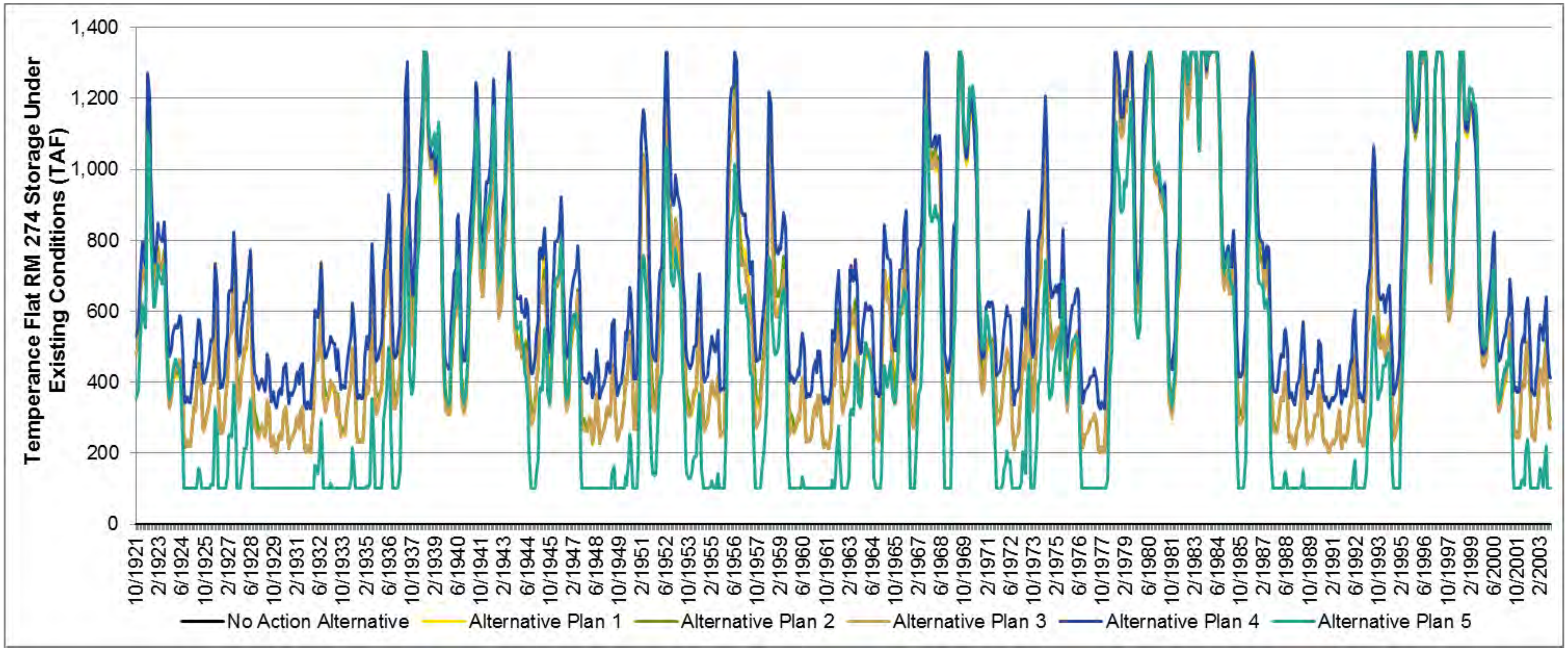
Key: TAF = thousand acre feet

Figure 3-1. October 1921—September 2003 Simulated Millerton Lake Storage Under Existing Conditions (TAF)



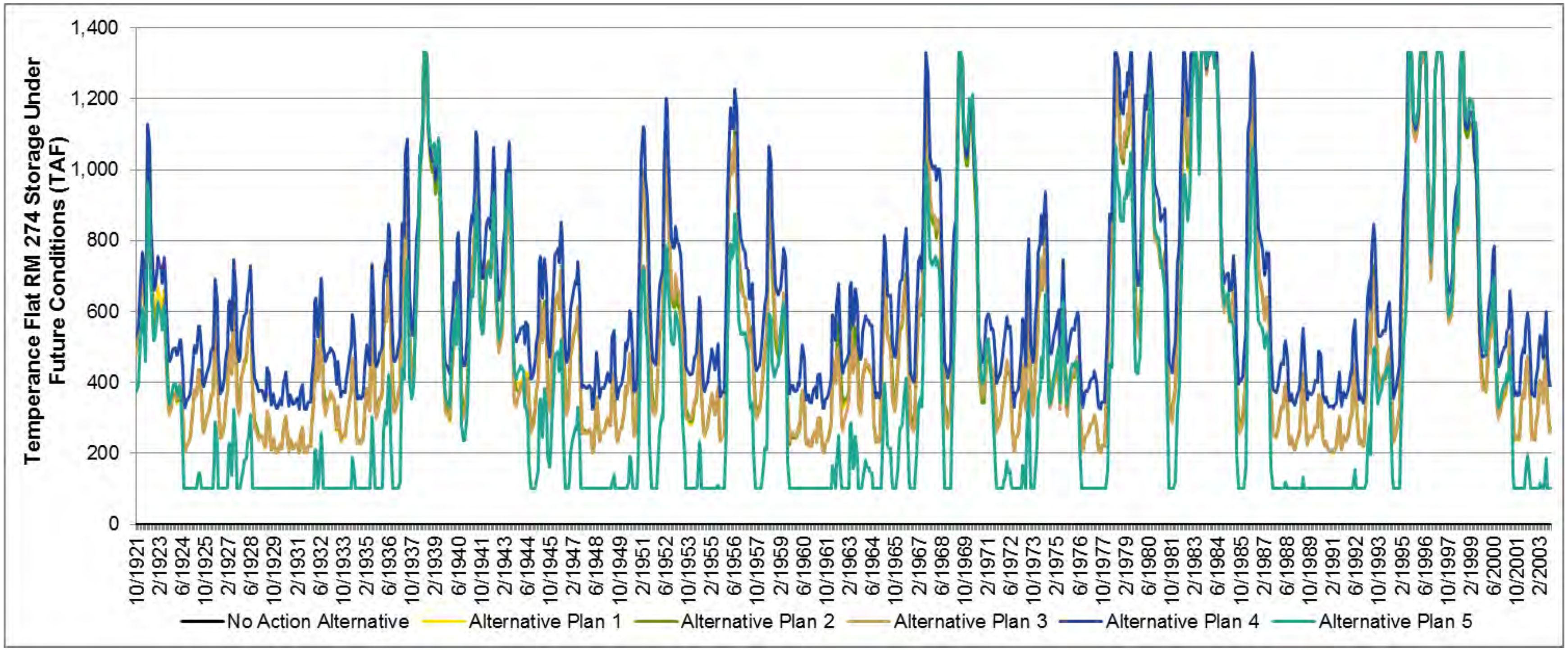
Key: TAF = thousand acre feet

Figure 3-2. October 1921—September 2003 Simulated Millerton Lake Storage Under Future Conditions (TAF)



Key: RM = river mile TAF = thousand acre feet

Figure 3-3. October 1921—September 2003 Simulated Temperance Flat RM 274 Reservoir Storage Under Existing Conditions (TAF)

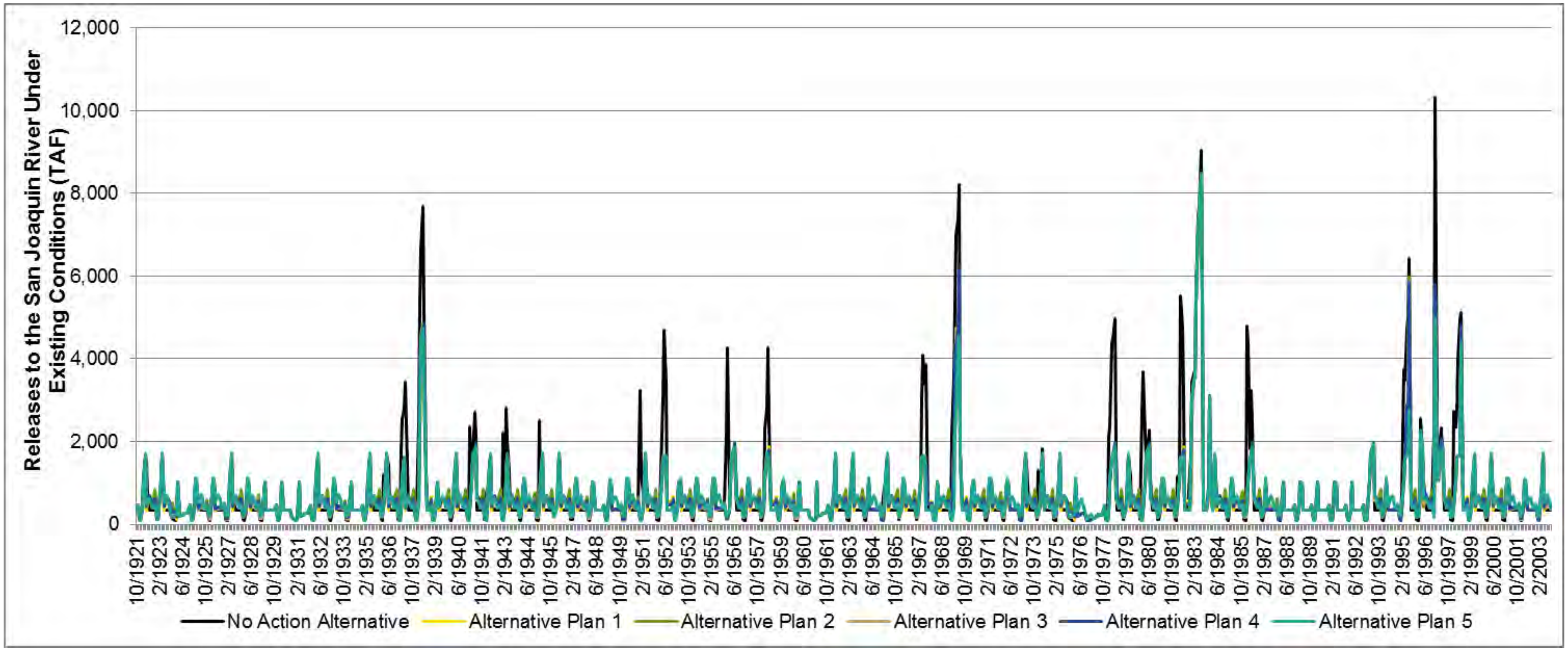


Key: RM = river mile TAF = thousand acre feet

Figure 3-4. October 1921—September 2003 Simulated Temperance Flat RM 274 Reservoir Storage Under Existing Conditions (TAF)

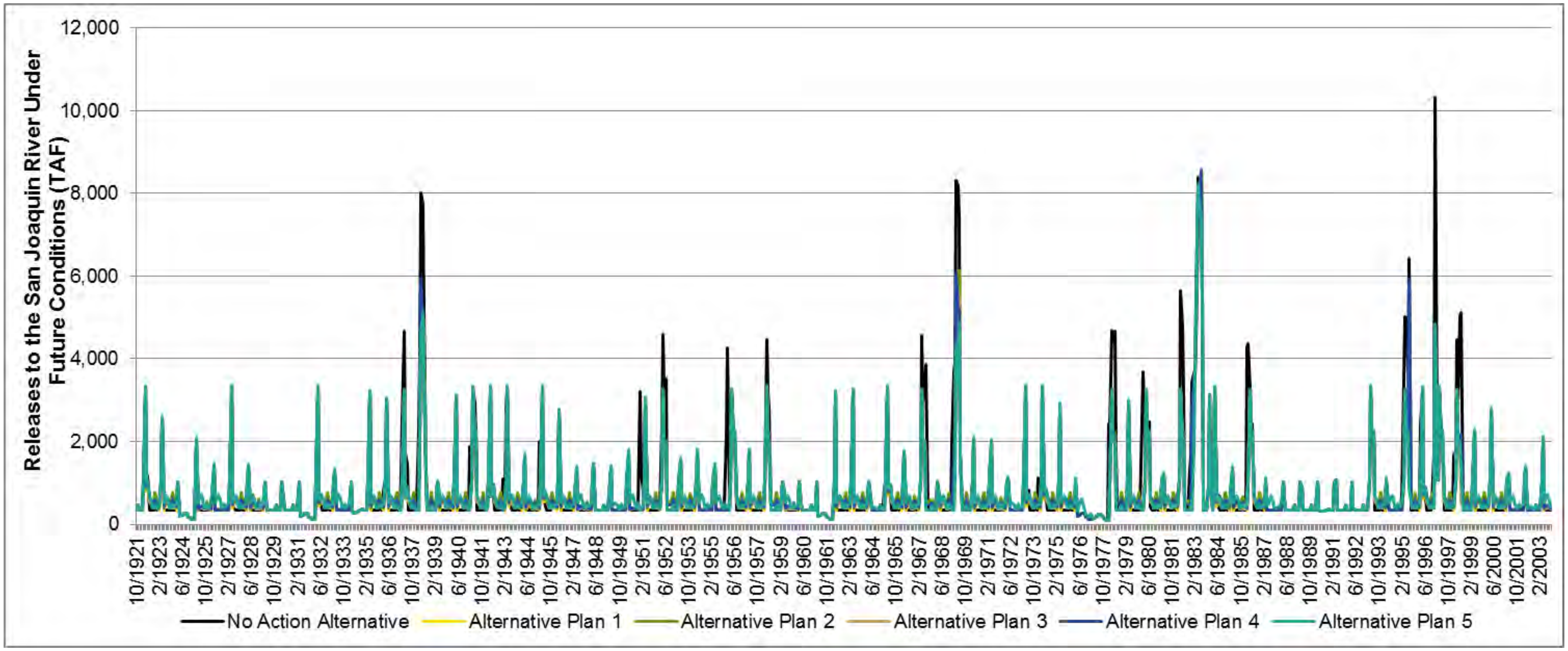
Releases to the River Results

Figure 3-5 and Figure 3-6 show the simulated releases from Friant Dam to the San Joaquin River for the existing and Future conditions of No Action Alternative and action alternatives. These releases include Restoration Flows, new water supply conveyed down the San Joaquin River under action alternatives, snowmelt releases, and flood releases. Capacity-constrained Restoration Flows are fully met by the alternative plans under existing conditions, and full Restoration flows are released from Friant Dam by all alternative plans under the future conditions. Figure 3-5 through Figure 3-7 show simulated monthly average releases to the San Joaquin River. More detailed tables of simulated monthly average release are included in the CalSim II Modeling Attachment.



Key: TAF = thousand acre feet

Figure 3-5. October 1921—September 2003 Simulated Releases from Friant Dam to the San Joaquin River Under Existing Conditions (TAF)



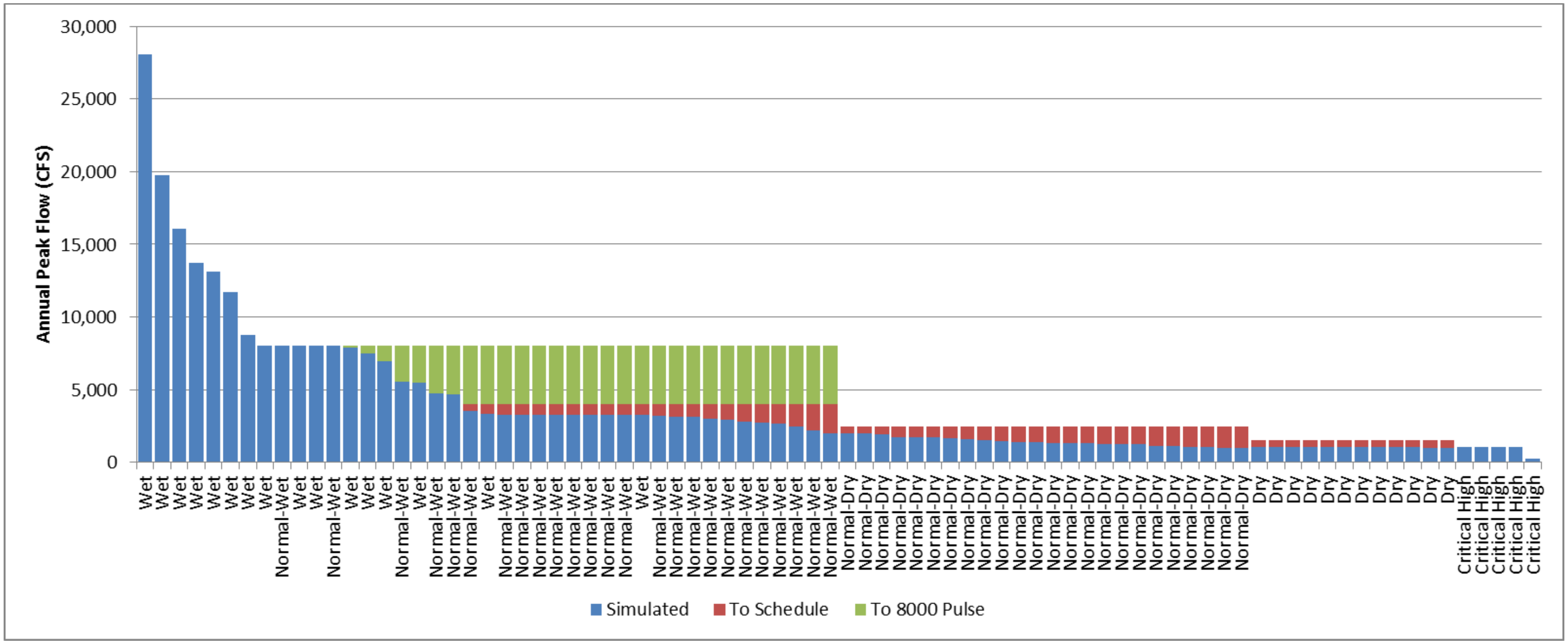
Key: TAF = thousand acre feet

Figure 3-6. October 1921—September 2003 Simulated Releases from Friant Dam to the San Joaquin River Under Future Conditions (TAF)

Annual San Joaquin River Flow Peaks

The SJRRP flows input to CalSim II are the mean monthly flow that is equivalent to the monthly volume specified by Exhibit B of the Settlement. These monthly flows are converted to daily flows using the modified interpolation process described in Chapter 3, Daily Model. The resulting daily flows, while they do include the volume required to meet the Exhibit B flow schedule, do not match it on a day-to-day basis, and do not include the partial month peak flow rates in Exhibit B. The Settlement also includes provisions for short-term pulse flows and considerable flexibility in real time adaptive flow management within the volume limits of the year, making the specific flow target for any specific day impossible to predict. This process described in Chapter 3, Daily Model gives a consistent, repeatable set of daily flows that include the volume of release over a time period that allows for the flexibility inherent in the Settlement and was assumed appropriate for use in this EIS for operational analysis. This assumption was also used in all simulation modeling performed in support of the SJRRP PEIS/R. However, because the simulated flow in any specific day may not represent the flow schedule in Exhibit B, simply taking the highest daily simulated flow in any year as the peak annual flow is not appropriate for an analysis of flood or “flushing” flows.

For this analysis, the peak annual flows were determined by selecting the largest single daily flow from the daily model simulation output. This was then compared to the single highest daily flow from Exhibit B for the appropriate year type. If the simulated value was less than the Exhibit B value the annual peak was set at the Exhibit B value. The Settlement also allows for an 8,000 cfs pulse for several hours in wet and normal-wet years. For these years, the annual peak flow was set to 8,000 cfs. This analysis was only performed for future conditions because the existing conditions limit SJRRP releases to channel capacity, and no additional pulse flows are anticipated. Figure 3-7 shows the results of this process for the No Action Alternative.



Key: cfs = cubic feet per second

Figure 3-7. Achievable San Joaquin River Peak Flow Releases at Friant Dam Under the No Action Alternative, Including Sustained and Peak Flood Pulse Flows Under the SJRRP Restoration Flow Schedule

X2

One of the principle features of the 1995 Bay-Delta Water Quality Control Plan (WQCP) provides the estuarine habitat objective, known as X2, for Suisun Bay and the western Delta. The X2 location, which is simulated by CalSim II, is the position of the 2 parts per thousand (ppt) salinity contour (isohaline), one meter above the bottom of the estuary, as measured in kilometers upstream from the Golden Gate Bridge. The location of the salinity contour in the Delta is regulated from February through June by the location of the X2 objective, and is required to be maintained at not more than 75 kilometers (approximately 47 miles) from February through June.

The position of X2 is managed through CVP and SWP reservoir releases and, in some instances, curtailment of Delta pumping. Table 3-4 and Table 3-5 provide a summary of X2 from the routed CalSim II model described earlier in this chapter. As shown in Table 3-4 and Table 3-5, under the action alternatives, X2 would remain below 75 kilometers between February and June. Detailed X2 results are included in the CalSim II Modeling Attachment.

Table 3-4. Monthly Average Simulated X2 Position for All Years

	Existing Level (2005)						Future Level (2030)					
	Existing Conditions (km)	Change from Existing Conditions (km)					No-Action Alt. (km)	Change from No-Action Alternative (km)				
Month		**Alt. Plan 1**	**Alt. Plan 2**	**Alt. Plan 3**	**Alt. Plan 4**	**Alt. Plan 5**		**Alt. Plan 1**	**Alt. Plan 2**	**Alt. Plan 3**	**Alt. Plan 4**	**Alt. Plan 5**
October	83.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	83.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
November	82.2	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	82.2	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
December	76.2	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	76.0	0.0 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)
January	67.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	67.4	0.0 (0.0%)	0.0 (0.1%)	0.0 (0.1%)	0.0 (0.1%)	0.0 (0.1%)
February	61.0	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.1%)	0.0 (0.0%)	0.0 (0.0%)	60.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
March	60.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	60.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
April	63.5	0.0 (0.1%)	0.0 (0.0%)	0.0 (0.1%)	0.0 (0.0%)	0.0 (0.1%)	63.4	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
May	67.5	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	67.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
June	74.5	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	74.7	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.1%)
July	80.5	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	80.5	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.0 (0.1%)	0.1 (0.1%)
August	85.5	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	85.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
September	83.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	83.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)

Source: DSM2 Ver 8.0.6 (Node X2)

Note:

[1] Simulation period: 1922–2003. Change as measured from Existing Condition/No Action Alternative. Dry and critical years as defined by the Sacramento Valley Index.

Key:

Alt. = Alternative

km = kilometer

Table 3-5. Monthly Average Simulated X2 Position for Dry and Critical Years

	Existing Level (2005)						Future Level (2030)					
	Existing Conditions (km)	Change from Existing Conditions (km)					No-Action Alt. (km)	Change from No-Action Alternative (km)				
Month		Alt. Plan 1	Alt. Plan 2	Alt. Plan 3	Alt. Plan 4	Alt. Plan 5		Alt. Plan 1	Alt. Plan 2	Alt. Plan 3	Alt. Plan 4	Alt. Plan 5
October	86.5	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	86.5	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
November	86.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	86.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
December	84.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	84.7	0.0 (0.0%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.0 (0.0%)
January	79.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	79.5	0.0 (0.0%)	0.1 (0.1%)	0.1 (0.1%)	0.1 (0.1%)	0.0 (0.0%)
February	72.8	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	72.5	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
March	70.4	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	70.4	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
April	72.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	72.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
May	77.7	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	77.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
June	82.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	82.8	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
July	86.1	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	86.1	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
August	88.8	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	88.6	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
September	90.9	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	91.0	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)

Source: DSM2 Ver 8.0.6 (Node X2)

Note:

1. Simulation period: 1922–2003. Change as measured from Existing Condition/No Action Alternative. Dry and critical years as defined by the Sacramento Valley Index.

Key:

Alt. = Alternative

km = kilometer

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Chapter 4
Temperature Modeling

This chapter describes reservoir and river temperature modeling conducted to support evaluation of the benefits and impacts of the Investigation alternatives. Results were used to assess the potential effects of temperature changes on fishery habitat conditions, described in EIS Chapter 5, “Biological Resources – Fisheries and Aquatic and Ecosystems.”

Reservoir Temperature Modeling

Temperature modeling of the Millerton Lake and Temperance Flat RM 274 Reservoir system was conducted to simulate the temperature of water released from Millerton Lake to the San Joaquin River. An existing CE-QUAL-W2 based two-dimensional temperature model of Millerton Lake and Temperance Flat RM 274 Reservoir was used for this analysis. The temperature model was developed specifically for the Investigation and its development is fully documented in the Investigation Plan Formulation Report, Reservoir Operations Technical Appendix (Reclamation and DWR 2008).

Model Description

The Millerton Lake and Temperance Flat RM 274 Reservoir temperature model is based on the CE-QUAL-W2 modeling platform. CE-QUAL-W2 is a two-dimensional (longitudinal and vertical) water quality and hydrodynamic model for rivers, estuaries, lakes, reservoirs, and river basin systems. CE-QUAL-W2 consists of directly coupled hydrodynamic and water quality transport models. Developed for reservoirs and narrow, stratified estuaries, CE-QUAL-W2’s capabilities include longitudinal and vertical hydrodynamics and water quality in stratified and nonstratified systems; multiple algae, epiphyton/periphyton, zooplankton, macrophyte, carbonaceous biochemical oxygen demand (CBOD), and generic water quality groups; internal dynamic pipe/culvert modeling; hydraulic structure (weirs, spillways) algorithms, including submerged and two-way flow over submerged hydraulic structures; and a dynamic shading algorithm based on topographic and vegetative cover. For this application, only temperature is modeled.

Model Calibration

Because the application of this model for the Investigation features a large reservoir that has not been constructed, no data were available for model calibration. The Millerton Lake portion of the model was calibrated, but the combined Millerton and Temperance Flat RM 274 Reservoir model was evaluated for "reasonableness." Results were evaluated against expected results given the reservoir size and operational characteristics.

Modeling Approach and Assumptions

The Millerton Lake and Temperance Flat RM 274 Reservoir temperature model was applied to the action alternatives by varying the water operation boundary conditions as appropriate for each alternative. Other boundary conditions, such as meteorology and inflow temperatures, remained constant between alternatives.

The Temperance Flat RM 274 Reservoir outlet was assumed to have a SLIS installed, which allows withdrawal from different levels in the reservoir for cold water pool management, in Alternative Plan 4. All other action alternatives were assumed to have a single low-level outlet from Temperance Flat Reservoir to Millerton Lake.

The operation of the SLIS is not specifically designed to improve Temperance Flat RM 274 Reservoir release temperatures, but is designed to improve Millerton Lake release temperatures for downstream ecological purposes through more efficient cold water pool management. The operations of the SLIS for Alternative Plan 4 were refined through a process of assuming a SLIS operation and running the Millerton Lake and Temperance Flat RM 274 Reservoir temperature model to estimate the temperature of the Millerton Lake release to San Joaquin River. These were then used with the SJR5Q, described later within this chapter, to simulate temperatures in the San Joaquin River. The resulting flows and temperatures were then input into the EDT fishery habitat model, described in Chapter 5, to estimate the ecosystem accomplishments associated with that specific SLIS operation scheme. The SLIS operation scheme was then adjusted and the process repeated to define the SLIS operation scheme that produced the most ecosystem improvements.

Period of Record

The temperature simulation output period is from 1980 to 2003 with 1-day flow and 6-hour temperature time steps to allow analysis of diurnal temperature fluctuations. The actual period simulated in the model is 1977 to 2003, with output on a 1-hour time step. The initial three years (1977 to 1979) are a “warm-up period” to capture appropriate antecedent conditions in Millerton Lake and Temperance Flat RM 274 Reservoir. The hourly outputs are averaged over the final desired flow and temperature time steps after model execution has completed.

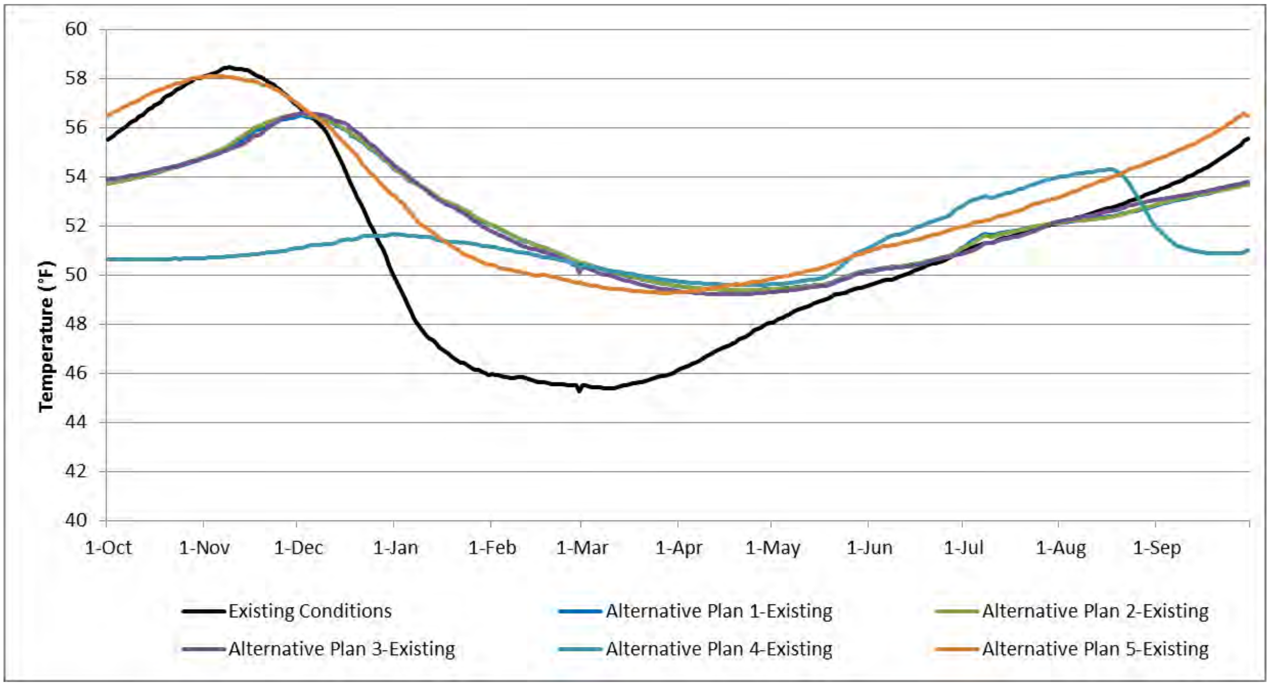
Water Operations Data

The Millerton Lake-Temperance Flat RM 274 Reservoir temperature model uses daily water operations data for San Joaquin River inflow, Millerton Lake and Temperance Flat RM 274 Reservoir storage, Friant-Kern Canal and Madera Canal diversions and controlled release and spill to the San Joaquin River from the daily model output, which described in Chapter 3.

Reservoir Temperature Modeling Results Summary and Discussion

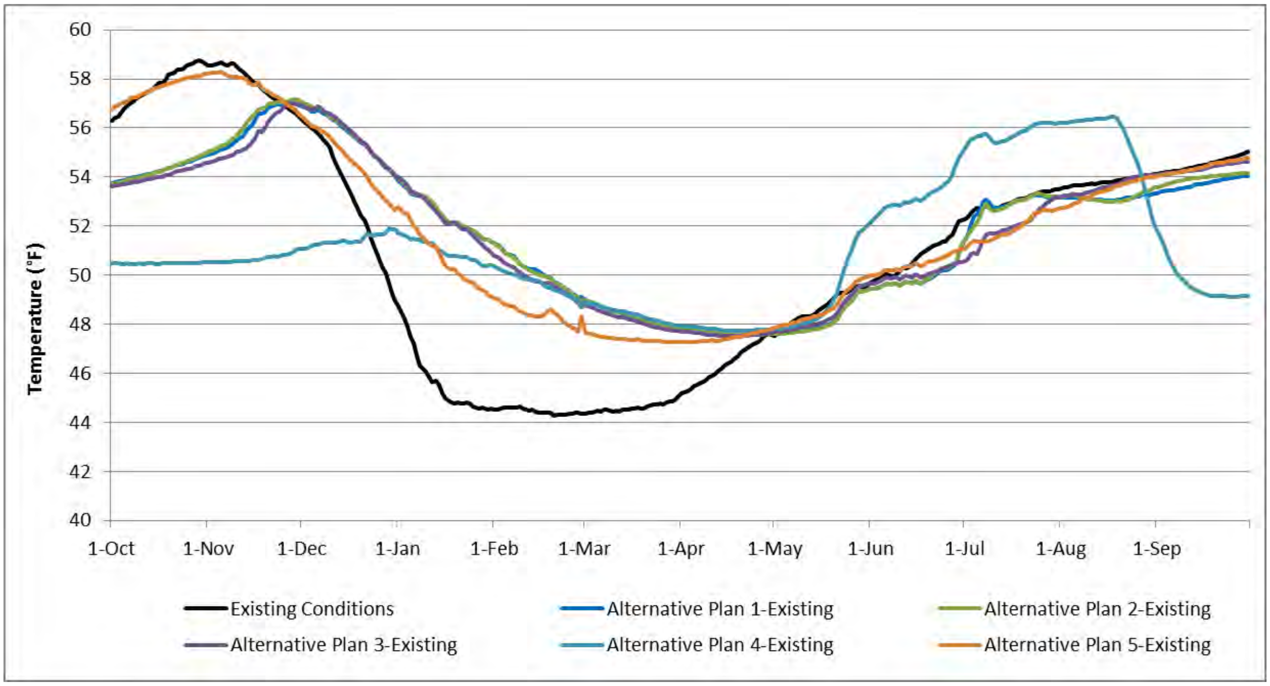
The Millerton Lake-Temperance Flat RM 274 Reservoir temperature model simulates reservoir temperature profiles, temperature of diversion to the Friant-Kern and Madera canals, and temperature of the spill and release from Temperance Flat RM 274 Reservoir and Millerton Lake.

Results of the reservoir temperature modeling for all alternative plans are shown in Figure 4-1 through Figure 4-10. These figures show mean daily San Joaquin River release temperature in wet, normal-wet, normal-dry, and dry SJRRP year types in existing and future conditions. In general, the action alternatives improve the release temperature from August to December, with greater improvements in alternatives with higher carryover storage in Temperance Flat RM 274 Reservoir. Alternative Plan 4, which includes a SLIS, has even further capacity to improve temperatures between August and December. The reservoir temperature data were used as input into river temperature modeling, discussed in the next section. CE-QUAL-W2 modeling output may be found in CE-QUAL-W2 Modeling Attachment.



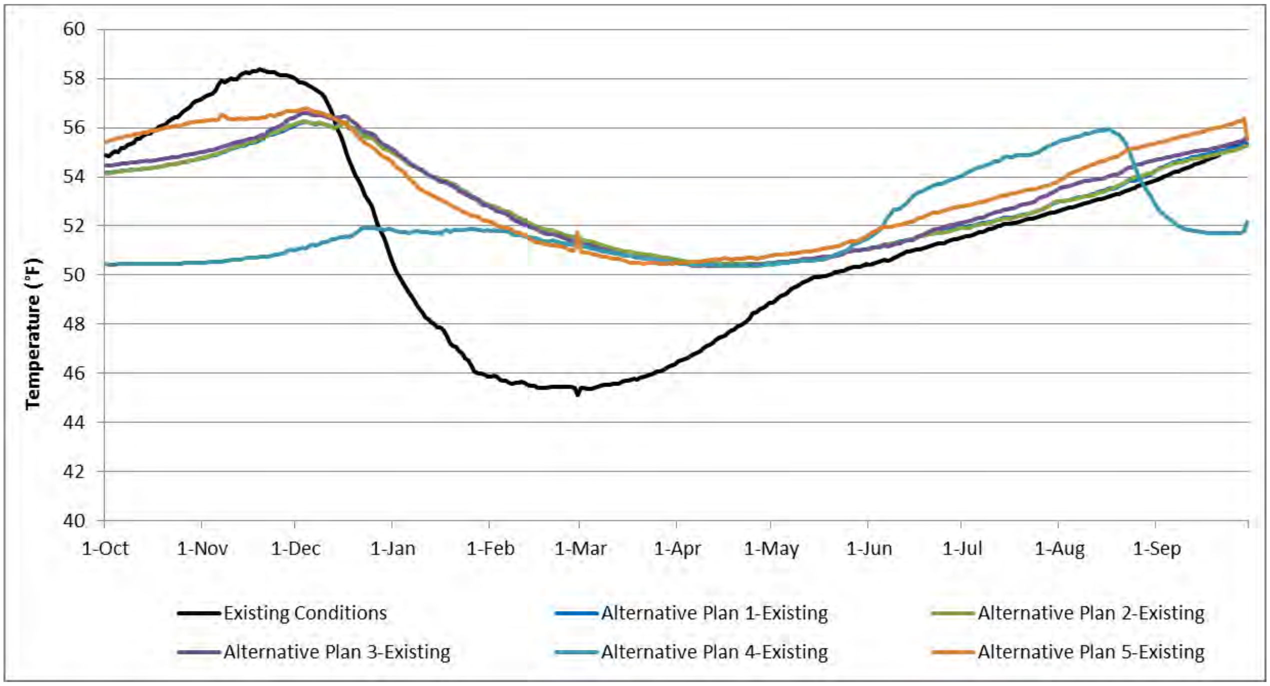
Key: °F = degrees Fahrenheit

Figure 4-1. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -All Years-Existing Condition



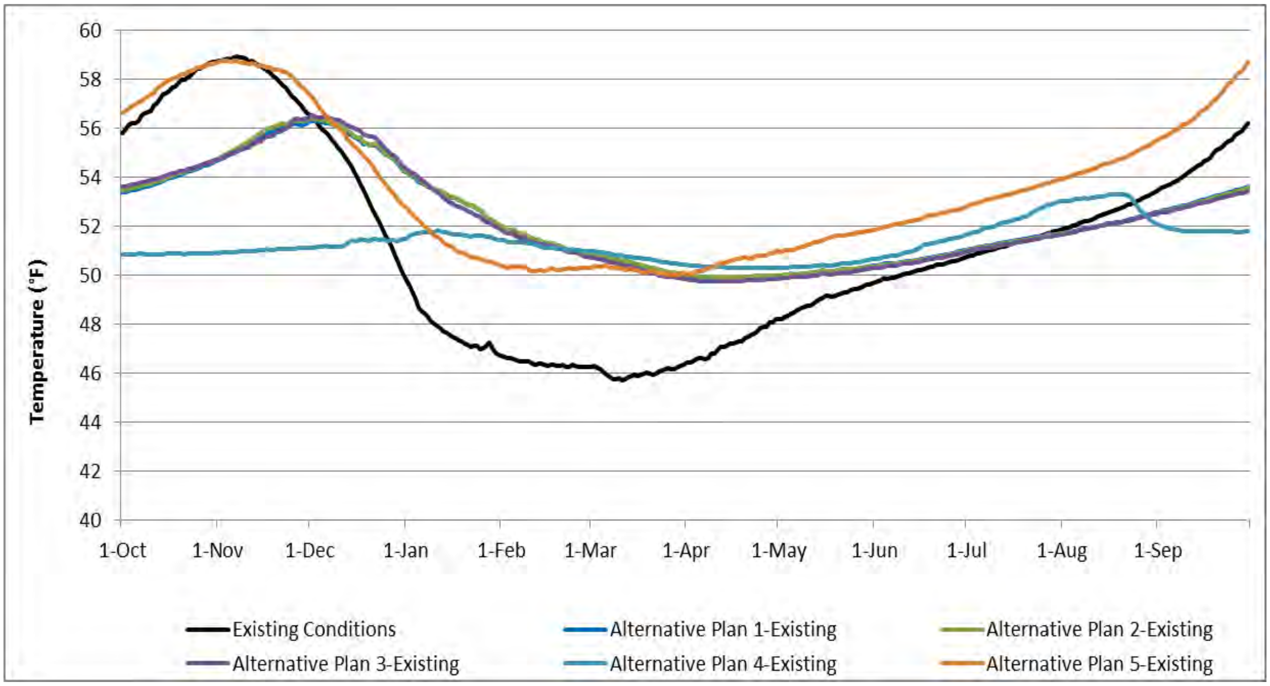
Key: °F = degrees Fahrenheit

Figure 4-2. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Wet Years-Existing Condition



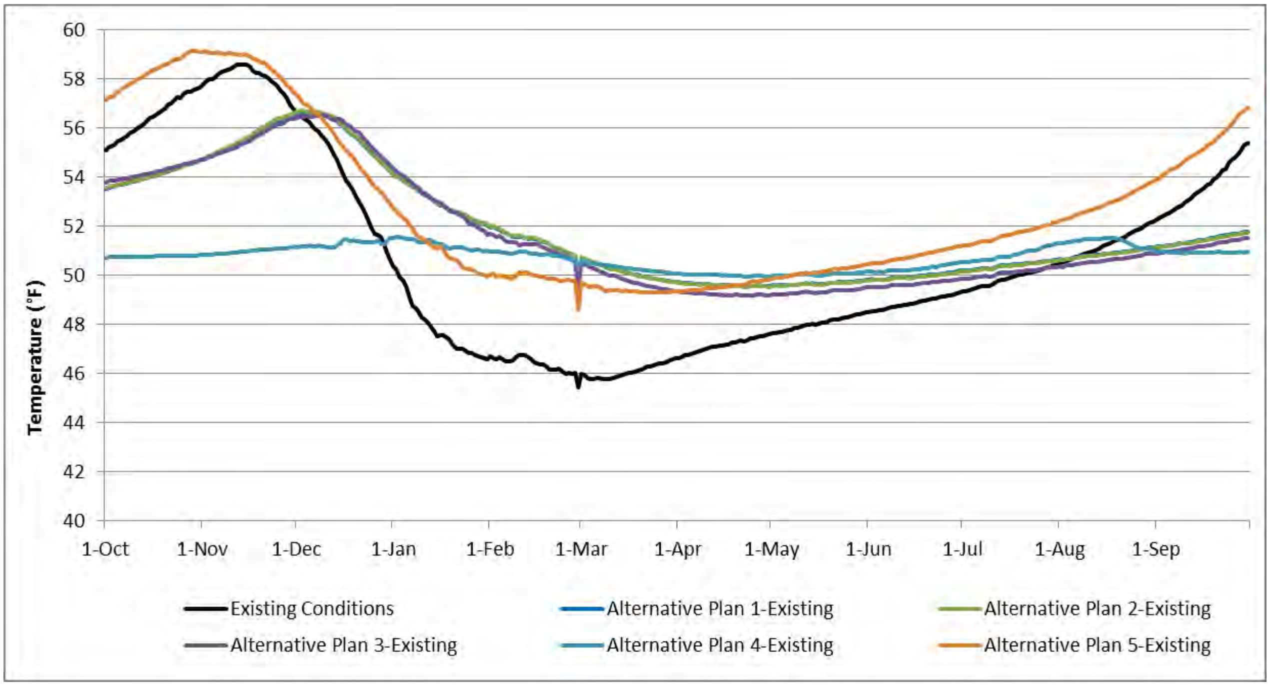
Key: °F = degrees Fahrenheit

Figure 4-3. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Normal-Wet Years-Existing Condition



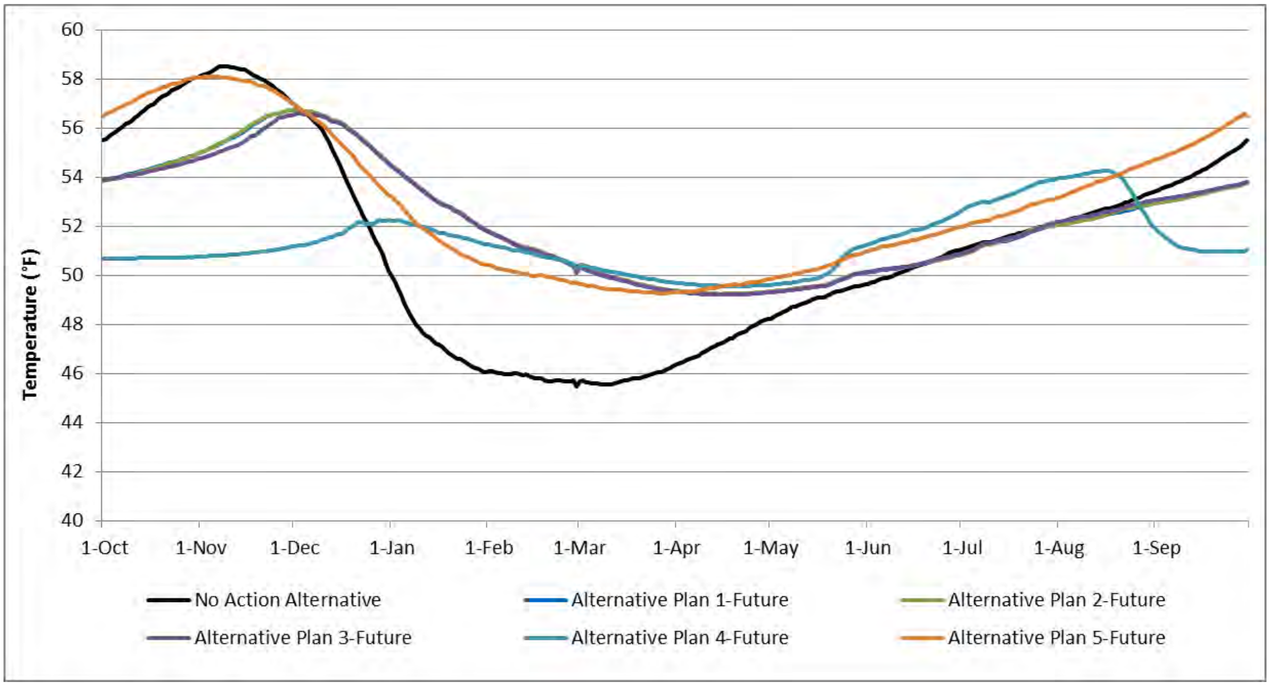
Key: °F = degrees Fahrenheit

Figure 4-4. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Normal-Dry Years-Existing Condition



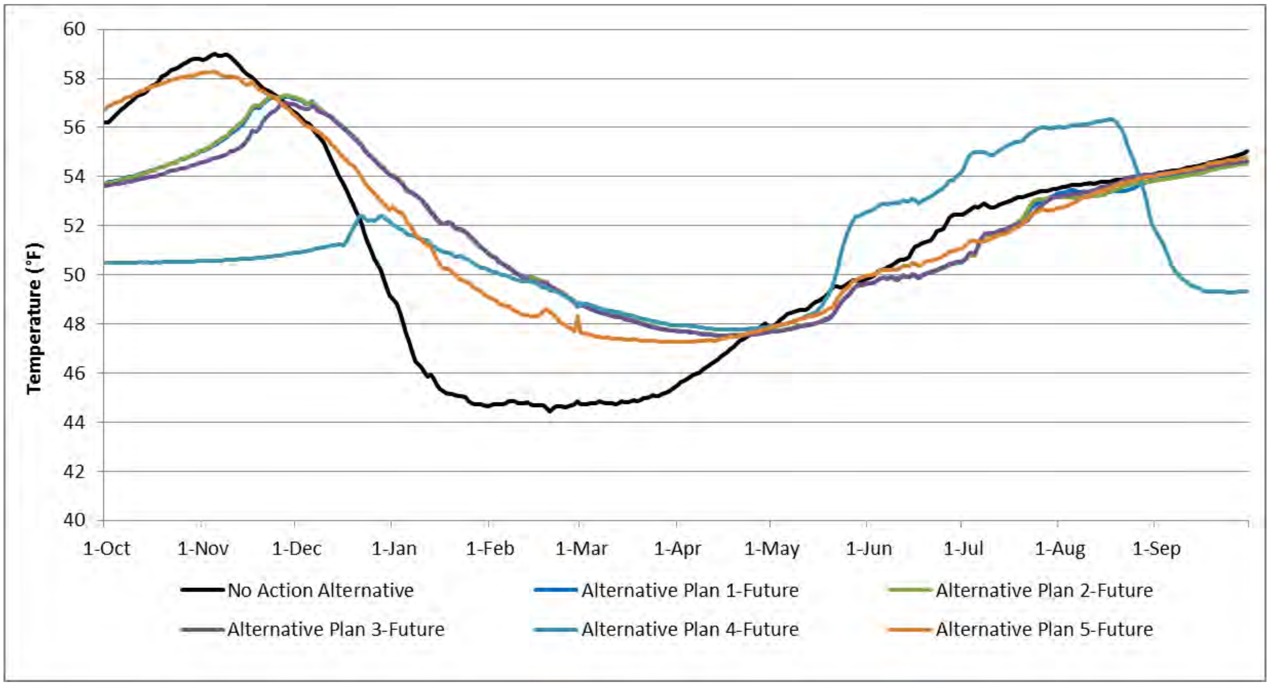
Key: °F = degrees Fahrenheit

Figure 4-5. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Dry Years-Existing Condition



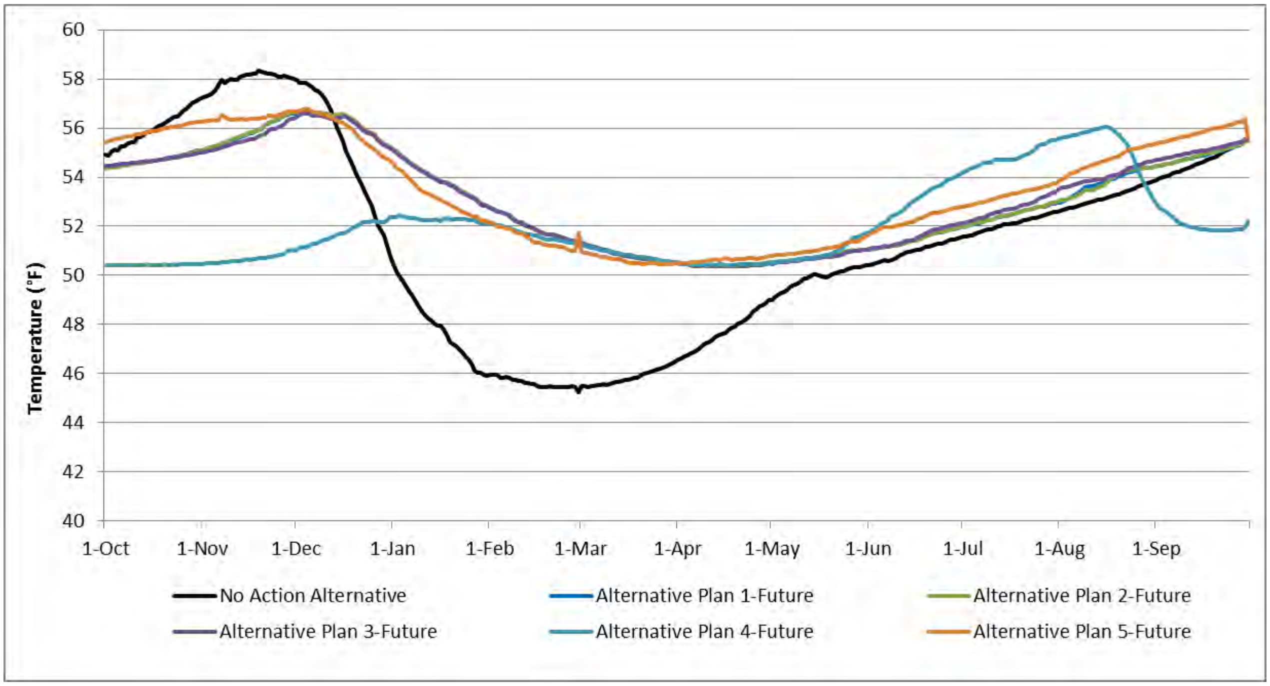
Key: °F = degrees Fahrenheit

Figure 4-6. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -All Years- Future Condition



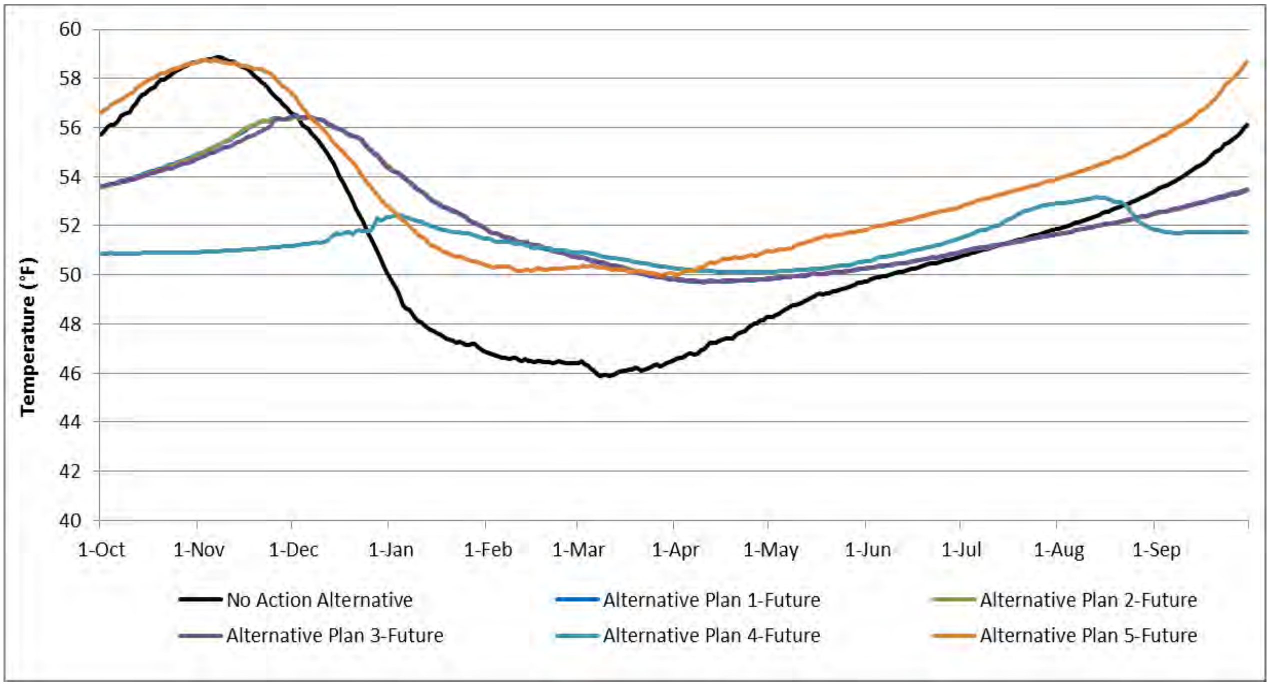
Key: °F = degrees Fahrenheit

Figure 4-7. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Wet Years- Future Condition



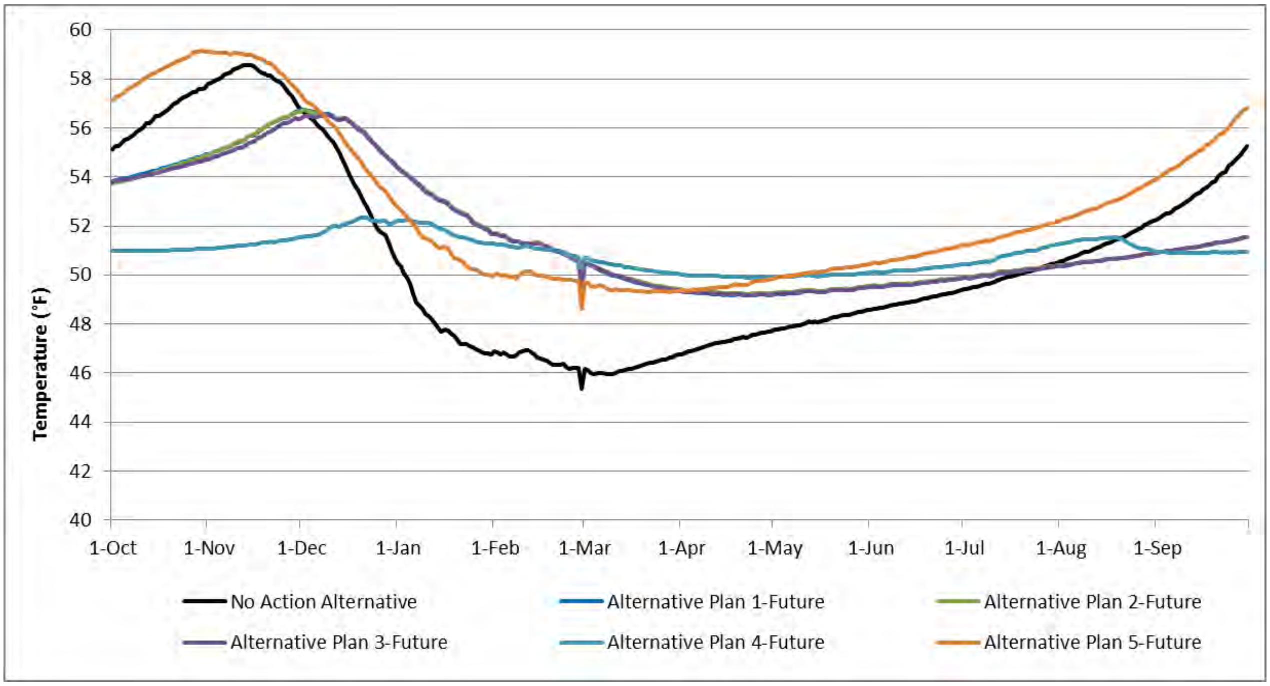
Key: °F = degrees Fahrenheit

Figure 4-8. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Normal-Wet Years- Future Condition



Key: °F = degrees Fahrenheit

Figure 4-9. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Normal-Dry Years- Future Condition



Key: °F = degrees Fahrenheit

Figure 4-10. Simulated Mean Daily Temperature (°F) of Friant Release to San Joaquin River -Dry Years- Future Condition

River Temperature Modeling

Temperatures in the San Joaquin River downstream from Millerton Lake are important to the success of salmon spawning in Reach 1 of the San Joaquin River. SJR5Q provides a method to evaluate the temperatures in this reach of the river.

The SJR5Q model was developed in support of the SJRRP, and is fully documented in the Modeling Appendix to the SJRRP PEIS/R (SJRRP 2012). This model was used without modification for this project as the Investigation would not impact the river except for changes in release temperatures and flows, both of which are simple inputs to the model.

Model Description

SJR5Q covers the San Joaquin River downstream from Millerton Lake to the confluence with the Merced River. The model was developed using the U.S. Army Corps of Engineers (USACE) HEC-5Q modeling tool, which can be used for simulating water flow and quality of reservoirs and streams. The HEC-5Q users' manual (USACE 1986) has a more complete description of the water quality relationships included in the model.

Modeling Approach and Assumptions

The model was applied to the different alternative plans by varying the water operation boundary conditions, as appropriate, for each alternative plan. Other boundary conditions, such as meteorology and accretions/depletions, remain constant between alternative plans.

Period of Record

The simulation period for SJRRP use is from 1980 to 2003, with 1-day flow and 6-hour temperature time steps to allow analysis of diurnal temperature fluctuations.

Millerton Lake Release Flow

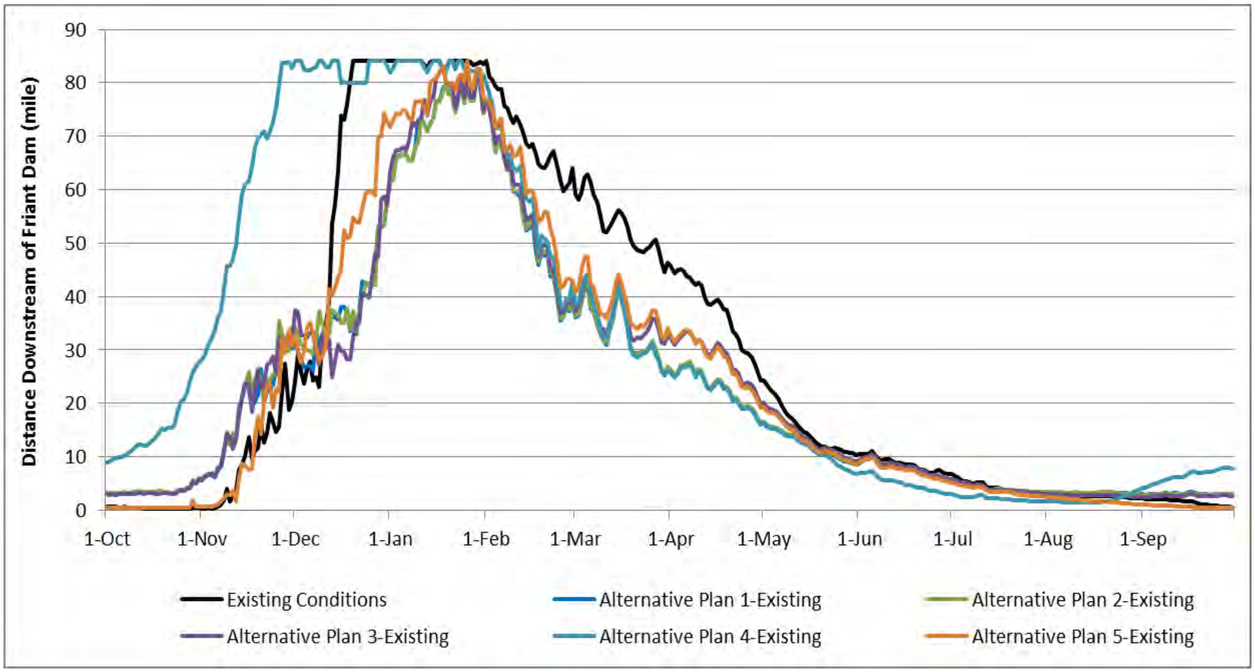
Daily Millerton Lake spills and release to the San Joaquin is obtained from the Millerton Lake-Temperance Flat Reservoirs temperature model, described in this chapter previously.

Millerton Lake Release Temperature

The Millerton Lake release temperature at a 6-hour time step for the entire simulation period is obtained from the Millerton Lake-Temperance Flat RM 274 Reservoir temperature model for each alternative plan and used as input to SJR5Q. The temperature is a weighted average of the Millerton Lake spill, if any, and outlet release temperatures.

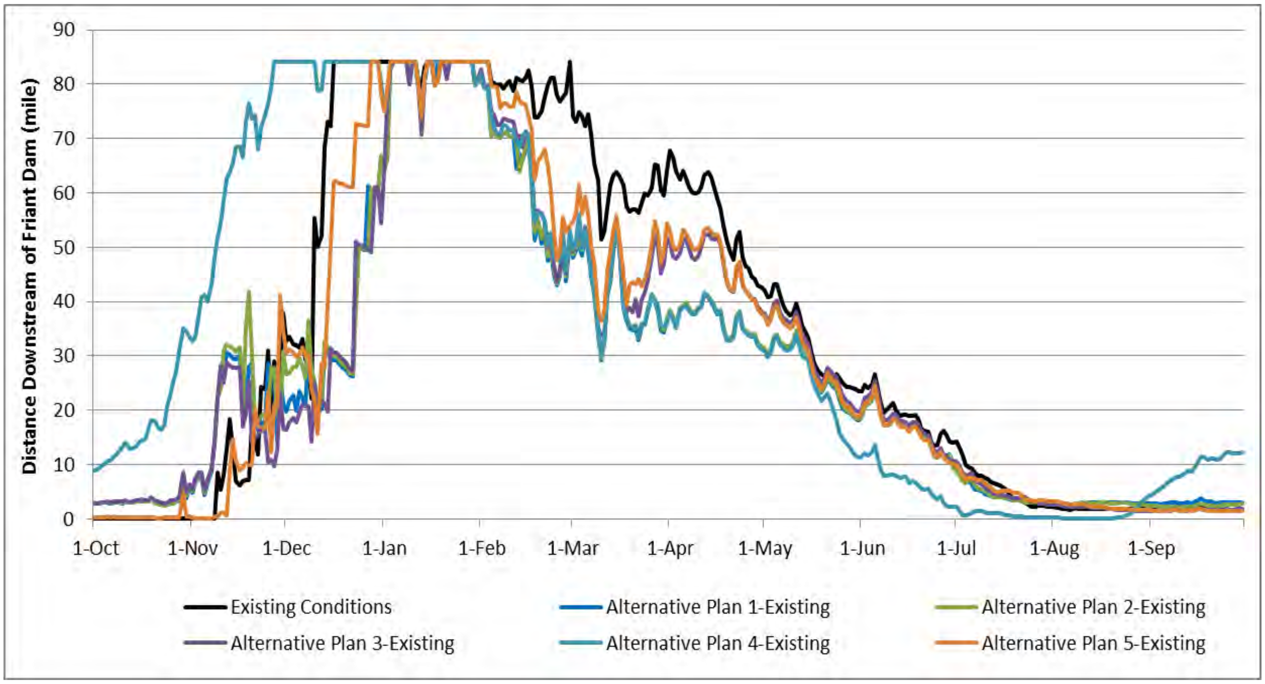
River Temperature Modeling Results Summary and Discussion

Results of the river temperature modeling for all alternative plans are shown in Figure 4-11 through Figure 4-20. These figures show how far downstream from Friant Dam the San Joaquin River stays at or below 55 degrees Fahrenheit in wet, normal-wet, normal-dry, and dry SJRRP year types in existing and future conditions. In general, the action alternatives improve the reach of cold water for fall months when spring-run Chinook are spawning, in comparison to the No Action Alternative, as well as during incubation of eggs and emergence of fry. Alternative Plan 4, which includes a SLIS, provides a slightly greater improvement in river temperature in the downstream reach than action alternatives without a SLIS. The river temperature modeling data was post-processed and used as input to the fish habitat modeling using the EDT model, discussed in Chapter 5. SJR5Q modeling output may be found in the SJR5Q Modeling Attachment.



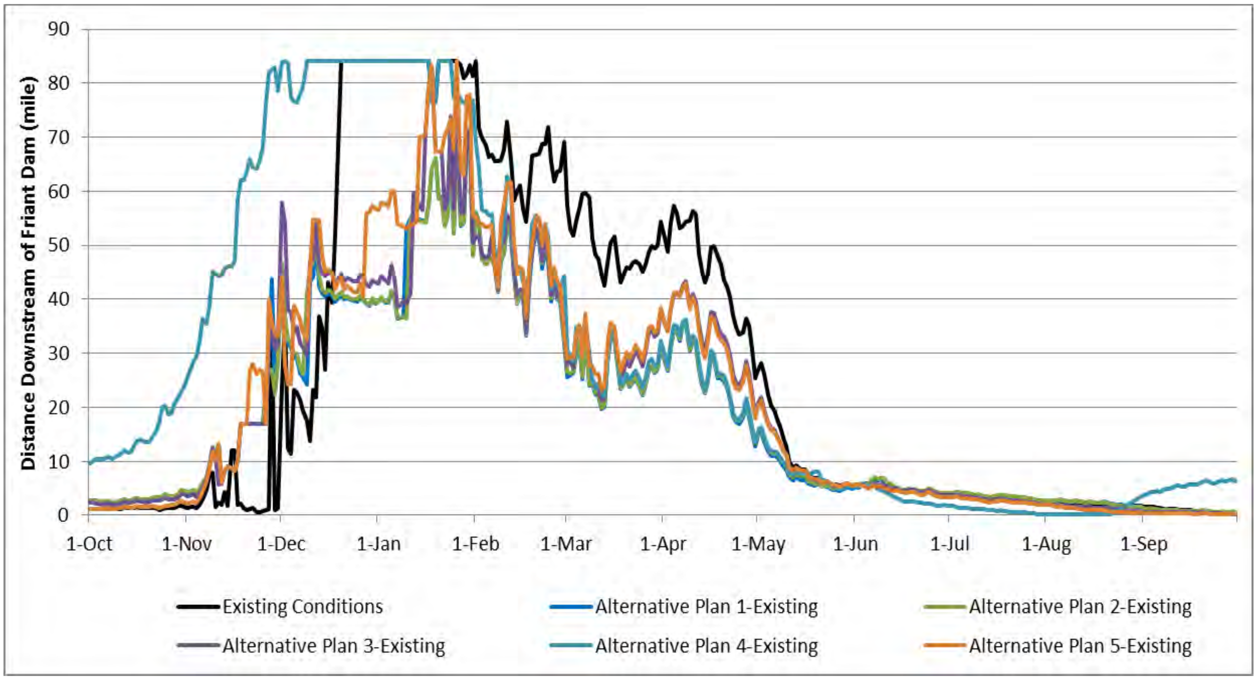
Key: °F = degrees Fahrenheit

Figure 4-11. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- All Years-Existing Condition



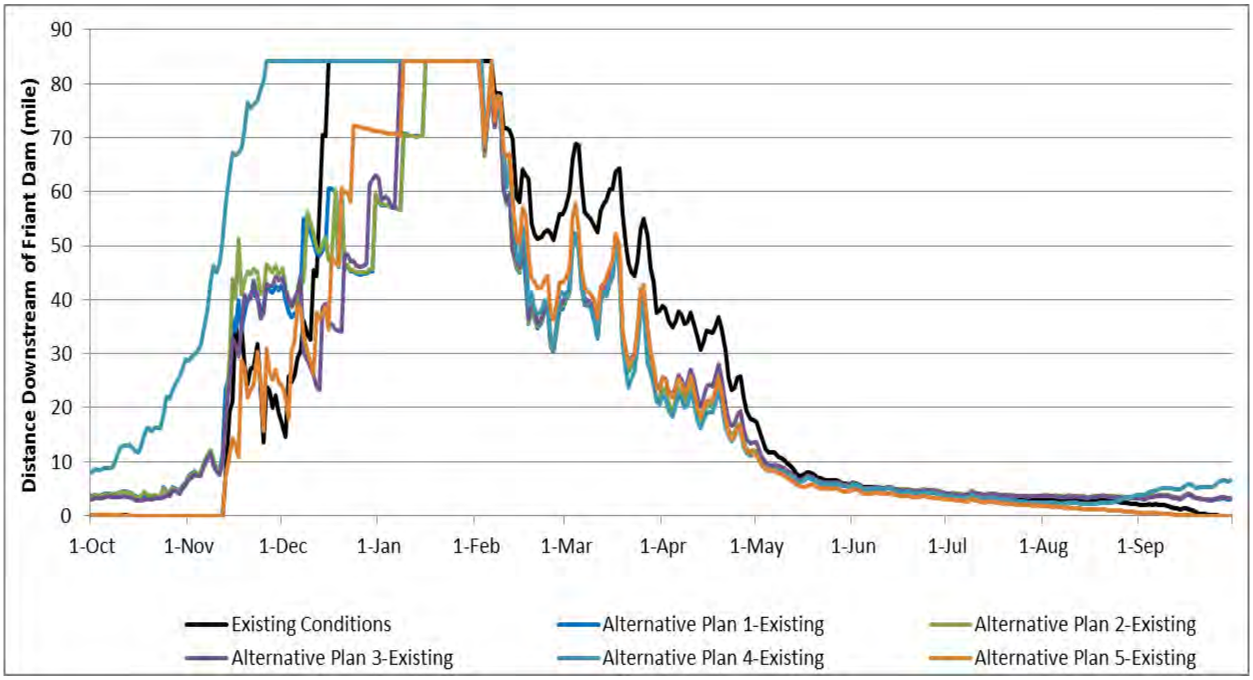
Key: °F = degrees Fahrenheit

Figure 4-12. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Wet Years-Existing Condition



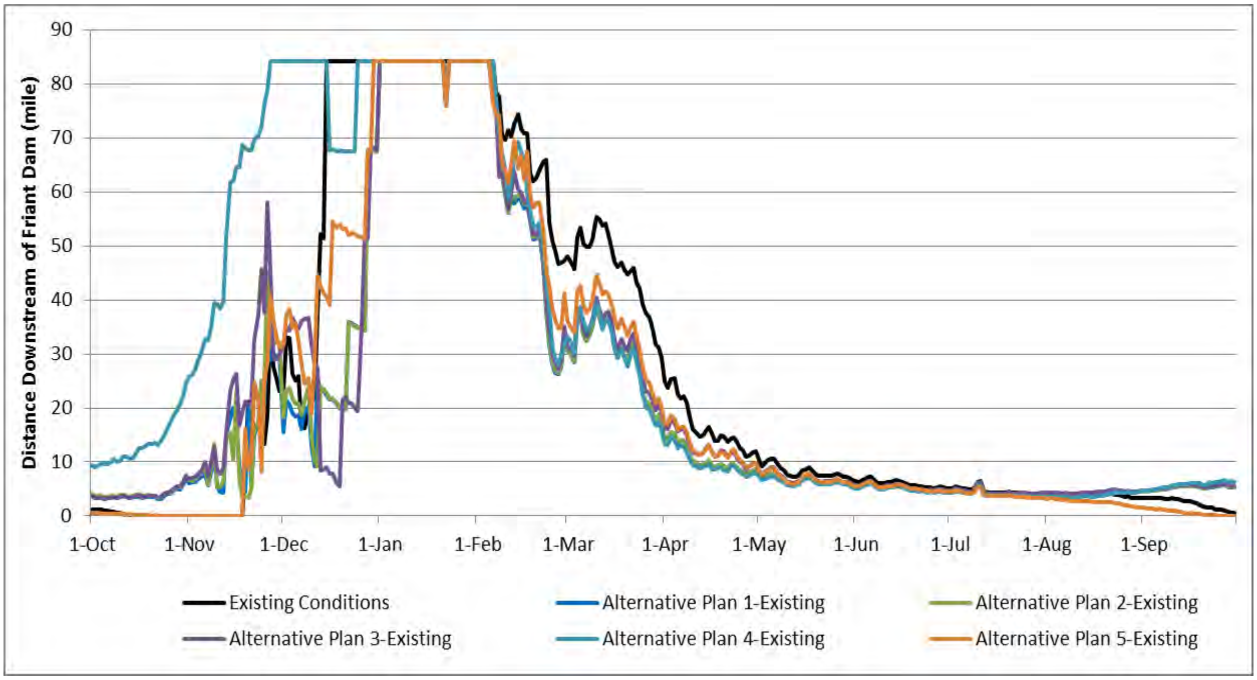
Key: °F = degrees Fahrenheit

Figure 4-13. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Normal-Wet Years-Existing Condition



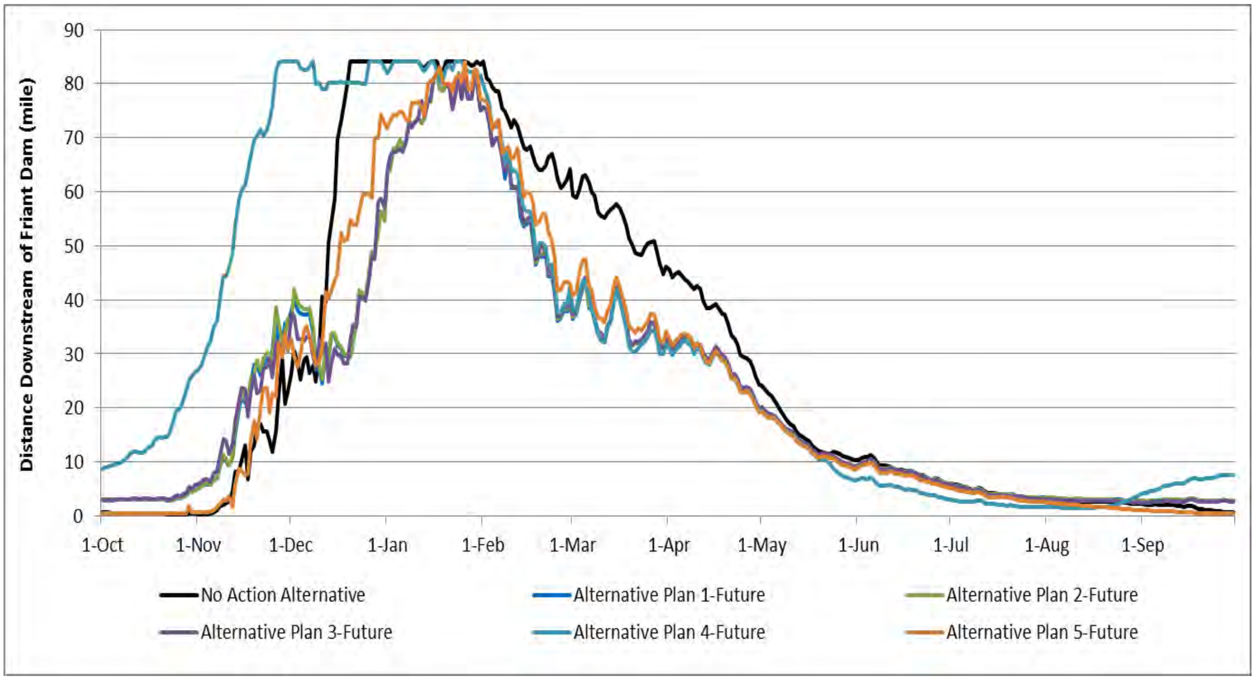
Key: °F = degrees Fahrenheit

Figure 4-14. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Normal-Dry Years-Existing Condition



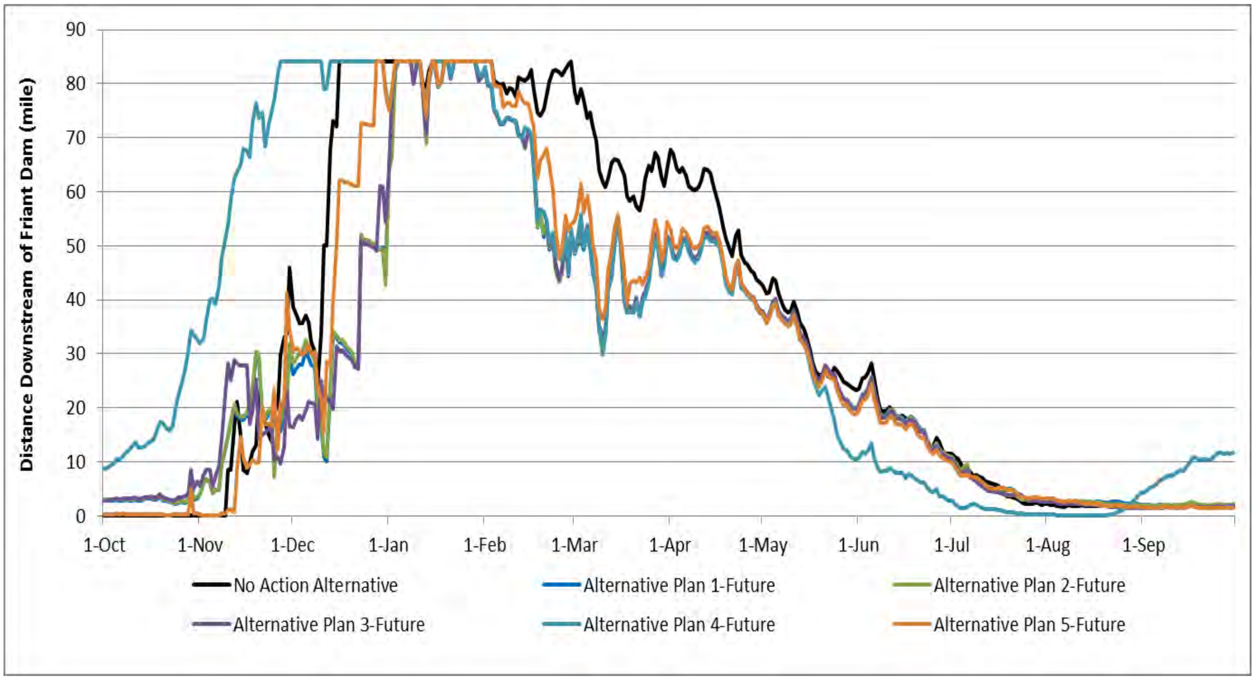
Key: °F = degrees Fahrenheit

Figure 4-15. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Dry Years-Existing Condition



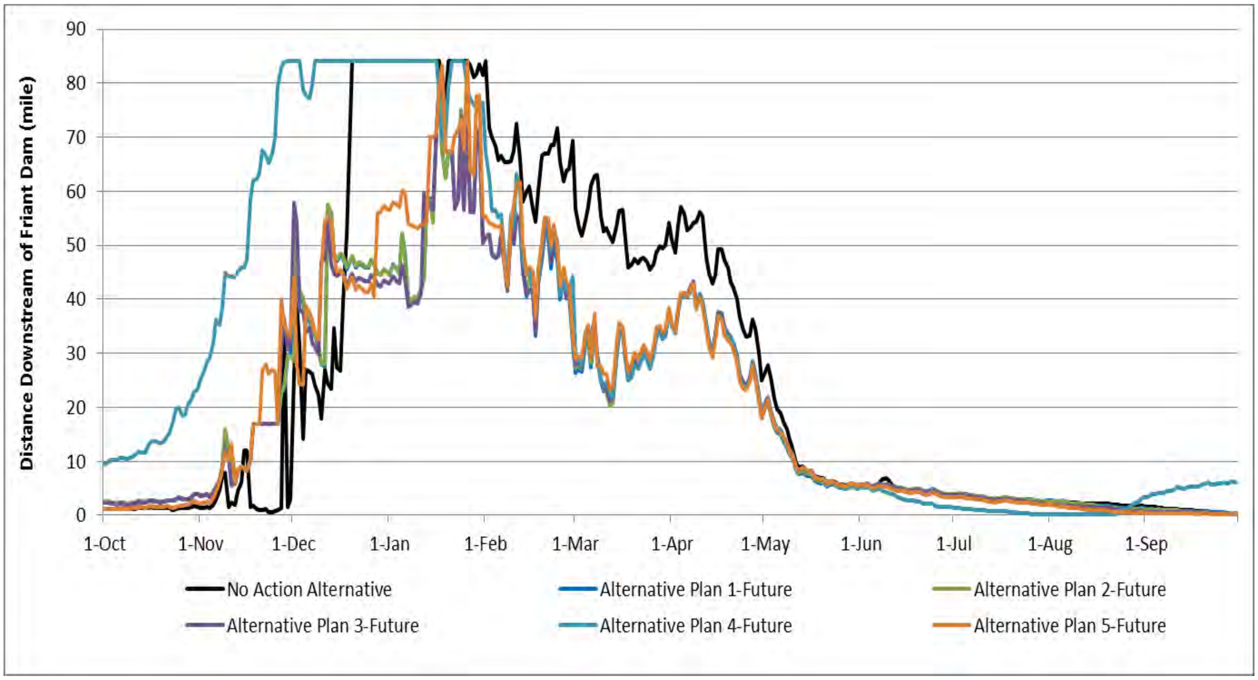
Key: °F = degrees Fahrenheit

Figure 4-16. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- All Years-Future Condition



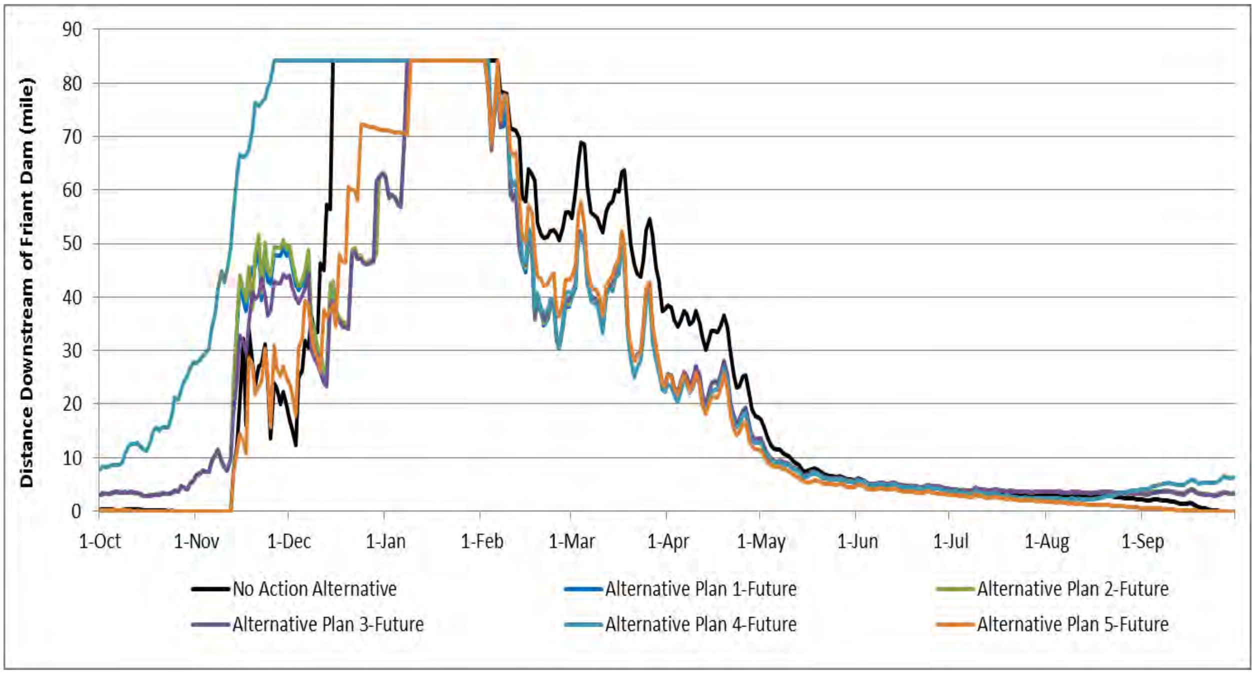
Key: °F = degrees Fahrenheit

Figure 4-17. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Wet Years-Future Condition



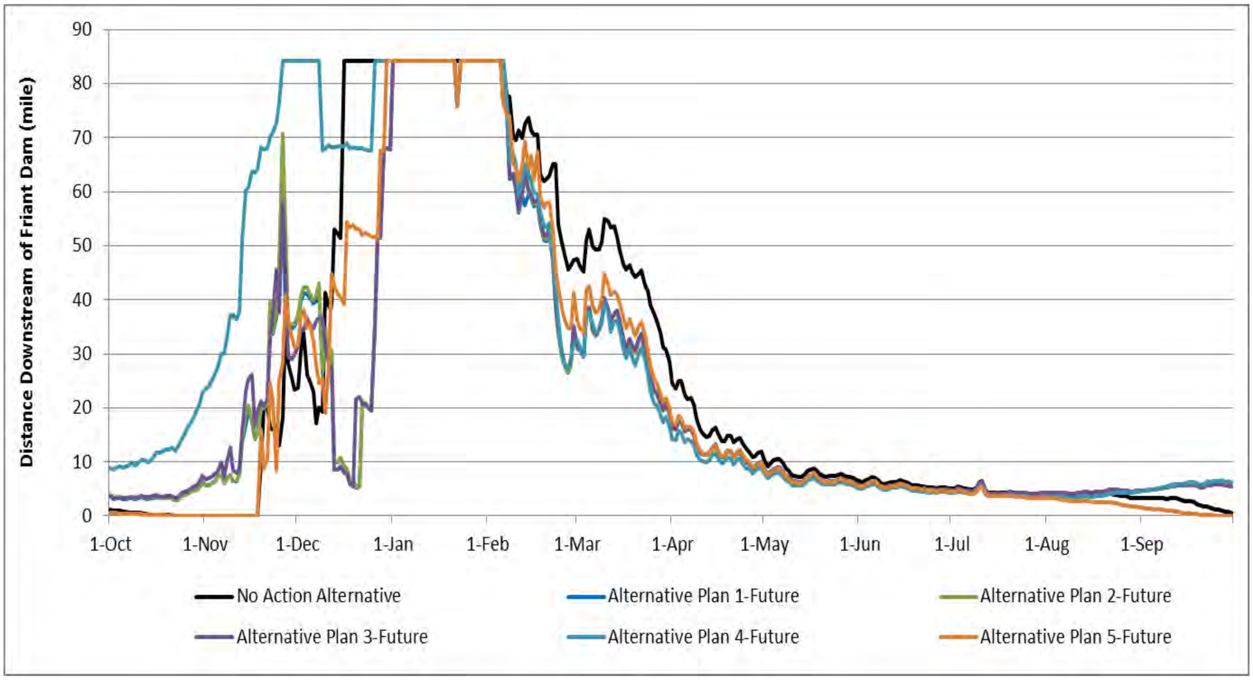
Key: °F = degrees Fahrenheit

Figure 4-18. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Normal-Wet Years-Future Condition



Key: °F = degrees Fahrenheit

Figure 4-19. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Normal-Dry Years-Future Condition



Key: °F = degrees Fahrenheit

Figure 4-20. Distance Downstream Where Simulated Mean Daily San Joaquin River Temperature Less than or Equal to 55°F- Dry Years-Future Condition

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Chapter 5
Ecosystem Modeling

This chapter describes modeling completed to assess improvements and impacts to fisheries habitat in Millerton Lake and Temperance Flat RM 274 Reservoir and the San Joaquin River under the Investigation alternatives plans.

Millerton Lake and Temperance Flat RM 274 Reservoir Fisheries

The Black Bass Spawning Production model (black bass model) is a spreadsheet model developed to evaluate the potential effects of the No Action Alternative and action alternatives on largemouth bass and spotted bass in Millerton Lake and Temperance Flat RM 274 Reservoir. The model combines information on reservoir operations and water temperature, described in previous chapters of this appendix, with life history of fish parameters to develop estimates of spawning production under the Investigation alternatives.

Model Description

The black bass model combines habitat and life history information to simulate spawning production for largemouth bass and spotted bass. Habitat data include reservoir water temperatures, described in Chapter 4, reservoir water surface level fluctuations obtained from the output of the daily model, described in Chapter 3, as well as the surface areas of elevation contours developed through interpolation of reservoir storage on a storage-elevation curve. Output of the daily model is used to develop a quarter-month time steps (7 or 8 days each, depending on the month) by averaging storage and water level changes, and using reservoir elevation-storage curves to compute the water level change as the difference between the water level on the final day of the current time step and the water level on the final day of the previous time step.

The black bass model combines this reservoir operations and temperature data with life history of fish, including egg and larval development times and in-nest survival rates of eggs and larvae. The life history parameters used in the model were derived primarily from studies of largemouth bass, though one study of smallmouth bass was also used. Comparable information for spotted bass is largely unavailable, but literature sources indicate that life history parameters for spotted bass are similar to those for largemouth bass, except for spawning depths, which are deeper for spotted bass (Greene and Maceina 2000; Reinart et. al., 1995; Aasen and Henry 1980; Vogele 1975). Therefore, with the exception of spawning depths, the black bass model developed for the Investigation uses the same life history parameters to simulate spawning production of largemouth bass and spotted bass. The life history parameters and equations used in the Investigation black bass model are derived from the following references:

- *Jackson, J.R. and R.L. Noble. 2000*. Relationship between annual variations in reservoir conditions and age-0 largemouth bass year-class strength. Transactions of the American Fisheries Society 129: 699-715.

- *Knoteck, W.L. and D.J. Orth. 1998*. Survival for specific life intervals of smallmouth bass, *Micropterus dolomieu*, during parental care. Environmental Biology of Fishes 51: 285-296.

- *Mitchell, D. 1982*. Effects of water level fluctuation on reproduction of largemouth bass, *Micropterus salmoides*, at Millerton Lake, California, in 1973. California Fish and Game 68(2): 68-77.

- Habitat data inputs for the model include reservoir water temperatures, storage volumes and bathymetric relationships (storage volume versus surface area and elevation).

Reservoir fisheries modeling for the Investigation uses the black bass model, which provides life history information for the black bass species, to estimate spawning production of largemouth and spotted bass in Millerton Lake and Temperance Flat RM 274 Reservoir. While the model uses quarter-month time steps, biological processes such as development of eggs and larvae may require more than one quarter-month for completion. Therefore, the model employed overlapping time steps, simulating events of two quarter months (the current and the next quarter month) during each time step.

Model Implementation

The black bass model for the Investigation uses the following 14 steps to determine reservoir fisheries impacts for the alternative plans:

- **Step 1 –** Uses the average and final reservoir storage volumes for each time step to determine, from lookup tables, the equivalent elevations and surface areas for each one-foot depth interval.

- **Step 2 –** Obtains average water temperatures for each time step.

- **Step 3 –** Computes egg incubation time from simulated water temperatures using the following equation, cited in Jackson and Noble (2000):

  $$I = 47.9 \times \exp(-0.13 \times T) \qquad (1)$$

  where

  I = incubation time in days
  T = water temperature in degrees centigrade

  Development time from egg hatching to leaving the nest is assumed to be equivalent to egg incubation time (Knoteck and Orth 1988 and as cited in Mitchell 1982) and is added to the egg incubation time.

- **Step 4 –** Sets days available for incubation and development of eggs/larvae based on water temperature thresholds, with days available per time step set at 7.6. Spawning temperature thresholds were derived from Figure 3 in Mitchell 1982, which is developed for largemouth bass, and days available for incubation and development of eggs/larva are dependent on time of year and water temperature using the following conditions:

  - Days available is set to zero when water temperatures are less than 16 degrees Celsius (°C) or greater than 24.5°C. Days available is also set to zero if the month is earlier than March or later than July because the bass eggs are not expected to be ripe before March and the females are assumed to be spawned out after July, regardless of water temperature.

  - If water temperature is between 16°C and 24.5°C during both quarter-month time steps, the model sets days available for incubation/development to 15.2. If temperature during the first quarter-month time step is between 16°C and 24.5°C, but temperature during the second time step is greater than 24.5°C, the model sets days available for incubation/development to 7.6 because incubation and development can occur during the first time step only. However, if water temperature is between 16°C and 24.5°C in first time step but is below 16°C during second time step, days available for incubation/development is set to zero because the time needed to complete egg incubation plus larval development time at 16°C and below (as computed in Step 3) is greater than 7.6 days and incubation and development cease at the low water temperature of the second time step.

- **Step 5 –** Computes the number of days that the bottom of the depth interval is inundated within the current quarter-month time step given the rate and direction of reservoir surface elevation change of the time step. If the direction of change is zero or positive, the number of days of inundation is 7.6. If the direction of change is negative, the number of days of inundation is the depth of the interval times the number of days required for one foot of elevation change.

- **Step 6 –** Computes the potential number of completed nest cycles (spawning through departure of larvae) for every two time steps (15.2-days). The potential number of nest cycles is a function of the development time (see Step 3) and the number of days during the time step available for egg and larval development (see Steps 4 and 5). It is computed as the days available for development (i.e., days bottom of depth interval is inundated and water temperatures are within thresholds) divided by the development time. Partial nest cycles result in total mortality, so only the integer portions of computed values are used.

- **Step 7** – Computes the proportion of eggs spawned per nest that hatch and survive through development to the stage that the larvae leave the nest. The assumed survival rate of eggs and larvae is 93 percent survival per day, obtained from Jackson and Noble (2000) for largemouth bass eggs and adopted for larvae based on results for smallmouth bass in Knotek and Orth (1998). This is depicted in the following equation:

$$S = 0.93D \qquad (2)$$

where

S = proportion of eggs and larvae surviving in successful nests
D = days for egg incubation plus larval development (see Step 3)

- **Step 8 –** Assigns a spawning depth suitability/nest density index value, which ranges from zero to 1, for each 1-foot depth interval from the reservoir surface to 15 feet for largemouth bass and from the surface to 22 feet for spotted bass. These indices were adopted from spawning habitat analyses reported in East Bay Municipal Utility District (EBMUD) et al. (1996) and were corroborated by Mitchell (2006). Depth ranges of 3 to 6 feet and 8 to 13 feet are considered optimal for largemouth bass and spotted bass spawning, respectively, and are assigned a value of 1.0. The surface layer and depths greater than 15 feet for largemouth bass and 21.5 feet for spotted bass are assigned a value of zero because wave action is assumed to destroy nests near the surface, and little or no spawning occurs below the maximum spawning depth. Spawning depth suitability/nest density index values for intermediate depths are computed through interpolation. The spawning depth suitability/nest density index values for every time step pair (15.2-days) and each depth interval was computed as the average of the values for the depths at the current and following time-step.

- **Step 9 –** Along with Steps 10 and 11, computes substrate conditioning factors based on the recent inundation and exposure history of the elevation contours. Step 9 computes the exposure to air conditioning factor. Exposure to air improves spawning habitat quality because organic sediment material is decomposed and wind and storm runoff remove fine sediments. Step 9 computes the air exposure factor using three sub-steps. The first sub-step determines the number of time steps during the preceding three years that each elevation contour in the reservoir basin was above the current reservoir surface elevation. The second sub-step reduces this number by 2 for each time step preceding the current time step that the current surface elevation contour was submerged. This adjustment causes loss of habitat value through re-submergence to proceed at twice the rate as gain of habitat by exposure. Sub-step 3 aggregates the values in sub-step 2 by depth interval. Finally, these values are divided by the maximum possible value (144, the number of quarter-months in 3 years) to obtain an air exposure index value between 0 and 1. The value would be 0 if the elevation of the contour remained below the water surface for all 144 quarter-month time steps of the preceding three years, and it would be one if the contour of the depth interval had been above the water surface in all of the time steps of the preceding three years.

- **Step 10 –** Computes the terrestrial plant growth substrate conditioning factor. Terrestrial plant growth results from exposure to air over successive weeks during the growing season. Once inundated, terrestrial plant growth benefits spawning habitat by providing cover for nests and larvae. This condition factor is computed as is the proportion of preceding time steps contiguous with the current time step that were above the current reservoir surface elevation contour during the preceding three years. This proportion is computed only for the growing season quarter-months, which are considered to be the 18 quarter-months from mid-February through June. Thus, there are a maximum of 54 quarter-months for the three-year period. The value of plants as cover for nests is considered to increase with the time available for their growth. Inundation is considered to terminate plant growth, but the cover value of previous plant growth remains for some time after inundation as the plants decompose. To account for this continuing but diminishing value of plants following inundation, the model removes two quarter-months for each time step following initial inundation of the contour. Like the exposure to air index, the terrestrial plant growth index ranges from zero to 1.

- **Step 11 –** Computes the sedimentation substrate conditioning factor. Sedimentation generally increases with the depth of a contour. Fine sediments and unoxidized organic material build up when an elevation contour sits in deep water, which adversely affects spawning habitat suitability. This factor is computed in three sub-steps. Sub-step 1 computes the average depth of each elevation contour over the three years before the current time step. Sub-step 2 subtracts this average depth from the maximum reservoir depth to minimum pool and divides this difference by this maximum depth. Sub-step 3 aggregates the computed sedimentation factors by depth intervals. The deeper the average depth of the elevation contour, the smaller the value of the factor, which reflects the reduced habitat suitability of substrate with fine sediment accumulations. Like the exposure to air and terrestrial plant growth indices, the sediment substrate condition index ranges from zero to 1.

- **Step 12 –** Combines the three substrate conditioning factors (indices) after scaling them according to their relative importance. The terrestrial plant growth factor, which is considered the most important of the three, is multiplied by five, the air exposure factor is multiplied by three, and the sedimentation factor is not changed. A one is added after multiplication for each of the factors to moderate their effects. Addition of one insures that the plant growth factor can modify the simulated spawning production no more than six-fold, the air exposure factor can modify simulated production no more than three-fold, and the sedimentation factor can modify simulated production no more than two-fold. If one were not added, the potential effect of the factors would approach infinity. Following addition of one to each of the scaled factors, the factors are summed and the sum is divided by eleven to make the maximum combined index value equal to one.

- **Step 13 –** Computes an index of spawning production density (i.e., production of larvae leaving the nest per unit area) for each time step and depth interval as the product of the combined substrate conditioning factor (Step 12), the depth suitabilities/nest densities (Step 8), proportion of eggs/larvae surviving per nest (Step 7), and computed nest cycles (Step 6).

- **Step 14 –** Computes an index of total spawning production (i.e., total production of larvae leaving the nest) per time step and depth interval as the product of the production density (Step 13) and the total surface area of the depth interval in the reservoir (Step 1).

Black Bass Modeling Results Summary and Discussion

Results of the black bass modeling are discussed within EIS Chapter 5, “Biological Resources – Fisheries and Aquatic and Ecosystems” and results are included in the Modeling Results Supporting Chapter 5 – Fisheries and Aquatic Ecosystems Attachment.

San Joaquin River Fisheries Habitat Modeling

The EDT model is a life-cycle and habitat model that has been applied to the San Joaquin River between Friant Dam and the Merced River for the SJRRP (herein referred to as the SJRRP EDT) to test potential spring-run Chinook salmon habitat improvements that could be provided by various restoration actions and changes in flow and temperature. To maintain consistency with the SJRRP and treatment of the changing San Joaquin River conditions, the Investigation has also applied the EDT model to measure potential improvements to spring-run Chinook salmon habitat resulting from Temperance Flat RM 274 Reservoir action alternatives.

Model Description

EDT characterizes the aquatic environment temporally (monthly) and spatially (stream reaches) “through the eyes of salmon.” Habitat in EDT is evaluated along numerous life history trajectories. Life history trajectories can be thought of as pathways through time and space that each fish might use to complete its life cycle, varying with respect to habitat quality and quantity. The potential performance of fish along these pathways is based on the exposure of fish to conditions along them. Exposure is controlled by defined life history tactics. Tactics are based on the generalized life history but also address how fish might behave within the watershed. Across a San Joaquin River population, some fish could spawn early or later, could spawn higher or lower in the system, could move quickly through some areas, and could pause in others. Each of these behaviors represents a different potential exposure of fish to conditions within the San Joaquin River between Friant Dam and the confluence with the Merced River.

EDT evaluates these conditions using a set of species- and life-stage-specific habitat relationships. The quality and quantity of habitat along each trajectory is assessed as the productivity and capacity of salmonids potentially using that pathway. The integration of performance across trajectories provides an estimate of the productivity and capacity of a fish population in the environment and their variation due to heterogeneity of the habitat and fish behavior. The population-level estimate of productivity and capacity can be disaggregated to study habitat constraints at reach, life-stage, and attribute levels, and to understand the basis for population level results.

EDT is a hierarchically organized, spatially explicit model that analyzes aquatic habitat along multiple salmonid life history trajectories to help managers and scientists investigate the biological and environmental constraints on species performance within a watershed. The model results in population-level metrics of productivity and capacity of a fish population.

For this analysis, productivity varies between alternative plans largely (though not entirely) as a result of water temperature and flow variation, while capacity varies due to temperature, flow variation, and channel width as a function of flow. EDT uses these relationships to characterize habitat along each life history trajectory. As a final step, productivity and capacity are integrated across all the trajectories to estimate the recruitment potential of the habitat in Beverton-Holt terms.

In summary, EDT characterizes habitat under an alternative plan in regard to the potential of the habitat to support spring-run Chinook salmon using the following metrics:

- **Productivity** – the density-independent survival rate (survival without competition). Productivity is computed as a function of habitat quality as affected by attributes such as temperature, water quality, and food.

- **Capacity** – the total abundance that could be supported by the quantity of suitable habitat. Capacity is a function of the quantity of habitat (square meters), productivity, and food.

- **Equilibrium abundance (Neq)** – The equilibrium abundance point on a Beverton-Holt function under steady-state conditions. Neq is computed from productivity and capacity. Neq can be considered the steady-state abundance of adults considering both habitat quantity and quality.

The model uses environmental data for each reach, including temperature and flow data, and quantifies the suitability of the environment in terms of productivity and capacity parameters of the Beverly-Holt production function. The analysis is carried out over hundreds or thousands of different life-stage trajectories and summarized for use.

The EDT application to the San Joaquin River breaks the river into 18 unique reaches. All required inputs and relationships were unchanged from the SJRRP application with the exception of the flow and temperature data specific to each alternative plan. An existing post-processing tool from the SJRRP was used to read the temperature and flow data from SJR5Q and prepare the data for input to the EDT model. This tool is fully described in the SJRRP PEIS/R Modeling Appendix (SJRRP 2012).

EDT Modeling Results Summary and Discussion

EDT output includes variables describing the productivity and capacity of fish habitat that could develop under the flow and temperature regimes for each alternative plan. Productivity and capacity can be combined into the abundance characteristic, representing the number of spawning fish that the habitat could sustain. Due to uncertainty and limited data regarding the survival of salmon as they migrate below the Merced River, to the ocean, and then return to spawn, results were developed to demonstrate a range of potential results for a low and high potential smolt-to-adult return rate (SAR).

The potential improvements due to Temperance Flat RM 274 Reservoir operations for spring-run Chinook salmon habitat were measured by comparing the water-year type weighted average abundance for each action alternative to that of the No Action Alternative as a percent improvement in abundance.

Results for spring-run Chinook salmon productivity, capacity, and abundance, as well as the percent change from No Action Alternative for each action alternative are shown in Table 5-1 and for the high SAR and in Tables for the low SAR. All results are for the future conditions. The tables also show the year-type probability weighted average abundance and percent change in abundance for each alternative plan compared to the No Action Alternative.

Table 5-1. Modeling Results and Percent Change for High Smolt-to-Adult Survival Rate by Year Type

Alternative	Habitat Productivity				Habitat Capacity				Equilibrium Abundance				Weighted Average Abundance
	Dry	Normal Dry	Normal Wet	Wet	Dry	Normal Dry	Normal Wet	Wet	Dry	Normal Dry	Normal Wet	Wet	
No Action Alternative	4.32	5.27	5.62	6.6	3,179	4,247	4,911	7,851	2,443	3,441	4,037	6,661	3,895
Alternative Plan 1	4.7	5.3	5.64	6.87	3,596	4,369	5,043	7,726	2,831	3,545	4,149	6,601	4,005
	8.8%	0.6%	0.4%	4.1%	13.1%	2.9%	2.7%	-1.6%	15.9%	3.0%	2.8%	-0.9%	2.8%
Alternative Plan 2	4.69	5.32	5.65	6.84	3,515	4,408	5,054	7,703	2,766	3,579	4,159	6,577	4,003
	8.6%	0.9%	0.5%	3.6%	10.6%	3.8%	2.9%	-1.9%	13.2%	4.0%	3.0%	-1.3%	2.8%
Alternative Plan 3	4.71	5.38	5.49	6.57	3,556	4,327	4,937	7,541	2,801	3,523	4,038	6,393	3,919
	9.0%	2.1%	-2.3%	-0.5%	11.9%	1.9%	0.5%	-3.9%	14.7%	2.4%	0.0%	-4.0%	0.6%
Alternative Plan 4	4.65	5.37	5.86	6.97	3,522	4,446	5,253	7,737	2,765	3,618	4,357	6,627	4,085
	7.6%	1.9%	4.3%	5.6%	10.8%	4.7%	7.0%	-1.5%	13.2%	5.1%	7.9%	-0.5%	4.9%
Alternative Plan 5	4.60	2.92	5.59	6.60	3,693	4,237	4,784	6,738	2,890	2,788	3,928	5,718	3,552
	6.5%	-44.5%	-0.6%	0.1%	16.2%	-0.2%	-2.6%	-14.2%	18.3%	-19.0%	-2.7%	-14.2%	-8.8%

Note:
Year types are San Joaquin River Restoration Program year types.

Table 5-2. Modeling Results and Percent Change for Low Smolt-to-Adult Survival Rate by Year Type

Alternative	Habitat Productivity				Habitat Capacity				Equilibrium Abundance				Weighted Average Abundance
	Dry	Normal Dry	Normal Wet	Wet	Dry	Normal Dry	Normal Wet	Wet	Dry	Normal Dry	Normal Wet	Wet	
No Action Alternative	3.09	3.80	4.25	4.83	611	827	944	1,444	413	609	722	1,144	682
Alternative Plan 1	3.29	3.74	4.15	4.96	677	833	943	1,417	471	610	716	1,131	686
	6.5%	-1.6%	-2.4%	2.7%	10.8%	0.7%	-0.1%	-1.9%	14.0%	0.2%	-0.8%	-1.1%	0.6%
Alternative Plan 2	3.28	3.76	4.15	4.94	649	840	945	1,413	451	616	717	1,127	685
	6.1%	-1.1%	-2.4%	2.3%	6.2%	1.6%	0.1%	-2.1%	9.2%	1.1%	-0.7%	-1.5%	0.4%
Alternative Plan 3	3.29	3.79	4.09	4.77	672	832	937	1,389	468	613	707	1,098	678
	6.5%	-0.3%	-3.8%	-1.2%	10.0%	0.6%	-0.7%	-3.8%	13.3%	0.7%	-2.1%	-4.0%	-0.6%
Alternative Plan 4	3.25	3.78	4.29	5.04	663	848	984	1,417	459	624	754	1,136	701
	5.2%	-0.5%	0.9%	4.3%	8.5%	2.5%	4.2%	-1.9%	11.1%	2.5%	4.4%	-0.7%	2.8%
Alternative Plan 5	3.23	2.07	4.14	4.79	696	813	902	1237	480	420	684	979	593
	4.5%	-45.5%	-2.6%	-0.9%	13.9%	-1.7%	-4.4%	-14.3%	16.3%	-31.0%	-5.2%	-14.4%	-13.1%

Note:
Year types are San Joaquin River Restoration Program year types.

Figure 5-1 shows the year-type weighted average percent improvement in abundance for each action alternative, as compared to the No Action Alternative, as a range between the low-SAR and high-SAR results. The percent change from No Action Alternative is based on weighted average abundance, weighted by the probability of each water year type. Figure 5-1 demonstrates the range of potential benefits and impacts for each action alternative to improve habitat conditions compared with the No Action Alternative.

Figure 5-2 through Figure 5-5 show the range and mean abundance for each of the four SJRRP water year types occurring from 1980–2003. All action alternatives improve abundance in the dry years, regardless of SAR. In normal-dry years, the Alternative Plans 1, 2, 3, and 4 also improve abundance in low- and high-SAR assumptions. In normal wet years, Alternative Plans 1 and 2 improve abundance in high-SAR assumptions, and Alternative Plan 4 improves abundance regardless of SAR. In wet years, the action alternatives do not improve abundance, regardless of SAR.

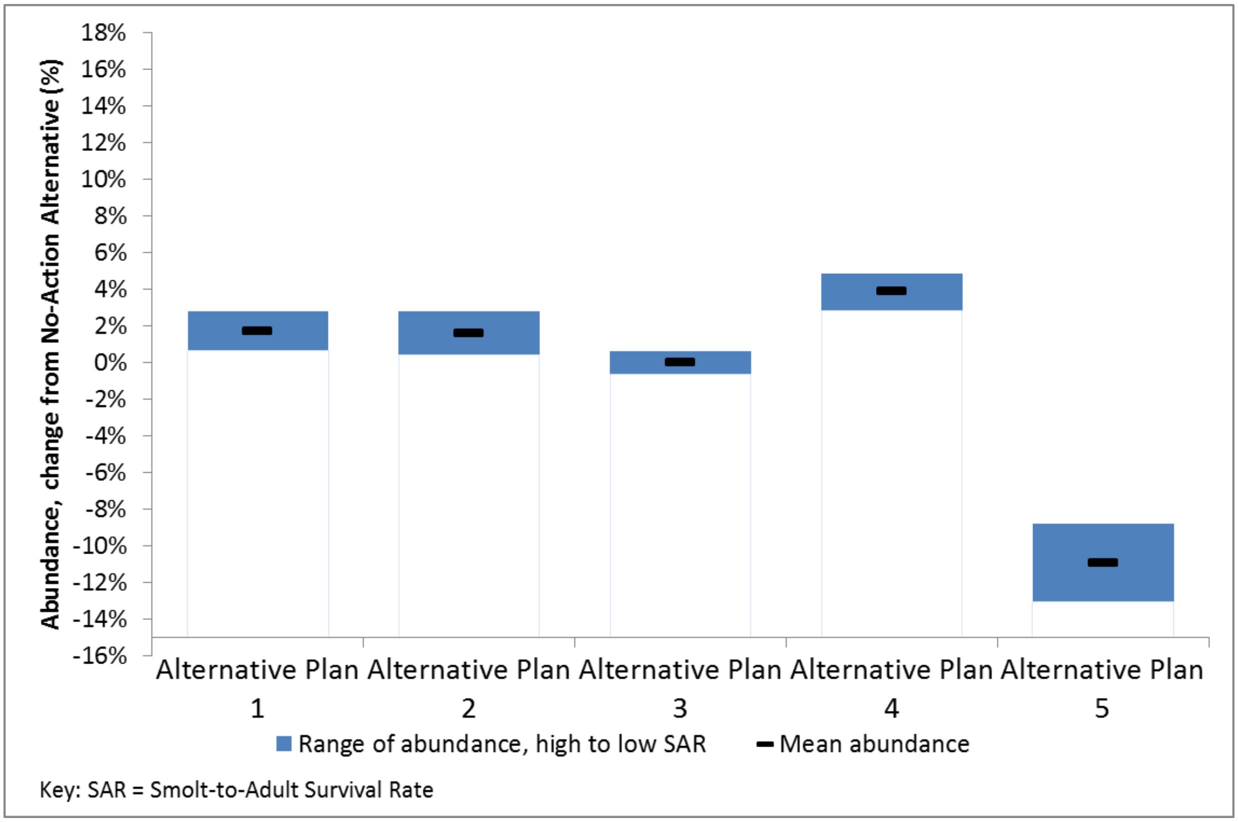

Figure 5-1. Spring-Run Chinook Salmon Abundance Range and Mean, Action Alternatives Compared to No-Action Alternative – Weighted Average

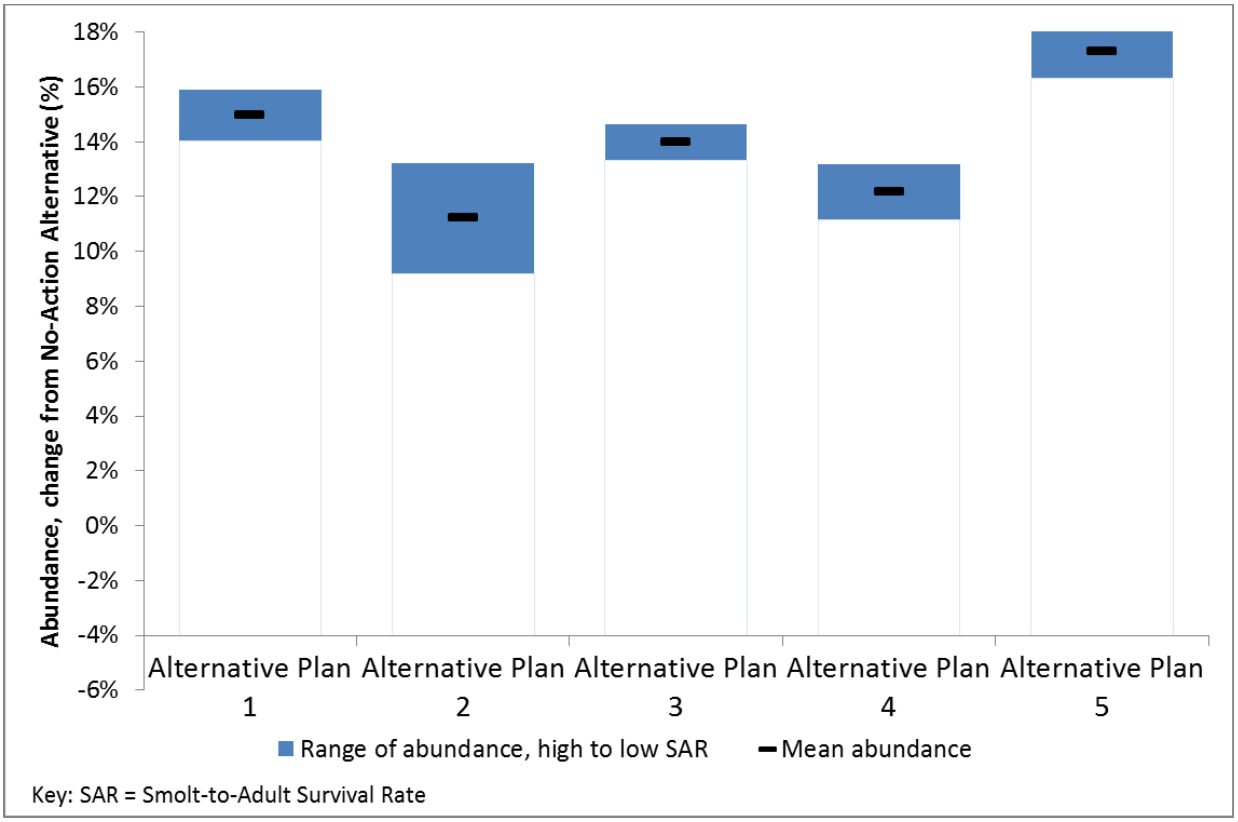

Figure 5-2. Spring-Run Chinook Salmon Abundance Range and Mean, Action Alternatives Compared to No-Action Alternative – Dry Years

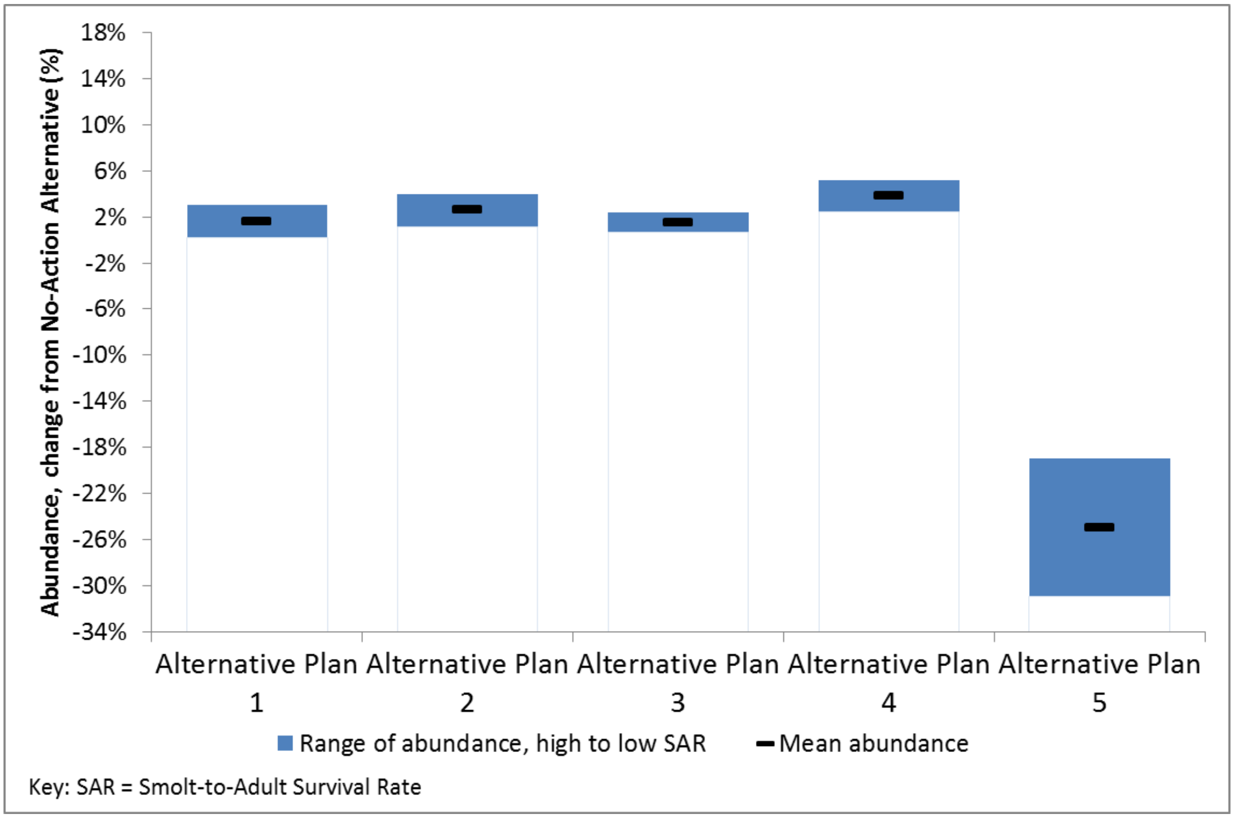

Figure 5-3. Spring-Run Chinook Salmon Abundance Range and Mean, Action Alternatives Compared to No-Action Alternative – Normal-Dry Years

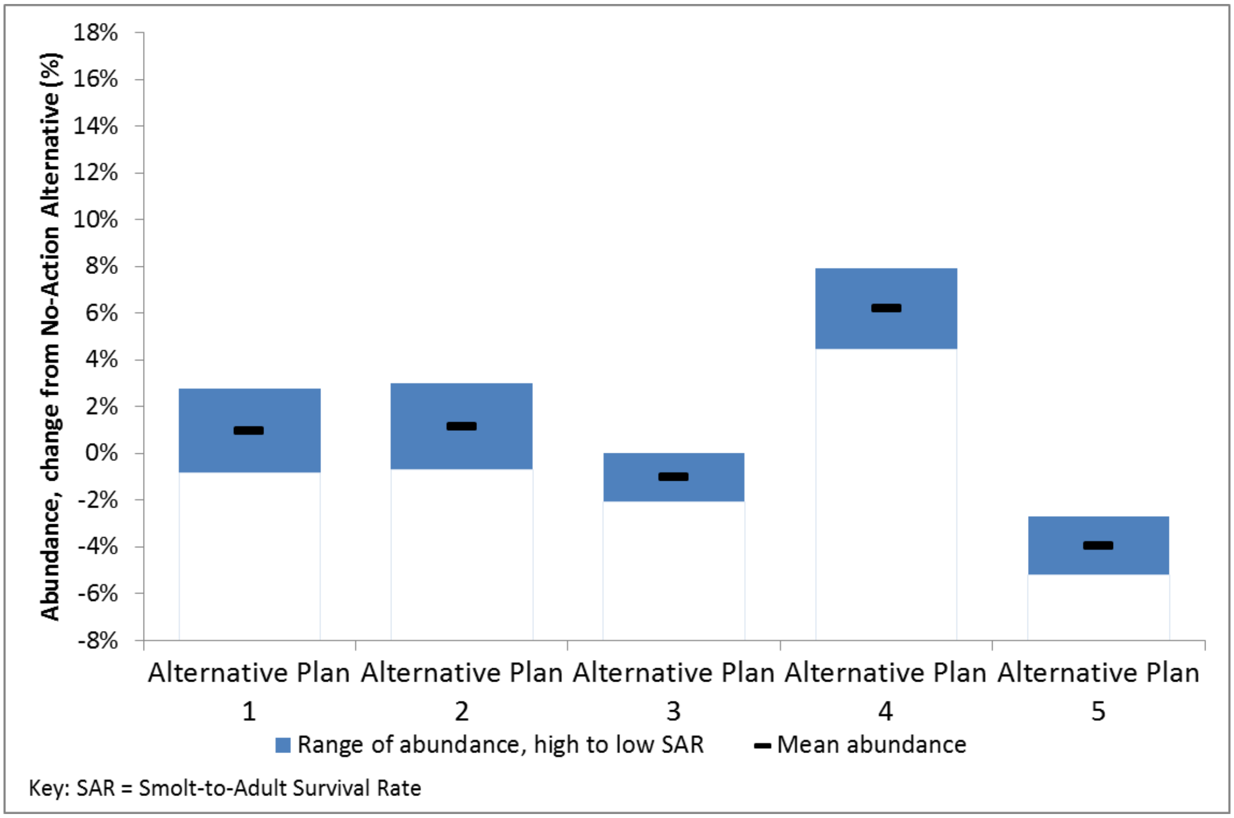

Figure 5-4. Spring-Run Chinook Salmon Abundance Range and Mean, Action Alternatives Compared to No-Action Alternative – Normal-Wet Years

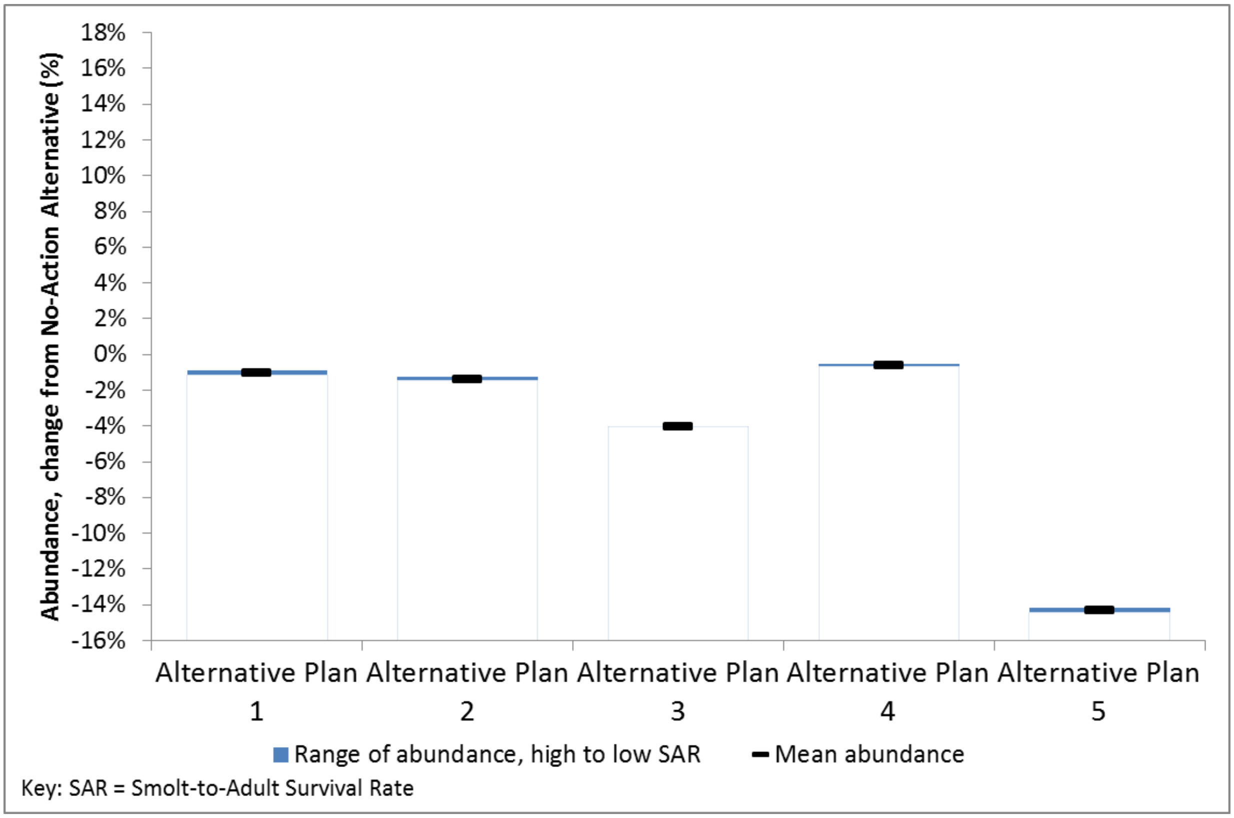

Figure 5-5. Spring-Run Chinook Salmon Abundance Range and Mean, Action Alternatives Compared to No-Action Alternative – Wet Years

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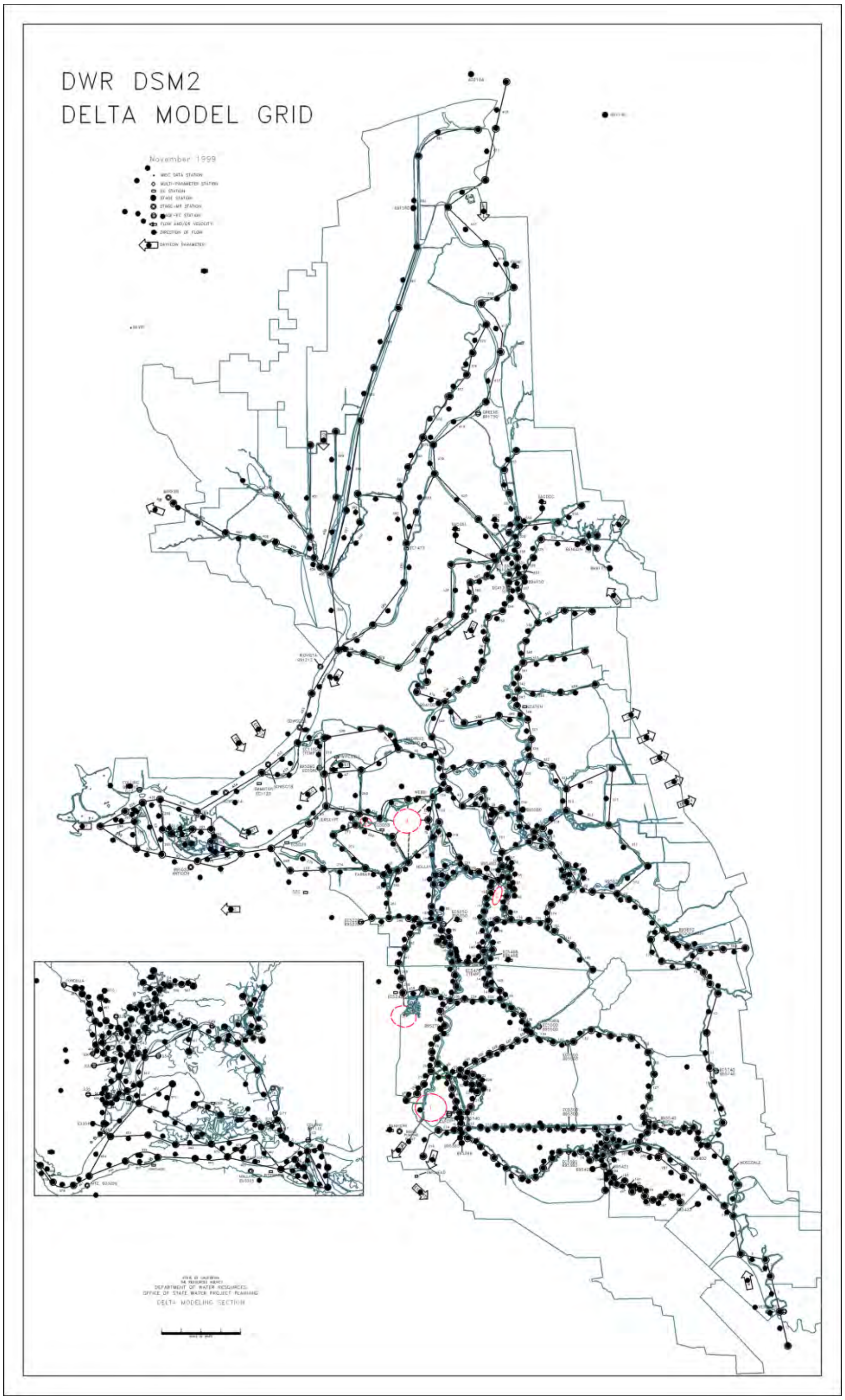
Chapter 6
Delta Hydrodynamic and Salinity Modeling

This chapter describes the Delta hydrodynamic and salinity modeling that was performed for the Investigation.

Model Description

Delta hydrodynamic and salinity modeling was performed using the Delta Simulation Model II (DSM2), a branched 1-dimensional, physically-based numerical model of the Delta developed by DWR in the late 1990s. DSM2 consists of two modules: DSM2-Hydro and DSM2-Qual. DSM2-Hydro, the hydrodynamics module, is derived from the USGS Four Point model. DSM2-Qual, the water quality module, is derived from the USGS Branched Lagrangian Transport Model. Details of the model, including source codes and model performance, are available from the DWR, Bay-Delta Office at the following web address: (http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm). Documentation of model development is discussed in annual reports to State Water Resources Control Board, *Methodology for flow and salinity estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*, by the Delta Modeling Section of DWR.

The DSM2 schematic is shown in Figure 6-1. Key DSM2 inputs include tidal stage, boundary inflow and salinity concentration, and operation of flow control structures. Table 6-1 summarizes basic input requirements and assumptions.



Source: California Department of Water Resources, Bay-Delta Office, Delta Modeling Section, http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2v6/dsm2.cfm

Figure 6-1. Illustration of DSM2 Schematic

Table 6-1. DSM2 Input Requirements and Assumptions

Parameters	Assumptions
Period of simulation	October 1922 – September 2003
Boundary flows	CalSim II output
Boundary stage	15-minute adjusted astronomical tide
Agricultural diversion & return flows	Delta Island Consumptive Use model, 2005/2020 LOD
Salinity	
Martinez EC	Computed from modified G-model, adjusted astronomical tide, and Net Delta Outflow from CalSim-II
Sacramento River	Constant value = 175 µS/cm
Yolo Bypass	Constant value = 175 µS/cm
Mokelumne River	Constant value = 150 µS/cm
Cosumnes River	Constant value = 150 µS/cm
Calaveras River	Constant value = 150 µS/cm
San Joaquin River	CalSim-II EC estimate using modified Kratzer equation
Agricultural drainage	Varying monthly values that are constant year to year
Facility Operations	
Delta Cross Channel	CalSim II output
South Delta barriers	Temporary barriers/SDIP operation of permanent barriers

Key:
µS/cm = microsiemens per centimeter
EC = electroconductivity
LOD = level of development
SDIP = South Delta Improvements Program

In DSM2 model simulations, electroconductivity (EC) is typically used as a surrogate for salinity. Results from the routed CalSim II modeling discussed in Chapter 3 are used to define Delta boundary inflows. CalSim II-derived boundary inflows include the Sacramento River flow at Hood, San Joaquin River flow at Vernalis, inflow from the Yolo Bypass, and inflow from the eastside streams. In addition, Net Delta Outflow from CalSim II is used to calculate the DSM2 salinity boundary at Martinez.

Planning Tide at Martinez Boundary

Tidal forcing is imposed at the downstream boundary at Martinez as a time series (TS) of stage (for the hydrodynamic module) and salinity (for the water quality module). DWR has traditionally used a "19-year mean tide" (or "repeating tide") in all DSM2 planning studies, in which the tide is represented by a single repeating 25-hour cycle. An "adjusted astronomical tide" was later developed by DWR that accounts for the spring-neap variation of the lunar tide cycle (California Department of Water Resources 2001a). However, before the Common Assumptions Common Model Package (CACMP) effort, the adjusted astronomical tide had only been developed for a 16-year period, from 1976 to 1991; the 19-year mean repeating tide was used for simulating the 73-year period (1922 through 1994).

An updated version of DSM2 has been developed that simulates an 82-year (1922 through 2003) CalSim II period of record using an adjusted astronomical tide and is the version used for this EIS.

Salinity Boundary Conditions

Salinity boundary conditions are defined at various locations, as described below.

Martinez

Salinity at the Martinez downstream boundary reflects intrusion of saltwater into San Pablo Bay from the ocean. It is determined using an empirical model known as the modified G-model (DWR 2001b). The model calculates a 15-minute TS of salinity values based on the adjusted astronomical tide and Net Delta Outflow. Since these aggregate flows are available from CalSim II, salinity at Martinez can be preprocessed and input to DSM2 as TS data. Each simulation has a different EC boundary condition at Martinez, reflecting the different inflows and exports from the Delta that occur in a particular scenario.

Sacramento River/Yolo Bypass/ Eastside Streams

The inflow salinities for the Sacramento River, Yolo Bypass, and eastside streams (Mokelumne River, Cosumnes River, and Calaveras River) were assumed to be constant at 175, 175, and 150 microsiemens per centimeter (µS/cm), respectively.

San Joaquin River at Vernalis

CalSim II calculates EC for the San Joaquin River at Vernalis using a modified Kratzer equation. The resulting EC values were used to define the inflow salinity for DSM2.

Agricultural and Municipal and Industrial Return Flows

The salinity of agricultural return flows was based on an analysis of Municipal Water Quality Investigations data (DWR 1995). Monthly, regional representative EC values of drainage were determined for three regions in the Delta (north, west, and southeast regions). EC values vary by month, but are constant from year to year and are independent of the level of development (LOD). EC values were highest for the west region due to its proximity to the ocean. The monthly EC values follow a seasonal trend with the highest concentrations occurring in winter and spring during the rainfall-runoff season (approximately 820 µS/cm to 1,890 µS/cm). Lowest drainage concentrations occur in July and August (approximately 340 μS/cm to 920 μS/cm).

Delta Channel Flow

Sacramento River water flows into the central Delta via the Delta Cross Channel and Georgiana Slough. The Delta Cross Channel, constructed in 1951 as part of the CVP, connects the Sacramento River to the Mokelumne River via Snodgrass Slough. Its purpose is to increase flow in the lower San Joaquin River and to reduce salinity intrusion and the movement of saline water from Suisun Bay toward Contra Costa Water District's (CCWD) Rock Slough intake and the Jones Pumping Plant. Two radial gates regulate flow through the Delta Cross Channel. When the gates are open, flow through the Delta Cross Channel is determined by the upstream stage in the Sacramento River. Similarly, flow through Georgiana Slough is a function of the upstream Sacramento River stage. Sacramento River water is also transported southward through Threemile Slough, which connects the Sacramento River just downstream from Rio Vista to the San Joaquin River.

The mouth of the Old River, located upstream from the mouth of the Mokelumne River, is the major conduit for water flowing from the Sacramento River, through Georgiana Slough and the Delta Cross Channel, via the Mokelumne River, to the south Delta. Additional water for the CVP/SWP export pumps moves through the mouth of the Middle River, Columbia Cut, Turner Cut, False River, Fisherman's Cut, and Dutch Slough. Net flows at the mouth of the Old River and Middle River are influenced by CVP/SWP exports and south Delta irrigation diversions (approximately 40 percent of total net Delta diversions). Previous DSM2 simulations indicate that about 45 percent of south Delta exports flows through the mouth of the Old River or through the False River. About 40 percent of the south Delta exports flows through the mouth of the Middle River, and about 10 percent of the flow is through Turner Cut. This division of flow is insensitive to the magnitude of exports (Jones and Stokes 2004).

Flow Control Structures

A number of flow control structures are currently operated seasonally in the Delta. These structures can have a major impact on water quality by changing the pattern of flow through the Delta.

Clifton Court Forebay

In all DSM2 simulations, the Clifton Court Forebay gates were operated tidally using "Priority 3." Under Priority 3, the gates are closed 1 hour before and 2 hours after the lower low tide. They are also closed from 2 hours after the high low tide to 1 hour before the high tide. Discharge is proportional to the square root of the head difference across the gates. Maximum flow was capped at 15,000 cfs. The discharge coefficient was set equal to 2,400, which results in a flow of 15,000 cfs for a 1.0-foot head difference.

Delta Cross Channel

The Delta Cross Channel has a major impact on salinity in the central and south Delta. CalSim II calculates the number of days the Delta Cross Channel is open in each month. The 1995 Water Quality Control Plan (State Water Board 1995) specifies that the gates be closed for 10 days in November, 15 days in December, and 20 days in January, from February 1 to May 20, and for 14 days between May 21 and June 15. In addition, the gates must be closed to avoid scouring whenever Sacramento River flow at the Delta Cross Channel is greater than 25,000 cfs. For DSM2 simulations, all partial month closings of the Delta Cross Channel were assumed to occur at the end of the month.

South Delta Barriers

DSM2 modeling of existing conditions includes the South Delta Temporary Barriers Project, which consists of four rock barriers that are temporarily installed across south Delta channels. The objectives of the project are as follows:

- Increase water levels, circulation patterns, and water quality in the south Delta area for local agricultural diversions.
- Improve operational flexibility of the SWP to help reduce fishery impacts and improve fishery conditions.

Details of the temporary barriers can be found on DWR's Web site (http://baydeltaoffice.water.ca.gov/sdb/tbp/index_tbp.cfm). Of the four temporary barriers, the Head of Old River barrier serves as a fish barrier and has been in place most years between September 15 and November 30 since 1963. The remaining three barriers serve as agricultural barriers and are installed between April 15 and September 30. Installation and removal dates of the barriers are based on the USACE Section 404 Permit, California Department of Fish and Wildlife 1601

Permit, and various Temporary Entry Permits required from landowners and local reclamation districts. Table 6-2 gives the assumed temporary barrier operation for modeling existing conditions.

Table 6-2. Temporary Barrier Simulated Operation

Barriers	DSM2 Channel No.	Closure	Complete Removal
Head of Old River (spring)	54	April 15	May 15
Head of Old River (fall)	54	September 15	November 30
Middle River	134	April 15	November 30
Old River near Tracy	99	April 15	November 30
Grant Line Canal	206	May 15	November 30

Key:
DSM2 = Delta Simulation Model 2

DSM2 modeling of future conditions includes the four proposed South Delta Improvement Program permanent operable barriers, one each at the head of the Old River, Grant Line Canal, Old River at Tracy Road Bridge, and Middle River at Old River (Reclamation and DWR 2005). These gates are intended to replace the existing temporary barriers to minimize the number of in- and out-migrating salmon moving toward export pumps; maintain adequate water levels for south Delta farmers to prevent cavitation from occurring in their irrigation pumps; and improve water quality in south Delta channels by providing better circulation. The DWR Delta Modeling Section developed three sets of operations for the gates: Plans A, B, and C. Plan A focused on achieving higher water levels, but did not result in significant improvement in water quality. Plan B modified Plan A gate operations, resulting in slight improvement in circulation and water quality compared to Plan A. Plan C gate operations evolved to achieve the objective of improving water quality with better flow circulation in south Delta channels, in addition to maintaining adequate water levels. Plan C permanent barrier operations were assumed for Future Condition DSM2 simulations.

Suisun Marsh Salinity Control Gate

The Suisun Marsh Salinity Control Gate limits flow in Montezuma Slough from Suisun Marsh during flood tide, and allows drainage from the marsh during ebb tide. The gates are not operated in the summer months (June through September) and are not operated at all in some wet years. Actual gate operations are triggered by salinity levels in Suisun Marsh. However, in DSM2 months, gate operations are an input to the model. Suisun Marsh diversion and drainage flows have relatively little effect on salinity upstream from Chipps Island.

Delta Island Consumptive Use

DSM2 uses the Delta Island Consumptive Use (DICU) model to develop agricultural diversions and return flows to each of 142 Delta subareas on a monthly time step. An associated routine allocates the diversions and return flows to approximately 250 diversion nodes and 200 drainage nodes in DSM2. The DICU model considers precipitation, seepage, evapotranspiration, irrigation, soil moisture, leach water, runoff, crop type, and acreage. The net DICU is computed as diversions plus seepage less drainage. Positive values indicate a net depletion of water from the Delta channels; negative values indicate a net return flow from the Delta islands into the channels. DICU follows the seasonal pattern of irrigation diversions during the summer and drainage return flows from winter runoff.

DSM2 net channel accretions and depletions match the aggregated values used in CalSim II so that the Net Delta Outflow is consistent between the two models.

Water Quality Conversions

DSM2 uses EC as a substitute for salinity. However, other water quality constituents were also needed to assess potential impacts of the alternative plans.

DWR has derived relationships between EC, bromide, and chloride at Delta export locations for use in the In-Delta Storage Investigations (Suits 2001). Suits (2001) gives a regression equation for EC at the Old River at Rock Slough as a function of chloride at Contra Costa Canal Pumping Plant No. 1, and a regression equation relating EC to chloride at the Los Vaqueros intake. The relationship between EC and chloride in the vicinity of the Clifton Court Forebay and Delta-Mendota Canal (DMC) intake is more complex. In general, the relationship depends on whether the source water is derived from the San Joaquin River or the Sacramento River. The regression equation established by Suits is conservative, giving high values of chloride for a given EC. The relationship between chloride and bromide is fairly uniform with little site-specific variation (Suits 2001). Therefore, a single regression equation can be used for different export locations. Regression equations used to convert EC to chloride are given in Table 6-3.

Table 6-3. Relationship Between Salinity Parameters

Location	Slope	Intercept
Old River at Rock Slough to Contra Costa Canal at CCWD Pumping Plant No.1	0.268	-24.0
Clifton Court Forebay	0.273	-43.9
DMC Intake	0.273	-43.9

Source: Suits 2001

Key"

CCWD = Contra Costa Water District

PP = Pumping Plant

Delta Hydrodynamic Modeling Results Summary and Discussion

Salinity objectives at selected compliance locations are described in the EIS in Chapter 15, “Hydrology – Surface Water Quality.” Output related to EC, chloride, and alternative plans’ ability to meet salinity objectives are provided in the DSM2 Modeling Attachment.

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Chapter 7
Hydropower Modeling

The purpose of this chapter is to provide information on impacts of the Investigation alternative plans on the power generation at Pacific Gas and Electric Company's (PG&E) Kerckhoff Hydroelectric Project (Kerckhoff Project) and the mitigation potential of the proposed hydropower facilities for the alternative plans. This chapter describes existing hydropower facilities in the upper San Joaquin River Basin between Friant Dam and Kerckhoff Lake, and methodology used to calculate hydropower generation and revenue for all alternative plans. In addition, the chapter describes methodology to calculate hydropower generation and pumping energy required in existing CVP and SWP hydropower facilities for all alternative plans.

Developing any surface water storage alternative considered in the Investigation could affect operations of existing hydropower facilities and provide opportunities for new hydroelectric power production. This chapter describes the methodology to evaluate hydropower energy and ancillary services at existing and proposed facilities. Ancillary services are defined as: (1) non-spin, (2) spin, (3) regulation-up, and (4) regulation-down. Since regulation-up is usually the highest value product of the four types of ancillary services being considered, only this product was modeled in PLEXOS®. Capacity accomplishments were not explicitly evaluated except that ancillary services are constrained by available capacity.

Hydropower accomplishment estimates were made using modeling approaches that applied output from water operations models developed for the Investigation. The water operations and models are further described in Chapter 3.

Hydropower Models

Four different hydropower models were used for the hydropower accomplishments evaluation in this analysis. This chapter is organized to provide a description of each model and its results. The four models are:

1. **Local Hydropower Generation** – Simulates existing local hydropower energy generation from the Kerckhoff

Power Project and Friant Power Project and proposed local hydropower generation at Temperance Flat RM 274 Reservoir based on daily operation simulation.

2. **PLEXOS®** – Simulates hourly hydropower generation and capacity at Temperance Flat RM 274 Reservoir and Kerckhoff Projects dispatch in an optimized manner to maximize the value of energy and ancillary services on an hourly basis.
3. **LongTermGen** – Simulates CVP system power generation and power consumption at pumping facilities based on monthly mean operation information from CalSim II.
4. **SWP_Powe**r – Simulates SWP system power generation and power consumption at pumping facilities based on monthly mean operation information from CalSim II.

Local Hydropower Generation

This section discusses the hydropower modeling performed at the Kerckhoff Power Project and the Friant Power Project for the alternative plans.

Model Description

An Excel-based post-processing tool was developed to prepare the required input data for the local hydropower generation model and was applied for each alternative plan. The tool extracts data from the Daily Model (described in Chapter 3) output for use in the local hydropower generation model. The data extracted are as follows:

- SJR Inflow to Kerckhoff
- Madera Canal Diversion
- Friant-Kern Canal Diversion
- Millerton Lake SJR Outlet Release
- Temperance Flat Reservoir Power Outlet Flow
- Millerton Lake EOD Storage
- Temperance Flat Reservoir EOD Storage

The local hydropower generation model was used to simulate existing and future daily energy generation from the Kerckhoff Project and Friant Power Project, and future daily energy generation from the proposed Temperance Flat RM 274 Reservoir powerhouse using the methodology and assumptions described within this section.

Hydropower Equation

A typical powerhouse configuration at the base of a dam is shown in Figure 7-1. Primary variables that affect energy generation at these powerhouses are flow rates available from storage reservoirs, head (the elevation difference between the upstream reservoir and the water level below the powerhouse), and equipment efficiencies and operational constraints. The water-power equation is defined by the following formula:

$$\mathrm{kW} = \frac{\mathrm{Q} \times \mathrm{H} \times \mathrm{e}}{11.81} \qquad (1)$$

Where:

kW = power (kilowatt)
H = net head (feet)
Q = flow rate through turbine (cubic feet per second)
e = efficiency of the turbine (%)
11.81 = unit conversion factor

To convert the power output kilowatt to energy kilowatt-hour (kWh), the water power generation equation must be integrated over time.

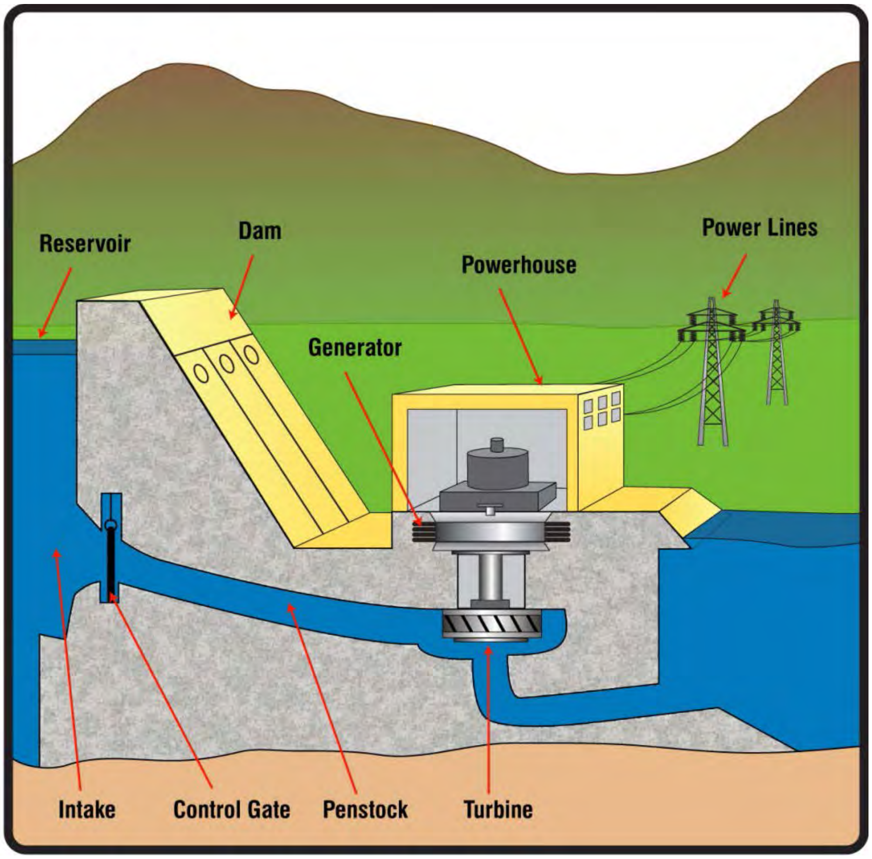

Figure 7-1. Typical Hydroelectric Energy Generation Facility

Net head (H) is the actual head available for power generation, and is used for computing the energy generated. The net head is the gross head, minus head losses through intake structures, penstocks, and outlet works. The gross or static head is determined by subtracting the tailwater elevation from the forebay water surface elevation. Head losses in this analysis are assumed to be 2 percent to 7 percent of the gross head, depending on powerhouse configuration.

Flow rate (Q) used for energy calculations is the rate of usable flow available for power generation. Usable flow is the flow passing through the powerhouse, and does not include spillway releases.

Efficiency (e) is the overall efficiency of the turbine and the generator. Generation efficiencies in this analysis are based on historical data, or are assumed using generator and turbine configurations and simulated hydrology.

The water-power equation, using results from daily water operations models, was used to calculate daily generation for existing and proposed hydroelectric powerhouses. The approach for estimating hydropower energy generation was as follows:

1. Water-level elevations of the forebay and tailwater or afterbay for each powerhouse are estimated based on reservoir storage output from the water operations model and bathymetric data.

2. Water elevations are then used to compute gross head and net head. Net head takes into account head loss in tunnels, penstocks, etc. Head loss in long conveyance tunnels is calculated based on a design flow.

3. Generation release is then calculated using net head and unit capacity. If the net head is outside the head range of the unit(s), the generation release is zero.

4. The number of hours that generation release can be sustained is then calculated, based on the daily flow from the water operations model.

5. Using the net head, the available water release for generation, and assumed efficiencies, the total power capacity (megawatt) is calculated.

6. Generation (megawatt-hours) is then calculated using the total number of hours the generation releases can be sustained and the total power capacity.

Kerckhoff Hydroelectric Project Assumptions

Simulated Kerckhoff Project generation was used as existing conditions, or the No Action Alternative, to address mitigation requirements for generation in the Investigation. The parameters and assumptions used in this hydropower generation analysis for the Kerckhoff Project are listed in Table 7-1 and described as follows:

- **Kerckhoff Lake Elevation** – Kerckhoff Lake levels would fluctuate hourly and daily due to the assumed ponding operations, up to approximately 5 feet. This change represents 1 percent to 2 percent of the gross head available to the Kerckhoff Project. To simplify Kerckhoff Lake operations in head calculations, a constant elevation at Kerckhoff Lake is assumed. The average Kerckhoff Lake elevation from 1986 to 2007 is 985.9 feet.

- **Head Loss** – Head loss is equal to values reported in Federal Energy Regulatory Commission (FERC) licensing documentation.
- **Efficiency** – This value assumes total efficiency of turbines, generators, transformers, and switchyard.
- **Tailwater Elevations** – Elevations are equal to values reported in FERC licensing drawings.
- **Flow** – Flow ranges are determined using flow exceedence curves.
- **Capacity** – Capacities are reported nameplate capacities.
- **Late Spring Shad Release** – Between May 15 and June 30 there is a minimum 400 cfs release out of Kerckhoff Powerhouse.
- **Minimum Kerckhoff Dam Release** – The minimum Kerckhoff Dam release, as required by FERC, is 25 cfs.
- **Kerckhoff Powerhouse No. 2 November Maintenance** – Kerckhoff Powerhouse No. 2 is shut off in November for maintenance.

Table 7-1. Kerckhoff Powerhouse Model Parameters

Powerhouse Parameters	Kerckhoff Powerhouse	Kerckhoff Powerhouse No. 2
Kerckhoff Lake Elevation (feet) (average 1986–2007 elevation)	985.9	985.9
Head Loss (feet)	33	33
Efficiency	0.75	0.87
Minimum Tailwater Elevation (feet)	638.5	546.2
Maximum Tailwater Elevation (feet)	638.5	580.8
Minimum Flow (cfs)	600	1,000
Maximum Flow (cfs)	1,900	4,800
Total capacity (megawatt)	38	155

Note:
All elevations are in North American Vertical Datum of 1988.
Key:
cfs = cubic feet per second

Proposed Temperance Flat RM 274 Reservoir Powerhouse Modeling Assumptions

The parameters and assumptions used in this hydropower analysis for proposed mitigation option powerhouses are listed in Table 7-2 and described as follows.

- **Tailwater Elevation –** The tailwater elevation is the elevation of Millerton Lake, and varies depending on Millerton Lake carryover storage targets.
- **Head Loss –**Head loss for Temperance Flat Reservoir unit(s) is estimated to be 2 percent of gross head.
- **Efficiency** – This value assumes total efficiency of turbines, generators, transformers, and switchyard.

Table 7-2. Proposed Powerhouse Model Parameters

Unit Parameters	Temperance Flat Reservoir
Tailwater Elevation (feet)	Millerton Lake elevations vary by alternative
Head Loss	2%
Efficiency	80%
Minimum Flow (cfs)	1,200
Maximum Flow (cfs)	3,450
Total capacity (megawatt)	80

Key:
cfs = cubic feet per second

Friant Power Project Powerhouses Modeling Assumptions

The parameters and assumptions used in this hydropower analysis for Friant Dam powerhouses were provided by Friant Power Authority and are listed in Table 7-3.

Table 7-3. Friant Power Project Powerhouses Model Parameters

Powerhouse Parameters	Friant-Kern Canal Outlet Powerhouse	Madera Canal Outlet Powerhouse	River Outlet Powerhouse
Tailwater Elevation (feet)	469	449	333
Head Loss	7%	6%	2%
Efficiency	85%	85%	85%
Minimum Flow (cfs)	360	435	50
Maximum Flow (cfs)	1000	1250	145
Total capacity (megawatt)	16	8.3	2

Note:
All elevations are in North American Vertical Datum of 1988.
Key:
cfs = cubic feet per second

Local Hydropower Generation Model Results

Local hydropower generation model results for the Friant Power Project are summarized in Table 7-4 through Table 7-10. Results are reported in gigawatt-hours (GWh).

Table 7-4. Power Accomplishments at Friant Power Project Facilities–Existing Conditions

Simulations	Friant Power Authority		
	Friant-Kern Canal	Madera Canal	River Outlet
Water Years	Energy (GWh) – Existing Conditions		
1976	16.5	5.1	16.4
1977	0.2	0.4	12.6
1978	32.8	20.4	15.4
1979	44.5	19.3	17.7
1980	35.4	28.7	17.1
1981	32.8	13.9	18.1
1982	39.1	20.4	16.1
1983	37.4	16.8	16.3
1984	46.0	25.9	19.2
2000	28.7	18.9	17.4
Average Annual Generation 1976–1984, 2000	31.3	17.0	16.6

Key:
GWh = gigawatt-hour

Table 7-5. Power Accomplishments at Friant Power Project Facilities–No Action Alternative

Simulations	Friant Power Authority		
	Friant-Kern Canal	**Madera Canal**	**River Outlet**
Water Years	**Energy (GWh) – Existing Conditions**		
1976	23.9	248.0	242.2
1977	9.6	115.5	115.5
1978	62.9	756.6	204.4
1979	31.3	569.4	336.9
1980	70.5	774.3	209.7
1981	23.1	400.5	358.5
1982	78.1	731.6	237.3
1983	90.5	954.5	180.2
1984	32.4	642.5	426.6
2000	25.9	521.0	305.6
Average Annual Generation 1976–1984, 2000	44.8	571.4	261.7

Key:
GWh = gigawatt-hour

Table 7-6. Power Accomplishments at Friant Power Project Facilities–Alternative Plan 1

Simulations	Friant Power Authority		
	Friant-Kern Canal	**Madera Canal**	**River Outlet**
Water Years	**Energy (GWh) – Existing Conditions**		
1976	29.0	9.8	19.5
1977	14.8	3.6	17.4
1978	30.6	30.4	19.0
1979	44.4	38.3	19.5
1980	43.1	37.7	19.5
1981	43.4	25.5	19.5
1982	35.4	31.0	19.6
1983	47.0	14.5	20.0
1984	47.7	39.7	19.9
2000	41.7	21.4	19.5
Average Annual Generation 1976–1984, 2000	37.7	25.2	19.3
Water Years	**Energy (GWh) – Future Conditions**		
1976	27.1	8.5	19.5
1977	13.9	3.4	18.3
1978	29.7	29.1	18.2
1979	43.6	35.1	19.5
1980	40.5	36.6	19.5
1981	43.2	21.6	19.5
1982	33.7	29.5	19.5
1983	46.9	13.6	19.9
1984	46.6	37.5	19.7
2000	37.0	19.3	19.5
Average Annual Generation 1976–1984, 2000	36.2	23.4	19.3

Key:
GWh = gigawatt-hour

Table 7-7. Power Accomplishments at Friant Power Project Facilities–Alternative Plan 2

Simulations	Friant Power Authority		
	Friant-Kern Canal	Madera Canal	River Outlet
Water Years	**Energy (GWh) – Existing Conditions**		
1976	29.0	9.9	19.5
1977	14.8	3.6	17.4
1978	30.8	30.5	19.0
1979	44.7	38.3	19.6
1980	43.0	39.5	19.6
1981	43.4	24.2	19.5
1982	35.3	31.2	19.6
1983	47.1	14.7	20.0
1984	47.9	39.6	19.9
2000	41.6	20.7	19.5
Average Annual Generation 1976–1984, 2000	37.8	25.2	19.3
Water Years	**Energy (GWh) – Future Conditions**		
1976	27.1	8.6	19.5
1977	13.9	3.4	18.3
1978	29.7	29.2	18.2
1979	43.6	34.9	19.5
1980	40.4	36.4	19.5
1981	43.1	21.0	19.5
1982	33.6	29.5	19.5
1983	46.9	13.7	19.9
1984	46.6	37.3	19.7
2000	36.8	18.7	19.5
Average Annual Generation 1976–1984, 2000	36.2	23.3	19.3

Key:
GWh = gigawatt-hour

Table 7-8. Power Accomplishments at Friant Power Project Facilities–Alternative Plan 3

Simulations	Friant Power Authority		
	Friant-Kern Canal	Madera Canal	River Outlet
Water Years	**Energy (GWh) – Existing Conditions**		
1976	29.0	9.9	19.5
1977	14.9	3.6	17.4
1978	29.7	29.9	19.0
1979	44.1	37.7	19.0
1980	41.6	38.9	19.4
1981	43.4	24.5	19.5
1982	34.4	30.1	19.5
1983	46.9	14.3	19.9
1984	47.5	39.2	19.8
2000	37.3	21.4	19.5
Average Annual Generation 1976–1984, 2000	36.9	24.9	19.3
Water Years	**Energy (GWh) – Future Conditions**		
1976	27.3	8.7	19.5
1977	14.0	3.5	18.3
1978	29.4	28.7	18.2
1979	43.5	34.9	19.5
1980	39.4	35.1	19.4
1981	43.2	21.9	19.5
1982	33.9	29.7	19.5
1983	49.3	13.6	19.9
1984	46.5	36.9	19.7
2000	37.0	18.9	19.5
Average Annual Generation 1976–1984, 2000	36.4	23.2	19.3

Key:
GWh = gigawatt-hour

Table 7-9. Power Accomplishments at Friant Power Project Facilities–Alternative Plan 4

Simulations	Friant Power Authority		
	Friant-Kern Canal	Madera Canal	River Outlet
Water Years	**Energy (GWh) – Existing Conditions**		
1976	29.0	9.9	19.5
1977	14.7	3.5	17.4
1978	31.8	24.7	19.1
1979	44.7	36.4	19.6
1980	42.4	34.2	19.5
1981	43.3	22.8	19.5
1982	36.5	29.6	19.6
1983	47.2	14.7	20.0
1984	48.4	38.5	19.9
2000	35.0	19.6	19.5
Average Annual Generation 1976–1984, 2000	37.3	23.4	19.4
Water Years	**Energy (GWh) – Future Conditions**		
1976	27.2	8.6	19.5
1977	13.8	3.4	18.3
1978	31.7	28.0	18.3
1979	44.1	35.7	19.5
1980	41.2	37.3	19.6
1981	43.1	21.0	19.5
1982	34.0	30.0	19.5
1983	47.1	14.5	20.0
1984	46.9	35.3	19.8
2000	34.6	18.1	19.5
Average Annual Generation 1976–1984, 2000	36.4	23.2	19.4

Key:
GWh = gigawatt-hour

Table 7-10. Power Accomplishments at Friant Power Project Facilities–Alternative Plan 5

Simulations	Friant Power Authority		
	Friant-Kern Canal	**Madera Canal**	**River Outlet**
Water Years	**Energy (GWh) – Existing Conditions**		
1976	29.3	11.9	19.1
1977	4.8	1.2	15.3
1978	28.7	29.6	17.2
1979	44.0	34.6	19.6
1980	41.9	37.4	19.5
1981	44.0	25.6	19.6
1982	36.5	31.6	19.7
1983	47.4	14.8	20.0
1984	48.5	39.8	19.9
2000	42.5	21.8	19.6
Average Annual Generation 1976–1984, 2000	36.8	24.8	18.9
Water Years	**Energy (GWh) – Future Conditions**		
1976	27.2	10.5	19.0
1977	4.3	1.1	15.3
1978	28.6	29.5	16.7
1979	43.8	32.3	19.6
1980	36.4	35.8	19.5
1981	40.8	26.2	19.2
1982	31.4	29.8	18.4
1983	45.8	12.8	19.9
1984	47.7	38.0	19.8
2000	42.1	20.6	19.6
Average Annual Generation 1976–1984, 2000	34.8	23.7	18.7

Key:
GWh = gigawatt-hour

PLEXOS®

Using the Local Hydropower Generation Model as input, the PLEXOS® model was used for those projects with dispatchable capacity to optimize the value of the hydropower attributes.

Model Description

PLEXOS®, a transmission-constrained power market simulation model, distributes that portion of dispatchable energy for which the energy market represents the highest value over the most valuable hours within a day or week using an hourly time step. If ancillary services represent a higher value product then PLEXOS® allocates a portion of dispatchable energy to the regulation-up market within a day or week using an hourly time step by optimizing among all market opportunities. This optimization assumes that ancillary services bid into the market are only called upon 50 percent of the time.

The Kerckhoff Powerhouse was assumed to be operated in a baseload manner; thus the generation is not available as ancillary services. Kerckhoff Powerhouse No. 2 has some storage capacity resulting in the assumption that half of the powerhouse capacity would be operated to produce baseload generation, and half would be dispatchable and could be bid into the ancillary services market. The proposed Temperance Flat RM 274 powerhouse was assumed to be 100 percent dispatchable for bid into the ancillary services market.

PLEXOS® Results Summary and Discussion

Simulated values for existing conditions and the No Action Alternative generation and ancillary services for the Kerckhoff Powerhouse and Kerckhoff No. 2 Powerhouse are summarized in Table 7-11 and Table 7-12.

Table 7-13 through Table 7-17 show potential hydropower accomplishments for the proposed Temperance Flat RM 274 Reservoir action alternatives.

Table 7-11. Power Accomplishments at Kerckhoff Hydroelectric Project Facilities–Existing Conditions

Simulations	Pacific Gas and Electric Company		
	Kerckhoff	Kerckhoff No. 2	
	Energy	Energy	Ancillary Services
Water Years	Energy and Ancillary Services (GWh) – Existing Conditions		
1976	23.9	245.6	241.4
1977	9.6	115.5	115.5
1978	62.9	756.6	268.2
1979	31.3	564.2	377.4
1980	70.5	772.5	273.1
1981	23.1	400.2	370.4
1982	78.1	730.2	296.1
1983	90.5	955.1	258.3
1984	32.4	634.2	478.0
2000	25.9	515.1	344.0
Average Annual Generation 1976–1984, 2000	44.8	568.9	302.2

Key:
GWh = gigawatt-hour

Table 7-12. Power Accomplishments at Kerckhoff Hydroelectric Project Facilities–No Action Alternative

Simulations	Pacific Gas and Electric Company		
	Kerckhoff	Kerckhoff No. 2	
	Energy	Energy	Ancillary Services
Water Years	Energy and Ancillary Services (GWh) – Existing Conditions		
1976	23.9	248.0	242.2
1977	9.6	115.5	115.5
1978	62.9	756.6	204.4
1979	31.3	569.4	336.9
1980	70.5	774.3	209.7
1981	23.1	400.5	358.5
1982	78.1	731.6	237.3
1983	90.5	954.5	180.2
1984	32.4	642.5	426.6
2000	25.9	521.0	305.6
Average Annual Generation 1976–1984, 2000	44.8	571.4	261.7

ey:
Wh = gigawatt-hour

Table 7-13. Power Accomplishments at Proposed Hydropower Facilities–Alternative Plan 1

Simulations	Temperance Flat Reservoir Powerhouse	
	Energy	Ancillary Services
Water Years	**Energy and Ancillary Services (GWh) – Existing Conditions**	
1976	83.7	135.0
1977	0.0	0.0
1978	555.6	219.8
1979	727.1	595.3
1980	691.0	450.2
1981	515.7	436.6
1982	600.5	265.8
1983	1,011.3	508.9
1984	842.4	684.2
2000	368.7	264.2
Average Annual Generation 1976–1984, 2000	539.6	356.0
Water Years	**Energy and Ancillary Services (GWh) – Future Conditions**	
1976	40.1	73.8
1977	0.0	0.0
1978	606.2	140.5
1979	701.8	481.3
1980	733.1	277.7
1981	373.4	351.9
1982	605.7	182.3
1983	965.6	479.9
1984	869.9	621.7
2000	265.2	121.6
Average Annual Generation 1976–1984, 2000	516.1	273.1

Key:
GWh = gigawatt-hour

Table 7-14. Power Accomplishments at Proposed Hydropower Facilities– Alternative Plan 2

Simulations	Temperance Flat Reservoir Powerhouse	
	Energy	Ancillary Services
Water Years	**Energy and Ancillary Services (GWh) – Existing Conditions**	
1976	83.7	135.0
1977	0.0	0.0
1978	555.6	219.8
1979	727.1	595.3
1980	691.0	450.2
1981	515.7	436.6
1982	600.5	265.8
1983	1,011.3	508.9
1984	842.4	684.2
2000	368.7	264.2
Average Annual Generation 1976–1984, 2000	539.6	356.0
Water Years	**Energy and Ancillary Services (GWh) – Future Conditions**	
1976	40.1	73.8
1977	0.0	0.0
1978	606.2	140.5
1979	701.8	481.3
1980	733.1	277.7
1981	373.4	351.9
1982	605.7	182.3
1983	965.6	479.9
1984	869.9	621.7
2000	265.2	121.6
Average Annual Generation 1976–1984, 2000	516.1	273.1

Key:
GWh = gigawatt-hour

Table 7-15. Power Accomplishments at Proposed Hydropower Facilities–Alternative Plan 3

Simulations	Temperance Flat Reservoir Powerhouse	
	Energy	**Ancillary Services**
Water Years	**Energy and Ancillary Services (GWh) – Existing Conditions**	
1976	83.7	135.0
1977	0.0	0.0
1978	555.6	219.8
1979	727.1	595.3
1980	691.0	450.2
1981	515.7	436.6
1982	600.5	265.8
1983	1,011.3	508.9
1984	842.4	684.2
2000	368.7	264.2
Average Annual Generation 1976–1984, 2000	539.6	356.0
Water Years	**Energy and Ancillary Services (GWh) – Future Conditions**	
1976	40.1	73.8
1977	0.0	0.0
1978	606.2	140.5
1979	701.8	481.3
1980	733.1	277.7
1981	373.4	351.9
1982	605.7	182.3
1983	965.6	479.9
1984	869.9	621.7
2000	265.2	121.6
Average Annual Generation 1976–1984, 2000	516.1	273.1

Key:
GWh = gigawatt-hour

Table 7-16. Power Accomplishments at Proposed Hydropower Facilities–Alternative Plan 4

Simulations	Temperance Flat Reservoir Powerhouse	
	Energy	Ancillary Services
Water Years	**Energy and Ancillary Services (GWh) – Existing Conditions**	
1976	169.1	248.9
1977	19.9	8.5
1978	542.5	266.3
1979	736.5	615.4
1980	685.3	464.1
1981	539.7	496.1
1982	621.5	373.3
1983	1,027.5	500.0
1984	845.0	682.8
2000	407.3	304.8
Average Annual Generation 1976–1984, 2000	559.4	396.0
Water Years	**Energy and Ancillary Services (GWh) – Future Conditions**	
1976	137.2	223.7
1977	15.2	8.5
1978	584.6	210.4
1979	742.6	603.7
1980	750.9	401.6
1981	484.4	520.1
1982	672.1	304.6
1983	1,005.1	508.8
1984	856.1	658.4
2000	370.7	292.0
Average Annual Generation 1976–1984, 2000	561.9	373.2

Key:
GWh = gigawatt-hour

Table 7-17. Power Accomplishments at Proposed Hydropower Facilities–Alternative Plan 5

Simulations	Temperance Flat Reservoir Powerhouse	
	Energy	**Ancillary Services**
Water Years	**Energy and Ancillary Services (GWh) – Existing Conditions**	
1976	98.7	157.7
1977	0.0	0.0
1978	459.3	71.6
1979	591.4	457.6
1980	690.8	366.1
1981	377.8	445.1
1982	584.7	286.3
1983	1,032.6	524.5
1984	754.7	763.8
2000	370.5	256.8
Average Annual Generation 1976–1984, 2000	496.1	332.9
Water Years	**Energy and Ancillary Services (GWh) – Future Conditions**	
1976	62.4	116.0
1977	0.0	0.0
1978	456.3	67.6
1979	562.9	403.8
1980	676.8	232.6
1981	266.9	293.0
1982	415.9	54.3
1983	966.3	385.7
1984	760.1	727.0
2000	356.0	251.2
Average Annual Generation 1976–1984, 2000	452.4	253.1

Key:
GWh = gigawatt-hour

LongTermGen

This section provides a brief description of the LongTermGen (LTGen) model, and the results for Investigation alternative plans.

Model Description

LTGen is a monthly model that simulates both power generation and consumption in the CVP system resulting from a CalSim II simulation (for the Investigation, operations data was the routed CalSim II model described in Chapter 3). Powerplants included in the LTGen model are: Trinity, Lewiston, Carr, Spring Creek, Shasta, Keswick, Folsom, Nimbus, and New Melones powerplants, and O'Neill and the CVP portion of Gianelli pumping-generating plants. Included pumping plants are: C. W. “Bill” Jones, the CVP portion of Banks, Contra Costa, Pacheco, the CVP portion of Dos Amigos, Folsom, Corning, and Red Bluff pumping plants; San Luis, Delta-Mendota Canal, and Tehama-Colusa relift pumping plants; and O'Neill and the CVP portion of Gianelli pumping-generating plants.

The Excel-based model reads reservoir storage and releases as well as powerhouse and pump station monthly flows from CalSim II outputs. The total monthly energy generation or usage is computed for each powerhouse and pump station in the system. The total energy is then divided into on and off peak periods, with the goal to maximize on-peak generation and off-peak pumping. The functions and parameters assumed in LTGen were mostly provided by the Western Area Power Authority (Western) of the U.S. Department of the Interior, which is responsible for managing energy generated from the CVP system. This model is fully documented in the SJRRP PEIS/R Modeling Appendix (SJRRP 2012).

LongTermGen Results and Summary Discussion

Table 7-18 and Table 7-19show changes from the Existing Conditions and the No Action Alternative in hydropower generation and pumping requirements for the CVP, for each action alternative, respectively. The CVP would have a loss of 2–14 GWh of net generation. The net generation losses are due to pumping requirements for moving new water supply from Temperance Flat RM 274 Reservoir to new beneficiaries in the action alternatives exceeding the CVP systemwide energy generation potential of the action alternatives. LTGen output tables are included in the Hydropower Modeling Attachment.

Table 7-18. Simulated Average Annual Net Energy Generation in CVP System – Existing Conditions

CVP Facilities	Existing Condition	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Energy Generation (GWh)	4,925	4,922	4,924	4,922	4,923	4,926
Energy Use (GWh)	1,179	1,179	1,186	1,183	1,183	1,179
Net Generation (GWh)	3,746	3,743	3,738	3,739	3,739	3,747
Change in Net Generation (GWh)		-2	-8	-7	-7	1

Key:
GWh = gigawatt-hour

Table 7-19. Simulated Average Annual Net Energy Generation in CVP System – Future Conditions

CVP Facilities	No Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Energy Generation (GWh)	4,912	4,914	4,914	4,914	4,914	4,914
Energy Use (GWh)	1,169	1,176	1,175	1,178	1,180	1,185
Net Generation (GWh)	3,743	3,738	3,739	3,736	3,734	3,729
Change in Net Generation (GWh)		-4	-3	-7	-9	-14

Key:
GWh = gigawatt-hour

SWP_Power

This section provides a brief description of the SWP_Power model, and the results for Investigation alternative plans.

Model Description

SWP_Power is a monthly model used to simulate both power generation and consumption in the SWP system resulting from a CalSim II simulation (for the Investigation, operations data was the routed CalSim II model described in Chapter 3). Simulated SWP powerplants include Oroville, the Thermalito Complex, Alamo, Mojave, Devil Canyon, Warne, and Castaic powerplants, and the SWP portion of the Gianelli Pumping-Generating Plant. Simulated SWP pumping plants are the SWP portion of Banks, SWP portion of Dos Amigos, Buena Vista, Teerink, Chrisman, Edmonston, Pearblossom, Oso, South Bay Aqueduct, Del Valle, Las Perillas, and Badger Hill pumping plants, and the SWP portion of the Gianelli Pumping-Generating Plant.

SWP_Power uses a methodology to calculate SWP energy generation and consumption that is very similar to LTGen’s. Functions and parameters in SWP_Power were provided by the State Operations Control Office.

SWP Power Results and Summary Discussion

Table 7-20 and Table 7-21 describe changes from the Existing Conditions and the No Action Alternative in SWP hydropower generation and pumping requirements, for each action alternative, respectively. The tables show that the SWP would have a loss of 51–120 GWh of net generation. The net generation losses are due to pumping requirements for moving new water supply from Temperance Flat RM 274 Reservoir to new beneficiaries in the action alternatives being greater than the SWP systemwide energy generation potential of the action alternatives, leading to a loss of net generation for SWP systemwide hydropower. SWP_Power output tables are included in the Hydropower Modeling Attachment.

Table 7-20. Simulated Average Annual Net Energy Generation in SWP System – Existing Conditions

SWP Facilities	Existing Condition	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Energy Generation (GWh)	4,435	4,488	4,467	4,468	4,463	4,423
Energy Use (GWh)	7,623	7,796	7,726	7,733	7,717	7,579
Net Generation (GWh)	-3,189	-3,309	-3,259	-3,265	-3,254	-3,156
Change in Net Generation (GWh)		-120	-70	-77	-65	32

Key:
GWh = gigawatt=hour

Table 7-1. Simulated Average Annual Net Energy Generation in SWP System – Future Conditions

SWP Facilities	No Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Energy Generation (GWh)	4,516	4,566	4,543	4,546	4,541	4,507
Energy Use (GWh)	7,933	8,091	8,017	8,020	8,010	7,900
Net Generation (GWh)	-3,417	-3,525	-3,473	-3,474	-3,469	-3,393
Change in Net Generation (GWh)		-108	-56	-56	-51	24

Key:
GWh = gigawatt-hour

Chapter 8
Recreation Modeling

Investigation action alternatives have the potential to affect recreation on Millerton Lake and create new recreation opportunities on or near the potential Temperance Flat RM 274 Reservoir. This chapter documents the recreation visitation modeling conducted to estimate changes in recreational visitation at Millerton Lake and the proposed Temperance Flat RM 274 Reservoir.

Background

For Alternative Plans 1 through 4, water surface elevations at Millerton Lake are higher (carry over at 340 TAF at elevation 550 feet) than under No Action Alternative conditions during the high-visitation recreational months of April, July, August, and September. Alternative Plan 5 also seeks to maintain Millerton Lake at 550 feet, but allows it to drop to a minimum carry over target of 130 TAF, or 472 feet. Further details on alternative plan operations are available in Chapter 3 of this Modeling Appendix.

It should be noted that Temperance Flat RM 274 Reservoir action alternatives would decrease the surface area of Millerton Lake (since the potential dam site is within the upstream portion of Millerton Lake) and may therefore affect activities that rely on access to that portion of the lake. For this reason, action alternative impacts of Millerton Lake water levels on recreational participation focused on impacts to recreational visitation in the wide portion of Millerton Lake, downstream from the potential dam site. Temperance Flat RM 274 Reservoir recreational visitation was estimated to be the net of impacted existing visitation in the upper portion of Millerton Lake.

Existing Millerton Lake Recreation

Millerton Lake visitation data was obtained from the California Department of Parks and Recreation, Millerton Lake State Recreation Area (SRA). The visitation data included monthly visits from July 2001 through June 2012, and annual visits from 1996 through 2008. Visits were categorized as paid day use, free day use, paid camping, and boat launches. No additional records are available indicating the specific recreational activities of day-use visitors. Additional information on primary recreational activities within the SRA was gathered through personal communication with the San Joaquin Sector Superintendent of State Parks (Gresham 2013). Table 8-1 displays average visitation to Millerton Lake based on attendance records from 2008 through 2012 categorized by visitors' primary purpose for visiting the Millerton Lake SRA.

Table 8-1. Calendar Year Attendance to Millerton Lake State Recreation Area

Visitor Type	Average Annual Visits[1]
Day Use (fee & paid)	343,267
Boat Launches	19,535
Camping	50,798

Source: California Department of Parks and Recreation, Millerton Lake State Recreation Area, Fiscal Year Total Visitor Attendance Reports, 2008−2012.

Note:

[1] Average annual visits for the years 2008 to 2012.

Table 8-2 and Table 8-3 provide Millerton Lake SRA visitor information used to model recreation use within the primary study area for the Investigation. Table 8-2 displays primary purpose boating, land-based, and overnight activity visitation downstream from RM 274 in the wide portion of Millerton Lake, based on estimates provided by the Millerton Lake SRA superintendent. Approximately 73 percent of boating activities, 94 percent of land-based activities, and 75 percent of overnight activities occur downstream from RM 274.

Table 8-1. Estimated Peak Recreational Season Annual Visitors Downstream from RM 274 by Primary Recreational Activity in Millerton Lake State Recreation Area

Boating Activities	**Percent of Use**[1]	**Estimated Users**[2]
Waterskiing/wakeboarding	30%	44,213
Personal Water Craft	20%	23,580
Boat fishing	30%	22,106
General[3]	20%	17,635
Land-Based Activities		
Picnicking/Swimming	80%	116,721
Other[4]	15%	14,738
Shoreline Fishing	5%	7,295
Overnight Activities		
Camping[5]	NA	45,030
Total	NA	291,318

Notes:

[1] Percentages provided by Kent Gresham, Millerton Lake Park Superintendent, personal communication with MWH, March 12, 2013

[2] Estimated users are based on 2011 Millerton Lake State Recreation Area data and represent peak recreational season visitors (April through September) in the wide portion of Millerton Lake downstream from the potential dam site.

[3] General boating activities include general recreational boating and sail boating.

[4] Other land-based activities include trail use, bird watching, and sightseeing.

[5] Camping includes land-based camping and boat-in camping.

Millerton Lake recreation enhancement analysis is based on the visitation data displayed in Table 8-3. Attendance records during the summer months of April through September were compiled for 2008 through 2012 to derive the share of annual visits that take place during each summer month. As the shares indicate, there is a decline in total visitation, camping, and boat launches from July to September. Lowering lake water levels in August are one of the reasons attributed to this decline.[1]

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[1] School starting in August and persistent hot weather may also be factors, according to Kent Gresham, Millerton Lake Park Superintendent, personal communication with MWH, March 12, 2013.

Table 8-3. Derived Share of Annual Visitation, by Month for Millerton Lake State Recreation Area

Month	Total Attendance	Camping	Boat Launches
April	9%	8%	6%
May	14%	13%	11%
June	17%	16%	16%
July	22%	22%	22%
August	14%	14%	18%
September	9%	11%	10%

Source: California Department of Parks and Recreation, Millerton Lake SRA, Fiscal Year Total Visitor Attendance Reports, 2008−2012.

Note:

[1] Weighted average of 2008 through 2012.

Model Description

To prepare an estimate of recreational impacts for the action alternatives, a spreadsheet model that assesses recreational activities was developed. The tool computes monthly 50 percent exceedence elevation values at Millerton Lake and 50 percent exceedence values of surface area for Temperance Flat RM 274 Reservoir for each month for each action alternative.

To evaluate the recreation activities below RM 274, action alternative storage volumes in Millerton Lake provided by the routed CalSim operations modeling described in Chapter 3 of this modeling appendix were used to obtain simulated Millerton Lake elevations. The elevation data was then used to provide estimates of changes in recreational activity visitation according to the degree of change anticipated[2] using lookup tables. For example, “moderate” or “very high” increases in Millerton Lake elevations over the No Action Alternative could translate into a 25 percent increase in boating visitation during months with available capacity (generally July, August, and September). Similarly, increases in land-based (such as shoreline fishing or picnicking) and camping visitation were estimated as improvements from the No Action Alternative for action alternatives that operate Millerton Lake within the optimal shoreline activity water-level range of 540 to 560 feet. Potential increases in recreational visitation within the

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[2] Anticipated changes in recreational visitation associated with water elevations were developed through coordination with Millerton Lake Park Superintendent Kent Gresham during personal communication with MWH, March 12, 2013.

Millerton Lake SRA below RM 274 due to action alternatives are associated with land and water-based recreational activities.

The specific composition of recreational activities expected above RM 274 and at a potential Temperance Flat RM 274 Reservoir has not been evaluated. As described in the Recreation Opportunities Attachment to the Investigation Feasibility Report (Reclamation 2014), land-based recreational features and opportunities above RM 274 were deemed suitable to be replaced such that land-based recreational visitation above RM 274 would be equivalent under all alternative plans. Potential recreation participation at Temperance Flat RM 274 Reservoir was assumed to be limited to water-based recreational activities and was calculated using the historical boating recreation to surface area relationship at Millerton Lake. The ratio of simulated Temperance Flat RM 274 Reservoir peak recreation season (April through September) surface acres to historical Millerton Lake surface acres was applied to 2011Millerton Lake SRA peak recreation season boating activity visitation to estimate potential boating recreational visitation in the new reservoir under the action alternatives.

Since the action alternatives would decrease the surface area of Millerton Lake by constructing Temperance Flat RM 274 Reservoir in the upstream portions of Millerton Lake, estimated Temperance Flat RM 274 Reservoir boating recreational visitation is estimated as the net of impacted existing boating visitation in the upper portion of Millerton Lake. The Temperance Flat RM 274 Reservoir recreation participation estimate is likely understated because only peak recreation season boating activity participation was estimated, no land-based activity or camping participation was estimated, and no off-season participation was considered.

Recreation Modeling Results and Discussion

Table 8-4 and Table 8-5 summarize the increase in recreation that was modeled due to increased carryover in Millerton Lake and the construction of Temperance Flat RM 274 Reservoir under the action alternatives. For both existing and future conditions, the majority of the increase in recreation comes from increased recreational boating activity in Temperance Flat RM 274 Reservoir. Temperance Flat RM 274 Reservoir provides an increased annual visitation of 54 to 91 thousand visitor days under existing conditions, and 37 to 86 thousand visitor days under future conditions. Smaller increases in recreation around Millerton Lake are provided by the action alternatives. Under both existing and future conditions, Alternative Plan 5 provides the smallest increase in recreation visitor days of all of the action alternatives. This is because Alternative Plan 5 provides the lowest carryover target in Millerton Lake (130 to 340 TAF) and Temperance Flat RM 274 Reservoir (100 TAF).

Recreation visitor days calculated from anticipated boating activities on Temperance Flat RM 274 Reservoir are greatest under Alternative Plan 4, estimated as 91 thousand visitor days under existing conditions and 86 thousand visitor days under future conditions. Other action alternatives have lower Temperance Flat RM 274 Reservoir minimum carryover targets and therefore have lower anticipated visitor days, ranging from 37 thousand to 82 thousand.

Table 8-4. Increase in Recreation Visitor Days Provided by the Action Alternatives Under Existing Conditions

Visitation	Alternative Plan 1	Alternative Plan 2	Alternative Plan 3	Alternative Plan 4	Alternative Plan 5
Annual Increase in Millerton Lake Visitor Days (1,000)	33	33	33	33	32
Annual Visitation at Temperance Flat RM 274 Reservoir Visitor Days (1,000)	81	82	77	91	54

Table 8-2. Increase in Recreation Visitor Days Provided by the Action Alternatives Under Future Conditions

Visitation	Alternative Plan 1	Alternative Plan 2	Alternative Plan 3	Alternative Plan 4	Alternative Plan 5
Annual Increase in Millerton Lake Visitor Days (1,000)	34	34	34	34	32
Annual Visitation at Temperance Flat RM 274 Reservoir Visitor Days (1,000)	74	75	72	86	37

Chapter 9
Groundwater Modeling

This chapter describes groundwater modeling that was performed to evaluate changes in regional groundwater conditions for the alternative plans considered in the Investigation. Due to modeling limitations, changes in groundwater levels as a result of the implementation of alternative plans were evaluated within the Friant Division only.

Model Description

Water supplies delivered to the Friant Division were extracted from routed CalSim II operations modeling described in Chapter 3 of this Modeling Appendix, and were used to estimate the amount of groundwater pumping required to meet existing and future levels of demand. Changes in regional groundwater conditions under the alternative plans resulting from changes in water supply deliveries to the Friant Division were analyzed using the Schmidt Tool. The Schmidt Tool was developed by Schmidt (2005) and is dependent on historical groundwater levels and estimated pumping within the Friant Division. This regional groundwater tool estimates the depth to groundwater within Friant Division contractor areas, according to relationships describing annual groundwater pumping and resulting depth to groundwater developed by Schmidt (Schmidt 2005).

The Schmidt Tool assumes that each Friant Division contractor area is underlain by a homogenous aquifer system that is not hydraulically connected to the surrounding areas. The tool also assumed that the relationships between pumping and aquifer drawdown within Friant Division contractor areas are linear and that enough groundwater supplies exist within each contractor area to accommodate simulated groundwater pumping. Use of the Schmidt tool for the Investigation analyses assumes that aquifer drawdown within the Friant Division districts will continue to 2030 according to the relationships estimated by Dr. Schmidt.

The linear relationship between groundwater pumping and aquifer drawdown was developed using pumping and depth to groundwater data from 1987 through 2003 from Burt (2005) to estimate average annual drawdown for the No Action Alternative and the action alternatives, thereby relying on the linear relationship assumed from 1987 through 2003 to evaluate the Investigation alternative plans under existing and future conditions. The estimated groundwater pumping for irrigation estimated by Burt (2005) was not corrected for well inefficiencies and represents the gross estimate of pumping used for irrigation scheduling, rather than the estimate that would be made in water balance calculations.

Due to the nature of these assumptions, regional groundwater conditions were assessed based on changes between the No Action Alternative and the action alternatives, rather than absolute values. As previously mentioned within this chapter, groundwater conditions within the Friant Division only were considered in the analysis.

Groundwater Modeling Results and Discussion

To estimate long-term groundwater level changes, the annual relationships been groundwater pumping and groundwater-level change within the Friant Division were applied for a 25-year period to correspond to 2030 conditions.

Table 9-1 (existing conditions) and Table 9-2 (future conditions) provide the estimated groundwater-level change for each of the Friant Division regions for the action alternatives. Groundwater levels at the individual contractor level were aggregated to the State Wide Agricultural Production (SWAP) model production regional level by weighting the estimated depth in each contractor region according to irrigated acreage. The SWAP model and production regions are discussed in detail in Chapter 10 of this Modeling Appendix.

As shown in

Table 9-1 and Table 9-2, groundwater levels are generally lower under the No Action Alternative. The action alternatives increase surface water supply deliveries to the Friant Division, thereby reducing demand for groundwater and resulting in lower depths to groundwater.

Table 9-1. Existing Condition Estimated Groundwater Level by Production Region for Temperance Flat RM 274 Alternative Plans

	2030 Base Depth to Groundwater (feet)					
SWAP Region	**No Action Alternative**	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**
R13a	245	214	218	217	220	213
R16a	85	85	85	85	85	85
R17a	32	29	28	27	29	18
R18a	192	122	131	130	135	119
R18b	193	139	146	145	150	134
R18c	87	61	64	64	66	59
R18d	185	149	154	153	156	147
R20a	303	284	287	286	288	283
R21d	410	195	223	219	237	188

Key:
RM = River Mile
SWAP = State Wide Agricultural Production

Table 9-2. Future Condition Estimated Groundwater Level by Production Region for Temperance Flat RM 274 Alternative Plans

	2030 Base Depth to Groundwater (feet)					
SWAP Region	**No Action Alternative**	**Alternative 1**	**Alternative 2**	**Alternative 3**	**Alternative 4**	**Alternative 5**
R13a	245	222	224	223	226	221
R16a	85	85	85	85	85	85
R17a	32	28	28	26	27	19
R18a	192	141	144	143	150	139
R18b	193	153	156	154	160	149
R18c	87	68	69	68	71	66
R18d	185	159	161	160	164	167
R20a	303	289	290	290	291	288
R21d	410	253	265	261	281	249

Key:
RM = River Mile
SWAP = State Wide Agricultural Production

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Chapter 10
Statewide Agricultural Production Model

This chapter addresses findings of an economic agricultural water supply reliability benefits analysis performed for the Investigation using the SWAP model. The economic benefits associated with increased water supply reliability to agriculture can be estimated using a variety of approaches described in the Federal Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) (WRC 1983). Commonly, willingness to pay is measured by the change in net income that would accrue to agricultural producers as a result of changes in water supply conditions. Reclamation has traditionally considered the farm budget analysis method its procedure of choice for valuing the economic benefits of changes in irrigation water supply. The SWAP model represents an example of a complex farm budget approach and is used to assess agricultural water supply benefits and impacts for the Investigation action alternatives.

Model Description

The SWAP model assumes that farmers select crops, water supplies, and other inputs to maximize profit subject to resource constraints, technical production relationships, and market conditions. Farmers are assumed to face competitive markets in which no single farmer can influence crop prices, but an aggregate change in production can affect crop price. This competitive market is simulated by maximizing the sum of consumer and producer surplus subject to the following characteristics of production, market conditions, and available resources:

- Constant Elasticity of Substitution (CES) production functions for every crop in every region
- Marginal land cost
- Groundwater pumping cost, including depth to groundwater

- Crop demand functions
- Crop demand shifts based on real income and population increases
- Resource constraints on land, labor, water, and other input availability by region
- Agronomic and economic constraints on perennial crop acreage changes, dairy herd and livestock silage requirements, stress irrigation, and other legal and physical constraints
- Technological change and climate-induced yield effects
- Legal restrictions on water transfers

CES has four inputs: land, labor, water, and other supplies. CES production functions allow for limited substitution among inputs, which allows the model to select optimal levels of both total output and input use, and consequently input use intensity. Parameters are calculated using a combination of prior information (i.e., externally generated estimates) and the method of Positive Mathematical Programming (PMP) (Howitt 1995).

Marginal land cost functions are estimated using PMP. Additional land brought into production is assumed to be of lower productivity and thus requires a higher cost to cultivate. The PMP functions capture the increasing cost of bringing additional land into production, by using acreage response elasticities that relate changes in acreage to changes in expected returns and other information. PMP cost functions are described in the section called Exponential Land PMP Cost Function.

A water-transfer module is included in SWAP that considers legal restrictions on water transfers, in addition to physical infrastructure and flow capacities, as estimated by engineers in the Watershed Science Center at University of California at Davis.

SWAP chooses the optimal values of land, water, labor, and other input use subject to these constraints and characteristics. Profit is revenue minus costs, where revenue is price multiplied by yield per acre times total acres, calculated for each crop in each region. Costs include both directly calculated input costs plus implicit costs described by the PMP function. Downward-sloping crop demand curves cause prices to decline as production increases (and vice versa), all other variables remaining constant.

The SWAP model incorporates project water supplies (SWP and CVP), other local surface water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. It also fallows land when that appears to be the most cost-effective response to resource conditions.

The SWAP model is used to compare the long-run response of agriculture to potential changes in SWP and CVP irrigation water delivery, other surface or groundwater conditions, or other economic values or restrictions. Results from Reclamation's and DWR's operations planning model CalSim-II (see Chapter 3) are used as inputs to SWAP through a standardized data linkage tool. Groundwater analysis is used to develop assumptions, estimates, and, if appropriate, restrictions on pumping rates and pumping lifts for use in SWAP.

The model self-calibrates using PMP, which has been used in models since the 1980s and was formalized by Howitt (1995). PMP allows the modeler to infer the marginal decisions of farmers while only being able to observe limited average production data. PMP captures this information through a nonlinear cost or revenue function introduced to the model. Further documentation regarding the SWAP model is available in Reclamation (2012)

Model Assumptions

This section describes SWAP modeling inputs developed for the Investigation alternative plans, as well as pre- and post-processing work conducted on model output.

Model Inputs

This section describes the SWAP regions, water supply inputs from operations modeling (described in Chapter 3), and changes in groundwater levels (described in Chapter 11).

Agricultural Production Regions

The number of SWAP production regions was expanded for the Investigation to allow isolation of the effects of alternative plans on the Friant Division from the rest of the Central Valley. The original SWAP model included 27 crop production regions in the Central Valley and 20 categories of crops. For the Investigation, the model area was divided into 36 crop production regions. The nine added SWAP regions are generally consistent with the Friant Division regions. Irrigated acres within the revised SWAP regions were adjusted through a Geographic Information System analysis using county level crop survey information provided by DWR. For several regions, existing model assumptions regarding surface water supply availability was reduced to ensure that surface water supplies were fully used under No Action Alternative conditions. Descriptions of each of the production regions are provided in Table 10-1. The crop production regions added to SWAP for the Investigation are highlighted.

Table 10-1. SWAP Regions Used in the Investigation

SWAP Region	Description of Major Water Users in SWAP Region
1	CVP Users: Anderson Cottonwood, Clear Creek, Bella Vista, Sacramento River miscellaneous users
2	CVP Users: Corning Canal, Kirkwood, Tehama, Sacramento River miscellaneous users
3a	CVP Users: Glenn Colusa ID, Provident, Princeton Codora, Maxwell, and Colusa Basin Drain MWC
3b	Tehama Colusa Canal Service Area. CVP Users: Orland Artois WD, most of County of Colusa, Davis, Dunnigan, Glide, Kanawha, La Grande, Westside WD
4	CVP Users: Princeton Codora Glenn, Colusa Irrigation Co., Meridian Farm WC, Pelger Mutual WC, Recl. Dist. 1004, Recl. Dist. 108, Roberts Ditch, Sartain M.D., Sutter MWC, Swinford Tract IC, Tisdale Irrigation, Sac River miscellaneous users
5	Most Feather River Region riparian and appropriative users
6	Yolo, Solano Counties. CVP Users: Conaway Ranch, Sac River Miscellaneous users
7	Sacramento Co. north of American River. CVP Users: Natomas Central MWC, Sac River miscellaneous users, Pleasant Grove Verona, San Juan Suburban
8	Sacramento Co. south of American River, San Joaquin Co
9	Direct Diverters within Delta Regions. CVP Users: Banta-Carbona, West Side, Plainview
10	Delta Mendota Canal. CVP Users: Panoche, Pacheco, Del Puerto, Hospital, Sunflower, West Stanislaus, Mustang, Orestimba, Patterson, Foothill, San Luis WD, Broadview, Eagle Field, Mercy Springs, Pool Exchange Contractors, Schedule II water rights, more
11	Stanislaus River water rights: Modesto ID, Oakdale ID, South San Joaquin ID
12	Turlock ID
13	Merced ID
13a	CVP Users: Madera, Chowchilla, Gravely Ford
14a	CVP Users: Westlands WD
14b	Southwest Corner of Kings County
15a	Tulare Lake Bed. CVP Users: Fresno Slough, James, Tranquillity, Traction Ranch, Laguna, Real. Dist. 1606
15b	Dudley Ridge WD and Devils Den (Castaic Lake)
16	Eastern Fresno Co.
16a	CVP Users: Friant Kern Canal. Fresno ID, Garfield, International
17	Hills Valley, Tri Valley.
17a	CVP Users: Friant Kern Canal Orange Cove
18	County of Fresno, Pixley ID, portion of Rag Gulch, Ducor, County of Tulare
18a	Lower Tule River ID, Tulare ID, Porterville ID, Stone Corral ID
18b	Delano-Earlimart ID
18c	Lindsay-Strathmore ID, Lindmore ID, Exeter ID, Ivanhoe ID, Lewis Creek ID
18d	Saucelito ID, Terra Bella ID, Tea Pot Dome WD
19a	SWP Service Area, including Belridge WSD, Berrenda Mesa WD
19b	SWP Service Area, including Semitropic WSD
20	CVP Users
20a	Southern San Joaquin MUD, Shafter Wasco ID
21a	SWP Users and CVP Users Served by Cross Valley Canal and Friant-Kern Canal
21b	Portions of Wheeler Ridge-Maricopa WSA
21c	SWP service area: Wheeler Ridge Maricopa WSD
21d	Arvin Edson WSD

Key:
CVP = Central Valley Project
IC = Irrigation Company
ID = Irrigation District
MWC = Mutual Water Company
SWAP = Statewide Agricultural Production Model
SWP = State Water Project
WD = Water District
WSD = Water Storage District

Water Supply Inputs

CalSim II was used to determine the water supply to agricultural users by region over an 82-year hydrologic period of record. Output from the model was aggregated to the SWAP production regions according to hydrologic conditions. Long-term average and dry year water supplies were considered for this analysis. In addition, Section 215 and Article 21 supplies were not directly included as water supply to agricultural users because of timing of deliveries. However, Section 215 and Article 21 supplies are included in the estimated groundwater level within the Friant Division production regions.

Operations data from the routed CalSim II model, described in Chapter 3 of this Modeling Appendix, are post-processed to estimate water deliveries to each SWAP production region. Changes in deliveries to SWAP production regions are shown in Table 10-2 and Table 10-3 for existing and future conditions, respectively.

Table 10-2. Estimated Changes in Water Deliveries by Statewide Agricultural Production Model Region Under Existing Conditions

SWAP Region	Changes in Water Deliveries (TAF) by Year Type, Existing Conditions									
	Alternative 1		**Alternative 2**		**Alternative 3**		**Alternative 4**		**Alternative 5**	
	Average	**Dry**	**Average**	**Dry**	**Average**	**Dry**	**Average**	**Dry**	**Average**	**Dry**
R1	-0.05	-0.01	-0.05	0.00	-0.06	-0.01	-0.04	-0.01	-0.05	0.00
R2	-0.03	0.01	-0.03	0.02	-0.03	0.01	-0.02	0.01	-0.10	-0.18
R3a	-0.43	-0.08	-0.09	-0.34	-0.19	0.12	-0.50	-0.61	0.29	0.09
R3b	-0.38	-0.05	-0.38	0.02	-0.41	-0.08	-0.32	-0.07	-0.39	-0.01
R4	-0.09	0.00	0.00	0.00	-0.09	0.00	-0.07	0.00	0.00	0.00
R5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R9	-0.17	-0.09	0.41	0.30	0.44	0.21	0.34	0.16	0.86	0.79
R10	-0.55	-1.44	7.62	4.09	8.21	2.87	6.94	2.23	14.24	11.22
R11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R13a	26.87	7.45	22.74	4.95	23.70	6.54	20.21	3.15	27.43	18.94
R14a	-7.18	-6.03	12.83	10.28	13.13	4.88	10.57	3.28	29.16	26.07
R14b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R15a	-1.49	-0.59	-0.51	-0.26	-0.54	-0.10	-0.56	-0.35	0.25	1.15
R15b	-0.08	0.03	-0.12	-0.12	0.00	0.17	-0.10	-0.06	-0.18	-0.03
R16	-0.01	0.01	0.03	0.04	0.03	0.03	0.02	0.03	0.06	0.07
R16a	4.31	2.82	3.55	2.27	3.66	2.61	3.33	1.88	4.49	4.56
R17	-0.02	0.01	0.05	0.06	0.05	0.05	0.04	0.04	0.10	0.11
R17a	-1.30	0.21	-1.32	0.21	-1.32	0.22	-1.23	0.14	-1.16	0.67
R18	-0.32	0.18	0.73	0.90	0.79	0.73	0.61	0.65	1.54	1.79
R18a	13.21	16.03	8.64	12.81	9.34	14.86	8.37	10.36	14.46	27.35
R18b	2.55	3.78	1.71	3.18	1.82	3.59	1.57	2.57	3.19	6.95
R18c	1.69	2.58	1.14	2.18	1.21	2.46	1.03	1.76	2.16	4.78
R18d	1.14	1.76	0.77	1.50	0.81	1.68	0.69	1.21	1.47	3.28
R19a	-1.00	-0.37	-1.27	-0.63	-0.91	0.14	-1.13	-0.37	-1.53	-0.15
R20	-0.48	-0.31	-0.82	-0.66	-0.09	0.39	-0.65	-0.31	-1.19	-0.13
R20a	-0.27	0.15	0.61	0.75	0.66	0.61	0.51	0.54	1.29	1.50
R21a	3.10	4.98	2.02	4.21	2.16	4.74	1.84	3.40	3.99	9.24
R21b	-0.46	-0.26	-0.72	-0.53	-0.19	0.28	-0.59	-0.26	-1.01	-0.11
R21c	-0.16	-0.06	-0.20	-0.09	-0.16	0.01	-0.18	-0.06	-0.23	-0.02
R21d	-0.32	-0.11	-0.40	-0.18	-0.31	0.02	-0.36	-0.11	-0.46	-0.05

Key:
SWAP = Statewide Agricultural Production Model

Table 10-1. Estimated Changes in Water Deliveries by Statewide Agricultural Production Model Region Under Future Conditions

SWAP Region	Changes in Water Deliveries (TAF) by Year Type, Future Conditions									
	Alternative 1		**Alternative 2**		**Alternative 3**		**Alternative 4**		**Alternative 5**	
	Average	**Dry**	**Average**	**Dry**	**Average**	**Dry**	**Average**	**Dry**	**Average**	**Dry**
R1	-0.07	-0.10	-0.08	-0.10	-0.07	-0.09	-0.07	-0.09	-0.07	-0.09
R2	-0.07	-0.10	-0.07	-0.10	-0.07	-0.09	-0.07	-0.09	-0.07	-0.09
R3a	-3.39	-4.36	-3.47	-4.03	-2.95	-3.06	-3.05	-3.31	-3.50	-4.02
R3b	-0.65	-0.78	-0.65	-0.78	-0.64	-0.76	-0.63	-0.75	-0.64	-0.76
R4	0.00	0.00	-0.02	0.00	-0.01	0.00	-0.02	0.00	-0.02	0.00
R5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R9	-0.15	-0.06	0.29	0.19	0.29	0.14	0.29	0.14	0.85	0.77
R10	-2.16	-0.90	4.16	2.75	4.19	1.99	4.17	1.95	12.24	11.04
R11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R13a	19.82	5.04	18.00	4.25	18.98	5.42	15.97	3.07	19.74	13.51
R14a	-7.07	-2.65	8.76	6.48	9.28	4.58	9.57	4.77	29.43	27.38
R14b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
R15a	-0.49	-0.22	0.22	0.25	0.24	0.16	0.22	0.17	0.99	1.16
R15b	-0.13	-0.03	-0.11	0.04	-0.12	0.03	-0.11	0.04	-0.13	0.03
R16	-0.01	-0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.06	0.05
R16a	3.17	1.85	2.85	1.65	2.94	1.81	2.42	1.35	3.33	3.43
R17	-0.02	-0.01	0.03	0.02	0.03	0.01	0.03	0.01	0.09	0.08
R17a	-0.94	0.18	-0.95	0.21	-0.93	0.27	-0.90	0.19	-0.86	0.73
R18	-0.27	-0.12	0.50	0.32	0.50	0.23	0.50	0.23	1.49	1.33
R18a	9.70	10.93	7.87	9.83	8.39	10.90	5.77	8.01	10.88	21.51
R18b	1.92	2.54	1.58	2.41	1.73	2.74	1.20	2.03	2.35	5.77
R18c	1.27	1.73	1.05	1.65	1.16	1.88	0.81	1.40	1.58	4.00
R18d	0.86	1.18	0.71	1.13	0.79	1.29	0.55	0.96	1.08	2.75
R19a	-0.97	-0.15	-0.84	0.11	-0.98	0.08	-0.84	0.11	-0.92	0.11
R20	-0.93	-0.19	-0.80	0.16	-0.87	0.12	-0.80	0.16	-0.84	0.16
R20a	-0.23	-0.10	0.42	0.27	0.42	0.19	0.42	0.19	1.25	1.12
R21a	2.34	3.34	1.90	3.19	2.11	3.64	1.43	2.70	2.93	7.74
R21b	-0.75	-0.15	-0.65	0.12	-0.72	0.09	-0.65	0.12	-0.69	0.12
R21c	-0.14	-0.02	-0.13	0.02	-0.15	0.01	-0.12	0.02	-0.14	0.02
R21d	-0.28	-0.04	-0.25	0.03	-0.29	0.02	-0.25	0.03	-0.27	0.03

Key:
SWAP = Statewide Agricultural Production Model

Groundwater Levels

Within SWAP, groundwater availability by production region is estimated as the residual between crop irrigation demands and surface water availability. This estimation is primarily the result of limited information regarding groundwater availability within each region. During the estimation stage of the model, groundwater availability is generally assumed to be the same as the estimated volumes during the calibration stage. However, groundwater availability within each of the Friant regions in this analysis is limited to the level of pumping estimated by the

SWAP model under the No Action Alternative for both the long-term average and dry year water supply conditions. This assumption was necessary to maintain consistency with the groundwater elevation estimates provided by the groundwater model. Absent these limits, the SWAP model may choose to pump additional groundwater (above baseline conditions) within the Friant regions due to the lower cost of groundwater resulting from the estimated improvement in groundwater elevations.

The groundwater modeling performed for the Investigation alternative plans and results are described in Chapter 9 of this Modeling Appendix. The results from the groundwater modeling are used as inputs to the SWAP model.

The cost of groundwater is determined in the model according to the pump lift requirement. The model assigns a unit cost that accounts for the cost to lift 1 acre-foot of water by 1 foot. The unit cost includes the estimated power cost based on 70 percent pump efficiency and the amortized capital cost of well construction.

Pre-Processing adjustments and Post-Processing

To adhere to the P&Gs and determine the contribution of Investigation action alternatives plans to National Economic Development (NED), a series of adjustments to the SWAP model and data are necessary. Adjustments fall into two categories: pre- and post-processing.

Pre-processing adjustments are made before optimization with the SWAP model and include adjustments to SWAP input data and exogenous projections of future costs and demands. They can be viewed as assumptions specific to the project and scenario being analyzed that would change the costs and returns, and therefore the decisions made by farmers. For the Investigation, pre-processing adjustments include agricultural production regions and irrigated crops update, crop demand shifts, technological change, and power costs.

Post-processing adjustments are applied to SWAP output and include adjustments to prices and costs. They are adjustments needed in order for the results to comply with the P&G (WRC 1983) and Reclamation guidelines for NED analysis. In particular, guidelines require that certain prices be used for valuing changes in physical inputs and outputs. They do not explicitly affect farmers’ decisions, so they are applied after the SWAP optimization. For the Investigation, post-processing adjustments include interest rates, other supply costs, fallow land costs, normalized crop prices, consumer surplus, water costs, and management charges.

Pre-processing Adjustments

This section summarizes the pre-processing adjustments, made before optimization with the SWAP model, relating to crop demand shifts, technological changes, and groundwater pumping power costs.

Crop Demand Shifts Crop demands are expected to shift in the future as a consequence of increased population, higher real incomes, changes in tastes and preferences, and other factors. The key changes included for the Investigation are population and real income. An increase in real income is expected to increase demand for agricultural products. Similarly, population increase is expected to increase crop demand. Changes in consumer tastes and preferences will have an indeterminate effect on demand and are not included in the analysis.

Because the Investigation affects a large segment of California agriculture, it is necessary to consider the entire market for California crops, including international exports. Increases in demand for crops produced in California may be partially offset by other production regions depending on changing export market conditions. For example, today California is the dominant producer of almonds, but this may change if other regions in the United States or the world increase production; an increase in almond demand could be partially met by other regions. However, additional demand growth from markets like China may offset this effect. The net effect is indeterminate. In the absence of data or studies demonstrating which effect would dominate, California export share is assumed to remain constant for all crops in the future. This is a key assumption and is consistent with publications for the California Energy Commission (Howitt et al., 2009b), the academic journal Climatic Change (Medellin-Azuara et al., 2008), and the 2009 DWR Water Plan (DWR 2009).

Crop demands are linear in the SWAP model, and population and real income changes induce a parallel shift in demand. Demand shifts are included for all of the alternative scenarios evaluated for the Investigation, including the No Action Alternative. Consequently, benefits estimates that compare No Action to one of the action alternatives compare identical future market conditions.

For purposes of the demand shift analysis, a distinction is made between two types of crops grown in California: California-specific crops and global commodities. Global commodity crops include grain, rice, and corn;[3] all other crop groups are classified as California crops. Global commodity crops are those for which there is no separate demand for California's production. For these crops, California faces a perfectly elastic demand, and is therefore a price taker. The Investigation does not consider the international trade market for these crops; it is assumed that California's export share will continue to remain small in the future. For California-specific crops, California faces a downward sloping demand for a market that is driven by conditions in the United States and international export markets. California's export share and international market conditions are assumed to remain constant, so demand shifts are based solely on United States conditions. The Investigation does not model changes in tastes and preferences, only the shift in demand for these crops that will result from increasing population and real income. A routine in the SWAP model calculates the demand shift depending on the year of the analysis (2005 or 2030 for the Investigation).

Since California is a small proportion of global production for commodity crops, the only necessary information to estimate the shift in future demand is the long-run trend in real prices. Formally, the Investigation assumes that California will retain its small share of the global market for these crops. A recent report by the World Bank (2008) projects price increases (in real terms) until 2015 for rice, corn, and grains. Many experts in the field believe this is an overestimate because long-run real prices have been historically declining for these crops. To address this contradiction, at Year 2015 the analysis allows the historical downward trend in real prices to resume. The projected near-term annual increases are combined out to 2015, with the long-run trend resuming in 2015 to estimate the total percentage demand shift (change in real price).

Demand for California specialty crops is expected to increase with increasing population and income in the United States. Changes in U.S. income and population are estimated and combined with income and population elasticities of demand to determine the shift in demand for these crops. Income and population increases can be directly related to shifts in demand.

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[3] Rice demand is very elastic but not perfectly elastic. For purposes of the demand shifting analysis, it is assumed to be perfectly elastic.

Shifts from income changes and population are combined to determine the overall shift in demand.

According to the Bureau of Labor Statistics, average incomes in the United States have increased 6.9 percent annually between 1982 and 1992, 5.6 percent annually between 1992 and 2002, and are projected to increase 5.4 percent annually until 2012, nominally (Bureau of Labor Statistics, 2007). With 3.4 percent average historical inflation, this is approximately 2 percent real annual income growth in the United States. According to the 2000 Census, the population in the United States is projected to increase by 5 percent every 5 years. These trends are extrapolated to determine income and population demand shifts used for the Investigation.

Technological Change Since World War II, crop yields have been increasing for most crops because of technological innovations such as hybrid seeds, better chemicals and fertilizer, improved pest management, and irrigation and mechanical harvesting advances. The expected future rate of growth in crop yields is a contentious topic among researchers, and there is no general consensus on the expected rate of yield growth in the future within California or globally. The P&G (WRC 1983) allows for yield increases with several caveats; the most important is that if yields increase, the cost of research and development (R&D) needs to be incorporated. Furthermore, higher production costs need to be incorporated. No reliable and consistent data are available on the costs of R&D or expected production costs with higher yields, so adjustments to crop yield through technology were omitted from the Investigation analysis.

It is important to note that the SWAP model does allow for some yield response to changing market conditions. This effect is referred to as endogenous yield changes. The SWAP model includes full CES production functions for each crop and region. As such, there is some endogenous yield change in response to changing market conditions. For example, the SWAP model allows for more inputs (e.g., labor, other supplies, and water) to be applied to existing land to increase yields. The relationship between inputs and yield varies by crop and region. Each relationship is determined in the PMP routine and based on empirical data. The ability to adjust input use and generate marginally higher yields is consistent with observed practices. In general, this is plus or minus a few percentage points from the mean yield. Note that this is separate from technological (exogenous) yield change, which was not included in the analysis.

While technological change is omitted from the Investigation analysis, demand shifts are incorporated. This means that all of the increase in demand will be met with some combination of additional inputs applied to existing land (endogenous yield increases), additional land into production, and shifting crop mix. Supply response to higher prices is typically composed of several components, the largest of which include acreage and yield response. Because exogenous technological change is not incorporated in the analysis, endogenous yield effects and acreage responses may be overstated.

Groundwater Pumping Power Costs Groundwater is typically the most expensive water supply because of the cost of pumping. Real power costs are expected to increase in the future, and groundwater pumping relies heavily on the cost of electricity. SWAP model input data were updated under the Investigation to break down groundwater pumping costs into fixed capital, energy, and operations and maintenance (O&M) components. Energy pumping costs are escalated according to future marginal power cost estimates.

For the Investigation, a single future scenario is considered for each of the alternatives: 2030. A marginal power cost escalator is determined for each year and applied to the energy cost component of groundwater costs. The cost escalator is the ratio of the expected future power cost in 2030 to the base power cost in 2005, in 2005 dollars per megawatt-hour.

Expected future power costs are calculated using DWR’s forward price projections analysis using wholesale power costs. This calculates an average power cost for each month as the average of the peak (upper bound) and off-peak (lower bound) rates. An average of the monthly costs generates an average yearly cost. This cost is used to generate the power cost escalator by taking the ratio of the future year average to the current year average. The power cost escalator for 2030 is 1.54. Power costs are expected to increase by 54 percent in real terms by 2030.

Post-processing Adjustments

This section summarizes the post-processing adjustments that are made after optimization with the SWAP model.

Interest Rates Capital costs are currently included in the SWAP input data as annual capital recovery values in “other supply costs.” University of California Cooperative Extension (UCCE) crop budgets prepared in different years use different interest rates to represent market conditions in the respective year of the budget. SWAP input data are based on budgets prepared between 2002 and 2010. Interest rates varied between 4 and 10 percent, depending on the budget. A consistent interest rate of 6.25 percent was used for all SWAP input data.

For the Investigation, the P&G (WRC 1983) requires that the federal discount rate be used for all interest and capital recovery calculations. The federal discount rate for Fiscal Year 2013 was 3.50 percent. A post-processing adjustment was applied to cost data components to adjust the interest rate from 6.25 percent to 3.50 percent. For interest on operating capital, a simple ratio adjustment of 3.50/6.25, or 0.56, is used. However, capital recovery costs include both a principal and interest component. Capital recovery factors were computed for a range of useful lives using both the SWAP rate of 6.25 percent and the federal discount rate of 3.50 percent, and it was determined that a ratio of 0.83 was an acceptable approximation for adjusting SWAP capital recovery charges for a P&G analysis. This ratio corresponds to an average useful life of between 15 and 20 years for farm investments.

Other Supply Costs The SWAP model uses CES production functions with four aggregate inputs: land, labor, other supplies, and water. Other supplies include the cost of seed, fertilizers, chemicals, custom harvest, irrigation system, and other capital recovery costs. For the Investigation, it was necessary to identify individual components of the other supplies category to make P&G-required adjustments.

Two methods are available for disaggregating other supply costs in the SWAP model. The first method would use a nested CES production function to separate fixed capital and variable inputs. This is likely the preferred methodology, but would require substantial structural and coding changes to SWAP, and therefore was beyond the scope and time frame of the Investigation. Instead, a second approach was adopted where other supply costs remain an aggregate input in the CES production functions, but are proportionally allocated to the various components. For each crop and region, the total other supply costs are the sum of the individual components. This is done within the SWAP data file, and any further adjustments, such as for interest rates, are made post-optimization. This procedure implicitly assumes that all components of other supply costs adjust proportionally to any change in the aggregate input use.

Other supply costs were divided into 12 categories, the most detailed level of disaggregation allowed by the UCCE Crop Budgets. For NED post-processing adjustments, other supply costs were divided into variable costs and capital costs. Specifically, eight areas were identified and broken out for NED post-processing:

1. All other variable supply costs and labor
2. Interest on operating capital
3. Machinery capital recovery costs
4. Crop establishment costs
5. Buildings capital recovery costs
6. Irrigation system costs
7. Land rent and cash overhead
8. Land capital recovery costs

Capital recovery costs for machinery and buildings were discussed to decide whether changes should be included in a long-run NED analysis. These capital items are “lumpy” in the sense that, for example, the same machines and buildings are required for farming 205 acres or 200 acres. Consequently, it was assumed that machinery and building investments, even in the long term, were unlikely to change for projects providing only small increases in water supply and irrigated acreage. Growers would likely have existing machinery and farm buildings that could be used on small increments of new land, especially if that land had been developed and farmed in the recent past. This was the case for the initial application of SWAP to the Investigation, so capital recovery costs were removed from the NED analysis under all scenarios. Note that this did not mean they were assumed to be zero for any alternative, but only that they would not change when comparing an action alternative to the No Action Alternative. Operational costs of machinery (labor, fuel, and repairs) remained as a cost.

Land rent and cash overhead and land capital recovery costs were removed from the NED analysis under all scenarios. This was done because lands being brought into irrigated production are already considered a sunk investment, especially if they were previously developed for irrigation. Sunk investments are irrelevant to determining the economic feasibility of new project investments. In addition, land values largely reflect capitalized net returns, which are not appropriate for inclusion in a budget-based benefit analysis (the purpose of the budget is to compute those net returns). Finally, some crop budgets included land rent paid to an owner rather than capital recovery on owned land. From an NED perspective, rent is a transfer of income between owner and tenant; therefore, rents are removed from the NED analysis. The avoided variable cost of additional land brought into production is accounted for in a separate calculation based on fallow land costs, as described in the next section.

Interest on operating capital and capital recovery charges for permanent crop establishment and for irrigation systems was adjusted using interest factors as previously noted. No adjustments to the other SWAP supply costs (seed, fertilizer, chemicals, custom charges, and labor) were required to make them consistent with an NED analysis.

Fallow Land Costs If additional acres are brought into irrigated production, many of those acres are likely to represent land that was fallow in the past. As currently configured, SWAP does not account for the variable costs of production for these lands in the alternative plans. In most or all of the analyses planned for California, fallow land has already been developed for irrigated production and it is either in rotational fallow or has been set aside for some reason such as lack of water. Fallow land has a low annual maintenance cost (such as weed control, fence repair, and similar needs) that would be avoided if brought back into production.

An annual maintenance cost of $34.60 per acre (in 2005 dollars) was applied to the NED analysis for the Investigation. This cost estimate is from a recent San Luis Unit Drainage study (Reclamation, 2002). To determine the number of fallow acres brought into production under any alternative plan, each action alternative was compared to the No Action Alternative and the change in irrigated acres was calculated. Any additional acreage brought into production would avoid the annual fallow maintenance costs. Regions affected by the Investigation water supply changes include land that is developed and dry-farmed and land that is developed for irrigated production but fallow.

Normalized Crop Prices The base price per ton for each crop in the SWAP model is an average of 2005 through 2007 prices for each region (converted to the 2005 price level). These years are selected as a representation of farmer price expectation when planting decisions were made in 2005, the base year of data in SWAP. The calibration routine is designed to replicate the conditions farmers faced in 2005.

Prices under the alternative plans are estimated to represent conditions farmers would face in the future (e.g., 2030 for the Investigation). For the Investigation, future prices vary according to (endogenous) market effects and (exogenous) demand shifts. The SWAP model requires that the market for each crop in each region clears such that supply equals demand. Supply is governed by the production and cost functions, and demand is governed by downward-sloping California-specific demand curves. Thus the market-clearing price is determined endogenously by the model. Exogenous demand shifts were discussed in the previous section called Crop Demand Shifts and capture demand shifts due to income and population increases. The net effect varies by crop and region but is taken to represent the expected future prices under any of the alternative scenarios.

As an exception to general guidance, the P&G allow for real price changes over time. Changes in prices due to changes in production are endogenously determined within the SWAP model, and this is consistent with market-based analysis allowed by the P&G (WRC 1983).

The P&G state that U.S. Department of Agriculture (USDA) current normalized price (CNP) be used for benefits calculations when available. USDA has adjusted these prices to remove any federal subsidies, because such subsidies represent an NED cost that must be accounted for in comparing project benefits and costs. CNPs were used to adjust future prices after SWAP optimization as follows:

- For crop groups covered by USDA’s CNP estimates, SWAP prices were converted to scaled CNP.

- For crop groups without available CNP, the SWAP-predicted prices were used.

CNPs were identified for six crop groups in the SWAP model: corn, cotton, dry beans, grain, rice, and sugar beets. CNPs were not available at projected future conditions, whereas the SWAP model provided predictions of future crop prices. Therefore, CNPs for these six crops were scaled by the predicted real price increase by SWAP. The resulting procedure used CNPs, as required by the P&G (WRC 1983), and combined the additional information on expected real price increase from SWAP. Table 10-4 summarizes the results of this procedure. The scenario used in the example is the No-Action Alternative in 2025; different scenarios result in different adjustment ratios and, consequently, different scaled CNPs.

Table 10-4. Comparison of Crop Prices Used in SWAP Model Update and Application to Federal Feasibility Analysis

Crop	CNP	SWAP 2005	SWAP 2025	Ratio	Scaled CNP
Corn	107.81	144.39	203.00	1.41	151.57
Cotton	1,086.59	2,016.50	2,638.63	1.05	1,137.03
Dry Bean	852.74	774.88	841.08	1.09	925.60
Grain	137.94	155.43	212.01	1.19	164.69
Rice	280.19	230.79	389.87	1.42	397.81
Sugar Beet	37.55	41.50	41.88	1.01	37.89

Note:
Crop prices are presented at 2005 price levels.
Key:
CNP = current normalized price
SWAP = Statewide Agricultural Production Model

The CNP scaling ratio varies from 1.01 to 1.41. The largest increase in real price is expected for corn. This is largely due to an anticipated increase in demand. All scaled CNPs are above reported CNPs. However, only rice and dry beans scaled CNPs are above the SWAP estimate for 2025 under the No Action Alternative.

Consumer Surplus Consumer surplus is the benefit (welfare gain) that consumers realize from being able to purchase crops at less than their maximum willingness to pay. Intuitively, the market price is determined where supply equals demand; however, many consumers would be willing to pay more than the market price (represented as a downward-sloping demand curve). In other words, what consumers actually pay is below the maximum willingness-to-pay for all units up to the market-clearing quantity. Mathematically, this is the area under the demand curve and above the market-clearing price. The area is called consumer surplus and is calculated in the SWAP model.

A change in the price of a crop will change the resulting consumer surplus and should therefore be included in a NED benefits analysis. Although this topic is not explicitly mentioned in the P&G for determination of irrigation benefits, it is consistent with the P&G overall conceptual basis that all benefits should be based on willingness to pay. For the Investigation, SWAP calculated the change in aggregate consumer surplus for each of the alternatives relative to the No Action Alternative.

This procedure attributes all change in consumer surplus to the NED benefits calculation. However, some California production is exported internationally, so benefits to consumers would be outside the United States and should not be included in the NED analysis. A study conducted by the Agricultural Issues Center (AIC) at University of California, Davis reports that about 24 percent (in value terms) of California production is exported overseas (AIC 2011). As a rough test of the effect of non-domestic surplus on the analysis, this fraction was applied to the results of the irrigation benefits for Investigation action alternatives. The change in consumer surplus was reduced by 24 percent to approximate the portion attributable to the United States, and NED benefits were reduced by just over 5 percent. On the other hand, this approach omits consumer and producer surplus in forward-linked markets (for example, processing markets that rely on California production as inputs). Consequently, the net effect on benefits is indeterminate. For the Investigation, consumer surplus benefits were included but forward-linked benefits were omitted.

Water Costs In an NED benefit-cost analysis of a proposed project, the incremental investment and annual costs of the new water supply are accounted for on the cost side of the ledger, so including them as water costs within the benefits analysis would effectively be double-counting.

Current Reclamation water management plans were reviewed to provide a breakdown of total water charges into district charges versus CVP water costs. Then the CVP portion of water costs in SWAP related to the new project water supply were added back into net returns (benefits) in the post-processing stage to avoid double-counting in the NED calculation.

Finally, the changes in the amount and cost of groundwater pumping were explicitly accounted for in SWAP and included in the benefits calculated. The SWAP post-processing spreadsheets explicitly calculated and itemized the change in groundwater pumping cost, such that they were not masked by other components of the benefits.

Management Charge Reclamation guidelines for preparing NED analysis under the P&G (WRC 1983) recommend including management costs at no less than 6 percent of variable costs. The post-processing step calculated the total variable costs reported by the SWAP model and added 6 percent of this number as a management charge. This item is broken out separately in the post-processing spreadsheets used to calculate benefits.

Adjustment to 2013 Dollars As previously mentioned, SWAP returns were expressed in 2005 dollars. All P&G (WRC 1983) returns, after adjustment, were indexed to 2013 dollars by means of the Federal Reserve Bank's Gross National Product Implicit Price Deflator.

Treatment of "Other Crops" as Defined in the P&G The P&G (WRC 1983) describe a procedure for using a set of so-called basic crops for estimating the benefits of irrigation water supply. These include grains, hay, cotton, and similar commodities whose price would be unaffected by the project's increased production. The rationale for this procedure is to avoid claiming benefits for specialty crops that have higher average net returns but for which market demand is limiting. In other words, the P&G (WRC 1983) basic crop procedure is intended to avoid claiming benefits for crops that cannot be supported by existing markets or whose increased production would drive down prices to all producers of those crops (including producers outside the project study area).

SWAP analysis explicitly accounts for the market demand for all crops and therefore incorporates any price effects caused by production changes. It also accounts for any shifts of production from existing regions in California to the project area. In general, SWAP's predictions of crop acreage changes resulting from new water project supply fall predominantly, but not completely, within the set of basic crops. This occurs because the model accounts for relatively inelastic demand for specialty crops and relatively steep marginal costs for bringing new specialty crop land into production. When specialty crop acreage does increase, it is accompanied by a model-wide price effect. It is acknowledged that the model does not include effects on other production regions outside of California. Foreign suppliers, in particular those in Mexico and other

Central and South American countries, could be affected by price effects or even displacement of market share. However, shifting net returns from production from foreign countries to the United States is considered an NED benefit.

Because SWAP explicitly accounts for price and cost effects associated with production of nonbasic crops, NED analysis using SWAP does not restrict irrigation benefits to only the basic crops.

SWAP Modeling Results and Discussion

SWAP modeling results are discussed below with respect to changes in net farm revenue and NED benefits.

Change in Net Farm Revenue

From a local perspective, agricultural water supply reliability benefits may be measured by the expected changes in net farm revenue relative to the No Action Alternative. Table 10-5 and Table 10-6 provide long-term average and dry year existing and future condition net farm revenue results from SWAP modeling, respectively. Existing condition increases in the average annual net farm revenue range from $16.7 million for Alternative Plan 4 to $25.5 million for Alternative Plan 5. Future condition increases in the average annual net farm revenue range from $13.9 million for Alternative Plan 4 to $22.1 million for Alternative Plan 5.

Table 10-5. Expected Change in Net Farm Revenue Relative the No Action Alternative Under Existing Conditions, for Statewide Agricultural Production Model Regions, by Water Year Type

Alternative Plan	Average Year ($1,000)	Dry Year ($1,000)
1	18,205	33,540
2	18,207	32,833
3	18,625	32,579
4	16,671	28,889
5	25,486	45,793

Note:
Dollar values are expressed in January 2013 price levels.

Table 10-6. Future Condition Expected Change in Net Farm Income, Relative to the No Action Alternative, for Statewide Agricultural Production Model Regions, by Water Year Type

Alternative Plan	Average Year ($1,000)	Dry Year ($1,000)
1	15,024	25,675
2	15,789	26,365
3	16,525	26,761
4	13,927	23,100
5	22,090	38,079

Note:
Dollar values are expressed in January 2013 price levels.

NED Benefits

NED agricultural water supply reliability benefits are measured by the expected changes in adjusted net farm income relative to the without-project conditions for each of the proposed alternatives for long-term average and dry year conditions. As described previously, changes in net farm income calculations are adjusted to calculate the NED benefit consistent with the P&Gs (WRC 1983). Table 10-7 and Table 10-8 present estimated annual NED agricultural water supply reliability benefits by Investigation action alternative for existing and future conditions, respectively. Existing condition increases in the average annual NED benefit range from $19.6 million for Alternative Plan 4 to $32.3 million for Alternative Plan 5. Future condition increases in the average annual NED benefit range from $15.5 million for Alternative Plan 1 to $28.1 million for Alternative Plan 5.

Table 10-7. Existing Condition NED Benefit, Relative to the No Action Alternative, for Statewide Agricultural Production Model Regions, by Water Year Type

Alternative Plan	Average Year ($1,000)	Dry Year ($1,000)
1	19,792	38,846
2	21,369	38,784
3	22,620	39,262
4	19,623	33,226
5	32,289	57,375

Note:
Dollar values are expressed in January 2013 price levels.

Key:
NED = National Economic Development

Table 10-810. Future Condition NED Benefit, Relative to the Action Alternative, for Statewide Agricultural Production Model Regions, by Water Year Type

Alternative Plan	Average Year ($1,000)	Dry Year ($1,000)
1	15,462	29,776
2	18,598	30,342
3	19,521	31,180
4	16,166	26,379
5	28,062	44,773

Note:
Dollar values are expressed in January 2013 price levels.

Key:
NED = National Economic Development

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Chapter 11
Regional Economic Impact Modeling

This chapter addresses findings of a regional economic impact analysis for Temperance Flat RM 274 Reservoir alternative plans. The analysis satisfies the requirements of the regional economic development (RED) account of the P&G (WRC 1983).

The findings incorporate examination of the region-wide economic impacts to sales, personal income, and employment resulting from (1) the short-term construction-related expenditures associated with the Temperance Flat RM 274 Reservoir, and (2) the long-term, static changes in agricultural output and recreation visitation due to potential implementation of alternative plans. This regional analysis does not include other potential NED direct effects, such as changes in M&I water supply quantity and quality, flood control, or other categories potentially affected by the alternative plans. These categories of economic impacts are not likely to have discernable regional impacts measureable in the RED account.

The remaining portions of this chapter describe:

- Regional economic impact analysis with input-output modeling
- Regional economic impact analysis of alternative plans
- Results of regional economic impact analysis

Model Description

Various approaches are available to assess the effect of a proposed project on a region's economy. One of the most common and widely accepted approaches is through the use of input-output (I-O) models. The use of I-O models in economic impact analyses has increased dramatically with the advent of established and commercially-maintained, annual data sets. Accompanying software that incorporates and uses the I-O concept reduces both the time and cost of conducting regional economic impact assessments.

I-O analysis represents a means of measuring the flow of commodities and services among industries, institutions, and final consumers within an economy (or study area). An I-O model uses a matrix representation of a region’s economy, business sectors, and their interrelationship, to predict the effect that changes in one sector will have on other sectors as well as consumers, government, and foreign suppliers in the economy. I-O models capture all market transactions in an economy, accounting for inter-industry linkages and availability of regionally produced goods and services. The resulting mathematical formulas allow I-O models to simulate or predict the economic impacts of a change in one or several economic activities on an entire economy. It is a static, linear model of all purchases and sales, or linkages, between sectors of an economy.

The measurement of linkages within a regional economy is based on the concept of a multiplier. A multiplier is a single number that quantifies the total economic effect resulting from initial spending, or output in a sector. For example, an output multiplier of 1.7 for the “widget” production sector indicates that every $100,000 of widgets produced (the initial spending, or output in this industry) supports a total of $170,000 in business sales throughout the economy (total output of all linked industries), including the initial $100,000 in widget output. Many types of multipliers can be produced by an I-O model, including specific multipliers for estimating impacts on industry output, employment, and value added–the main metrics of I-O analysis results. Each of these metrics is defined and described below.

- **Industry output** is the value of goods and services produced in a region, which includes the value of intermediate inputs (e.g., raw materials, insurance and financing, fuel) used in the production process and value added. Intermediate inputs may or may not originate from a region. For example, direct industry output for construction refers to the value of construction, although some of the intermediate inputs used in the construction process may be imported into the region.

- **Value added** is the difference between industry output and the cost of intermediate inputs, and consists of four components (1) employee compensation, (2) proprietor income, (3) other property income, and (4) indirect business tax. Labor income represents the sum of employee compensation and proprietor income.

- **Employment** is measured by the change in the number of annual full-time, part-time, and temporary positions. Estimated changes in employment are tied to economic relationships between industry output and labor productivity, regardless of availability and fluidity in the local labor force.

Components of industry output are displayed in Figure 11-1.

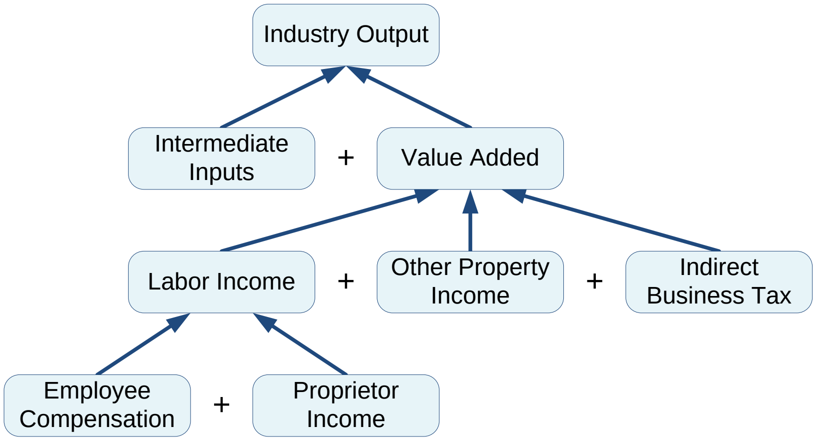

Figure 11-1. Components of Industry Output

Results from the I-O modeling to the RED account specified in the P&G (WRC 1983) is straightforward. The RED account considers changes in the distribution of regional economic activity through two measures: regional income, and regional employment. From the regional economic impact analysis, regional income is derived directly from the measure of “Personal Income.” Regional employment is associated with the measure of “Employment” from the regional economic impact analysis.

I-O Modeling Limitations

While I-O models are useful in providing broad-level estimates of very short-run responses to changes in production/expenditures, their key limitations are linearity, absence of behavioral considerations among consumers and producers, absence of detailed characteristics of markets and prices, and lack of formal constraints which might come into play in very large changes.

The limitations of I-O models are also the key advantages of Computable General Equilibrium (CGE) modeling. A CGE model is a nonlinear model of individual behavioral response to price signals, subject to labor, capital, and natural resources constraints (Charney and Vest, 2003). These advantages come with increased modeling complexity, much greater data needs, and time resources for operation. Therefore, while the use of CGE modeling is increasing, resource and data constraints make its use impractical at the multi-region level, and the use of I-O modeling is a practical choice for a large study area.

IMPLAN

The IMpact analysis for PLANing model (IMPLAN) is a commercially-available system of software and data commonly used to perform I-O based economic impact analysis for the Investigation. IMPLAN was used to assess the regional economic impacts associated with Investigation construction activities, and increased agricultural production and recreational visitation. The economic data needed to construct the central I-O table are extracted by the software purveyors from various sources generated by the Department of Commerce, the Bureau of Labor Statistics, and other federal and State agencies.

Data are organized for 528 distinct industry sectors of the national economy, commonly known as North American Industry Classification (formerly Standard Industry Codes). Industry sectors are classified on the basis of the primary commodity or service produced. National data are de-aggregated to produce data sets for each county in the United States, allowing analysis at the county level and for geographic aggregations such as clusters of contiguous counties, states, or groups of states.

IMPLAN predicts changes in industry output, value added, and employment as direct, indirect, and induced economic effects for affected industries within the study area, where total effects are calculated as the sum of direct effects, indirect effects and induced effects. Direct economic effects refer to the response of a given industry (i.e., changes in output, income, and employment) based on final demand for that industry. Indirect effects refer to changes in output, income, and employment resulting from the iterations of industries purchasing from other industries caused by the direct economic effects. Induced economic effects refer to changes in output, income, and employment caused by the expenditures associated with changes in household income generated by direct and indirect economic effects.

Model Assumptions

The alternative plans are likely to affect the regional economy as a result of the following three factors:

1. Creation of Temperance Flat RM 274 Reservoir will introduce short-term construction expenditure;
2. Improved long-term water supply reliability will alter, and in some cases increase, agricultural production and output; and
3. Improvements to water levels in Millerton Lake and creation of a new Temperance Flat RM 274 Reservoir will introduce new long-term recreational visitation and spending.

Regional economic effects are estimated in terms of changes in industry output, employment, and income with IMPLAN software and 2009 data. The following sections describe regional models, and the regional economic effects of the project construction expenditure, improved agricultural water supply reliability, and increased recreational visitation and spending.

Regional Models

Two I-O models were developed for the Investigation. The first incorporated economic activity in the six-county region (Fresno, Kern, Kings, Madera, Merced, and Tulare counties) encompassing the Friant and West San Joaquin southern CVP Divisions. The six-county regional model estimates the economic impacts to the local economy where the project would be constructed and primary economic effects would be experienced. A second regional economic impact model was developed to address effects at the California statewide level and that may accrue beyond the six-county region. Herein, the two models are referred to as the “Southern San Joaquin Valley” and “Statewide” models.

The Southern San Joaquin Valley model was used to generate estimates of the impact of the project construction expenditure, changes in agricultural production, and increases in recreational visitation to the local six-county region. The Statewide model is intended to capture effects of the alternative plans that transcend beyond the six-county region surrounding Friant and West San Joaquin Divisions. The Statewide model provides estimates of changes in agricultural production that may affect residents and businesses throughout the State.

In general, even when a project is concentrated in a particular region and sector, economic activity (sales and purchases) typically extend beyond that area both directly and indirectly. For example, agricultural inputs such as seed, fertilizer, insurance services, and fuel and transportation, often originate outside the region of emphasis. After accounting for direct sales and purchases, the indirect and induced transactions that result from income changes and secondary effects broaden the boundaries of the originally affected area.

Furthermore, the multidisciplinary nature of the alternative plans will result in categories of effects that are more likely to accrue outside the six-county region encompassing the Friant and West San Joaquin Divisions. These include M&I water supply, emergency water supply, and ecosystem benefits.

Economic Effects of Construction Expenditure

Construction cost estimates for Temperance Flat RM 274 Reservoir have been completed for alternative plans, and documented in the Engineering Summary Appendix of the Investigation Draft Feasibility Report (Reclamation 2014). Construction expenditures related to alternative plans are expected to take place over 8 years, and represent a short-term economic impact to the Southern San Joaquin Valley region. This construction estimate considers the necessary and appropriate size of the construction crew on an average annual basis, given the size and duration of the construction activity. It is estimated that a crew of approximately 450 workers per year would be sufficient for Alternative Plans 1, 2, and 3, and 460 for Alternative Plan 4. 450 workers per year would also be needed for Alternative Plan 5, which includes a LLIS as included in Alternative Plans 1, 2, and 3.

Construction expenditures will primarily and most directly benefit the Southern San Joaquin Valley construction sectors. The magnitude of the project’s economic impact, within a region, is determined by (1) the flow of project construction dollars into the region; and, (2) the proportion of the work performed and the resulting labor, equipment, and materials that originate from within each region. Spending benefits the businesses and residents in the region where the spending occurs if funding is from outside the region.

Development of Temperance Flat RM 274 Reservoir will require substantial capital investment costs both during the construction period and over the project's subsequent life and repayment period. The origin of the funding for both the capital investment and subsequent repayment will affect the extent that future construction and operation of Temperance Flat RM 274 Reservoir will represent net new spending to the region. Construction paid for by the local or regional cost share may not represent any net new economic activity for the region since there could be a corresponding and likely offsetting decrease in economic activity. The positive effects of local increased spending to the region's construction sector may be offset by reduced spending elsewhere within the local economy that would otherwise have occurred if that money was not used for Temperance Flat RM 274 Reservoir construction. However, the flow of project construction dollars into the region would represent new spending and income for the region's economy. For this analysis, it is assumed that the project construction expenditure will represent net new spending to the Southern San Joaquin Valley model region.

Additionally, it is possible that some direct project construction spending could "leak out" of the region and be used to acquire labor, equipment, or materials from another region, thus benefiting the economy in that other region. For this analysis, it is assumed that no direct project construction would be leaked from the Southern San Joaquin Valley model region; that is, the construction sector has sufficient capacity to absorb the new project without requiring importation of workers. Direct project construction spending will generate indirect and induced economic impacts on other sectors of the region's economy. Below, direct, indirect, and induced economic impacts modeled in IMPLAN for project construction spending are described.

Direct Impacts The Engineering Summary Appendix of the Investigation Draft Feasibility Report (Reclamation 2014) includes two types of construction costs: field costs (i.e., costs for onsite construction activities) and, non-contract costs (i.e., costs for offsite project development and implementation, as well as project-related land and mitigation costs). Total construction costs are evenly distributed over an 8-year construction period and are $267.5 million annually for

Alternative Plans 1, 2, 3, and 5, and $277.0 million annually for Alternative Plan 4. Annualized construction cost estimates were used in IMPLAN to determine the direct, indirect, and induced economic effects of the project construction activity on employment and output. Direct construction jobs were adjusted to ensure a direct employment ratio of 450 jobs per year for Alternative Plans 1, 2, 3, and 5, and 460 jobs per year for Alternative Plan 4.

The initial direct spending in a region related to each of the types of construction costs is considered the potential direct economic impact, which has employment and output effects tied to it. The source of funding for project construction costs has key importance in determining the magnitude of economic impacts. Direct impacts of field and non-contract costs and the way they were treated for IMPLAN modeling are discussed below.

Field Costs The project's field costs can be expected to represent a major direct regional economic effect of the project construction. Field costs consist of onsite construction expenditures for materials, equipment, and labor. For the purposes of this analysis it is assumed that all of the project's field cost spending will be performed with material, equipment, and labor sourced from within the same region that the construction activity is located. In other words, the analysis assumes that there is no significant leakage of field cost construction-related spending out of the Southern San Joaquin Valley economy. Full field-costs are considered direct new spending, before consideration of out-of-region investment.

This assumption is considered reasonable and practical for several reasons. First, the required skills, materials, or equipment that would need to be imported from outside the Southern San Joaquin Valley is unknown. Second, the six-county economy is relatively large and diversified, and therefore expected to have sufficient quantities of construction labor, materials, and equipment to meet the project's needs.

Non-Contract Costs In addition to the project's field cost, non-contract costs are expected to also contribute new economic activity to the Southern San Joaquin Valley economy. Non-contract costs include the various technical tasks necessary for project design and construction (i.e., legal services, environmental compliance, engineering, design, and construction management), as well as environmental mitigation, cultural resource mitigation, and land acquisition costs.

It is possible that some of the technical work for non-contract costs will be performed elsewhere. For this reason, not all non-contract-cost-related spending may occur in the Southern San Joaquin Valley region. But given the uncertainty in where this work would be performed, this analysis assumes no significant leakage of non-contract cost-related spending out of the Southern San Joaquin Valley economy.

Indirect and Induced Impacts Construction-related direct expenses were entered into the Southern San Joaquin Valley model, and IMPLAN estimated the total regional economic response of alternative plans' construction expenditures using the 2009 IMPLAN California counties dataset. A matrix representation of a region's economy was used to predict the effect of changes in one industry on others (indirect effect) and changes in household income (induced effect) through multipliers, taking into account inter-industry linkages and leakages outside the region. Indirect and induced impacts of project construction on employment and output related to alternative plans were estimated.

Economic Effects of Improved Agricultural Water Supply Reliability

Changes in agricultural production due to increased water supply reliability were estimated and documented in Chapter 10. Agricultural direct effects are expected to take place annually over the project life (100-years), and represent a long-term average annual economic effect to the region.

Changes in agricultural production will primarily and most directly benefit the region's agricultural sectors. In addition, direct changes in agricultural production will generate indirect and induced economic impacts on other sectors of the region's economy. Direct, indirect, and induced economic effects of changes in agricultural production and the approach used to quantify each effect and their magnitude are discussed below.

Direct Impacts

Agricultural direct effects by crop and region were obtained from output from the SWAP model. The output data were organized and entered as inputs to appropriate agricultural sectors within the Statewide and Southern San Joaquin Valley regional impacts models. In the latter case, only the portion of SWAP applied to the Friant and West San Joaquin Divisions was included in the Southern San Joaquin Valley model. County agricultural commissioner crop reports were used to revise and update the commodity categories within the Southern San Joaquin Valley model to improve the precision of estimates. This is typically necessary to "fine tune" the model to reflect unique regional conditions involving agricultural production. Such adjustments to the model were not necessary for the Statewide model because commodity-based data on employment and income are generally reliable at a State level.

Indirect and Induced Impacts

The total regional economic effects of changes in agricultural production were estimated using the 2009 IMPLAN California counties dataset. A matrix representation of a region's economy was used to predict the effect of changes in one industry on others (indirect effect) and changes in household income (induced effect) through multipliers. Indirect and induced impacts of changes in agricultural production on employment and industry output were estimated and presented later in this chapter.

Economic Effects of Increased Recreational Visitation and Spending

Increases in recreational visitation were estimated and documented in Chapter 8. Direct effects of increased recreational visitation and spending are expected to take place annually, and represent a long-term average annual economic effect to each region.

Increased recreational visitation and spending will primarily and most directly benefit the region's tourism-related sectors. In addition, direct increases in recreational visitation will generate indirect and induced economic impacts on other sectors of the region's economy. Direct, indirect, and induced economic effects of increases in recreational visitation and the approach used to quantify each effect and their magnitude are discussed below.

Direct Impacts

Recreational visitation direct effects by activities and region were obtained from output of the recreational modeling discussed in Chapter 8. Recreation visitor expenditure profiles, divided into use types and day use versus campers, were developed. Data for these expenditure patterns were not available for visitors to the recreation site (Millerton Lake); representative expenditure patterns were developed from the literature and comparable sites.

A number of studies that estimated recreation-related economic impacts were reviewed. A recent study prepared by DWR in support of FERC relicensing of Oroville Dam was selected as a representative case (DWR, 2004); the reservoir is similar to Millerton Lake in terms of the types of recreation opportunities provided and visitors. The study derived estimates of expenditures by visitors through a detailed survey. Although the report did not provide details distinguishing different types of visitors, their recreation activities, or for overnight campers, their expenditure patterns were considered a useful proxy estimate. Table 11-1 summarizes the expenditure pattern applied to all new recreation visits to Millerton Lake, regardless of activity type. The literature indicates that motor boaters, campers, and fishermen spend more per visitor day than other day use visitors. For this reason, the expenditure pattern applied here probably understates the actual impacts of recreation on the regional economy. Total recreation expenditures (i.e., total change in annual visitor-days multiplied by expenditures per day) were applied to appropriate sectors of the Southern San Joaquin Valley and Statewide models.

Table 11-1. Assumed Expenditure Pattern for Recreation Visitors to Millerton Lake

Category of Expenditure	Expenditure[1] ($/visitor-day)
Food and convenience stores	10.98
Gasoline service stations	11.57
Miscellaneous retail stores	10.80
Eating and drinking establishments	1.20
Other (recreation services, repair, apparel, and other business services)	9.70
Total	**44.24**

Source: California Department of Water Resources, 2004. Recreation Activity, Spending, and Associated Economic Impacts. Oroville Facilities Relicensing FERC Project No. 2100.

Note:

[1] Expenditure patterns are displayed in 2013 (January) dollars based on the Consumer Price Index.

Increased recreation visitation would generate an increase in purchases of goods and services. However, for many of the products sold (in retail food, fuel, and eating and drinking establishments), a large proportion of the raw materials or final products originate outside of the region. While sales transactions would generate economic activity, much of the revenue would “leak” out of the local economy and would thus not be available to circulate and create an otherwise large multiplier effect. This contrasts with basic industries, such as agricultural products, that yield a higher multiplier effect within the Southern San Joaquin Valley.

It should be noted that regional impacts related to recreation spending will be very different for visitors that originate from *outside* the defined region and visitors that originate from *inside* the region. Outside visitors represent a flow of expenditures into the regional economy while spending by residents within the region may represent a redistribution or substitution of spending for other activities. This is particularly important when considering the statewide model, where a large proportion of the visitors may originate from within the state. This is offset in part by greater expenditures per capita by more distant visitors (e.g., for food, lodging, and transportation). For the purposes of this analysis, no substitution of activities or other sites are considered in the regional impacts models.

Indirect and Induced Impacts

After recreation-related direct effects were applied, the total regional economic effects of increased recreational visitation were estimated using the 2009 IMPLAN California counties dataset. A matrix representation of a region’s economy was used to predict the effect of changes in one industry on others (indirect effect) and changes in household income (induced effect) through multipliers. Indirect and induced impacts of increased recreational visitation on employment and industry output were estimated and are presented in the Results and Discussion Section of this chapter.

IMPLAN Results and Discussion

The following section provides total industry output, person income, and employment results of the regional impact analysis conducted for the Investigation for each action alternative.

Total Industry Output

Total industry output results are given in Tables 11-2 (existing conditions) and 11-3 (future conditions). Total direct industry output from action alternative construction expenditure was calculated to be between $267.5 million and $277.0 million (existing and future conditions) annually for the 8-year construction periods. Over the life time of the project, the action alternatives are projected to have an annual direct total industry output between $17.1 million and $14.1 million (existing conditions) and $6.5 million and $15.2 million (future conditions) in the Southern San Joaquin Valley. In the statewide model, annual direct total industry output is expected to range from $3.8 million to $7.0 million (existing conditions) and $2.7 million to $5.0 million (future conditions) over the lifetime of the project.

Table 11-2. Total Industry Output Results for the Action Alternatives Under Existing Conditions

Impact Region/ Duration of Effects/ Activity Type	Industry Output per Year ($[1] million)	Alternative Plans				
			2	3	4	5
Southern San Joaquin Valley ***Short-Term Impacts (average annual over 8-year construction period)***						
Construction Expenditure[3]	**Direct**	$267.5	$267.5	$267.5	$277.0	$267.5
	Indirect & Induced	$151.6	$151.6	$151.6	$157.0	$151.6
	Total[2]	$419.1	$419.1	$419.1	$434.0	$419.1
Southern San Joaquin Valley ***Long-Term Impacts (average annual over project life)***						
Agricultural Production[3]	**Direct**	$6.2	$4.0	$5.2	$4.0	$7.5
	Indirect & Induced	$10.9	$9.3	$10.3	$8.7	$14.3
	Total[2]	$17.2	$13.3	$15.5	$12.8	$21.8
Recreational Visitation[3]	**Direct**	$1.6	$1.6	$1.5	$1.7	$1.2
	Indirect & Induced	$0.8	$0.8	$0.8	$0.9	$0.6
	Total[2]	$2.4	$2.4	$2.3	$2.6	$1.8
Project Operations and Maintenance[4]	**Direct**	$8.4	$8.4	$8.4	$8.4	$8.4
	Indirect & Induced	$1.2	$1.2	$1.2	$1.2	$1.2
	Total[2]	$9.6	$9.6	$9.6	$9.6	$9.6
TOTAL[2]	**Direct**	$16.2	$14.0	$15.1	$14.1	$17.1
	Indirect & Induced	$13.0	$11.3	$12.3	$10.9	$16.1
	Total[2]	$29.2	$25.3	$27.4	$25.0	$33.2

Table 11-2. Total Industry Output Results for the Action Alternatives Under Existing Conditions (contd.)

		Alternative Plans				
Impact Region/ Duration of Effects/ Activity Type	**Industry Output per Year ($[1] million)**		**2**	**3**	**4**	**5**
Statewide ***Long-Term Impacts (average annual over project life)***						
Agricultural Production	**Direct**	$5.8	$3.8	$4.8	$3.8	$7.0
	Indirect & Induced	$13.5	$11.6	$12.7	$10.9	$17.7
	Total[2]	$19.3	$15.4	$17.6	$14.7	$24.7

Notes:

General: The Southern San Joaquin Valley impact region includes Fresno, Kern, Kings, Madera, Merced, and Tulare counties.

General: The Statewide impact region includes the entire state of California.

[1] Industry output per year results are presented at January, 2013 price levels.

[2] All numbers are rounded for display purposes; therefore, line items may not sum to totals.

Table 11-3. Total Industry Output Results for the Action Alternatives Under Future Conditions

		Alternative Plans				
Impact Region/ Duration of Effects/ Activity Type	**Industry Output per Year ($[1] million)**		**2**	**3**	**4**	**5**
Southern San Joaquin Valley ***Short-Term Impacts (average annual over 8-year construction period)***						
Construction Expenditure[3]	**Direct**	$267.5	$267.5	$267.5	$277.0	$267.5
	Indirect & Induced	$151.6	$151.6	$151.6	$157.0	$151.6
	Total[2]	$419.1	$419.1	$419.1	$434.0	$419.1
Southern San Joaquin Valley ***Long-Term Impacts (average annual over project life)***						
Agricultural Production[3]	**Direct**	$4.5	$4.0	$4.2	$3.0	$5.5
	Indirect & Induced	$8.8	$8.6	$8.9	$7.2	$11.8
	Total[2]	$13.3	$12.6	$13.1	$10.2	$17.3
Recreational Visitation[3]	**Direct**	$1.5	$1.5	$1.4	$1.6	$0.9
	Indirect & Induced	$0.8	$0.8	$0.8	$0.9	$0.5
	Total[2]	$2.3	$2.3	$2.2	$2.5	$1.4

Table 11-3. Total Industry Output Results for the Action Alternatives Under Future Conditions (contd.)

		Alternative Plans				
Impact Region/ Duration of Effects/ Activity Type	**Industry Output per Year ($[1] million)**		**2**	**3**	**4**	**5**
Project Operations and Maintenance[4]	**Direct**	$8.4	$1.2	$9.6	$0.0	$0.0
	Indirect & Induced	$1.2	$9.6	$0.0	$0.0	$0.0
	Total[2]	$9.6	$10.8	$9.6	$0.0	$0.0
TOTAL[2]	**Direct**	$14.4	$6.7	$15.2	$4.7	$6.5
	Indirect & Induced	$10.7	$19.0	$9.7	$8.1	$12.3
	Total[2]	$25.2	$25.7	$24.9	$12.7	$18.8
Statewide ***Long-Term Impacts (average annual over project life)***						
Agricultural Production	**Direct**	$4.1	$3.6	$3.7	$2.7	$5.0
	Indirect & Induced	$10.7	$10.4	$10.8	$8.7	$14.4
	Total[2]	$14.8	$13.9	$14.5	$11.4	$19.4

Notes:

General: The Southern San Joaquin Valley impact region includes Fresno, Kern, Kings, Madera, Merced, and Tulare counties.

General: The Statewide impact region includes the entire state of California.

[1] Industry output per year results are presented at January, 2013 price levels.

[2] All numbers are rounded for display purposes; therefore, line items may not sum to totals.

Personal Income

Personal income results are given in Table 11-4 (existing conditions) and Table 11-5 (future conditions). Direct personal income benefits from action alternative construction expenditures were calculated to range from $109.4 million to $113.2 million annually (for both existing and future conditions) for the 8-year construction period. Over the lifetime of the project, the action alternatives are projected to result in an annual direct person income between $4.2 million and $3.8 million (existing conditions) and $6.7 million and $8.2 million (future conditions) in the Southern San Joaquin Valley. In the statewide model, annual direct personal income benefits of the action alternatives are expected to range from $0.7 million to $1.3 million (existing conditions) and $0.6 million to $1.1 million (future conditions) over the lifetime of the project.

Table 11-4. Personal Income Results for the Action Alternatives Under Existing Conditions

Impact Region/ Duration of Effects/ Activity Type	Personal Income per Year ($[1] million)	Alternative Plan				
		1	2	3	4	5
Southern San Joaquin Valley ***Short-Term Impacts (average annual over 8-year construction period)***						
Construction Expenditure[3]	Direct	$109.4	$109.4	$109.4	$113.2	$109.4
	Indirect & Induced	$54.7	$54.7	$54.7	$56.6	$54.7
	Total[2]	$164.1	$164.1	$164.1	$169.8	$164.1
Southern San Joaquin Valley ***Long-Term Impacts (average annual over project life)***						
Agricultural Production[3]	Direct	$1.4	$0.8	$1.1	$0.9	$1.5
	Indirect & Induced	$3.9	$3.2	$3.6	$3.0	$5.0
	Total[2]	$5.3	$4.0	$4.7	$3.9	$6.5
Recreational Visitation[3]	Direct	$0.8	$0.9	$0.8	$0.9	$0.6
	Indirect & Induced	$0.3	$0.3	$0.3	$0.3	$0.2
	Total[2]	$1.1	$1.1	$1.1	$1.2	$0.8
Project Operations and Maintenance[4]	Direct	$1.9	$1.9	$1.9	$1.9	$1.9
	Indirect & Induced	$0.4	$0.4	$0.4	$0.4	$0.4
	Total[2]	$2.3	$2.3	$2.3	$2.3	$2.3
TOTAL[2]	Direct	$4.2	$3.6	$3.8	$3.7	$3.4
	Indirect & Induced	$4.5	$3.9	$4.3	$3.7	$4.8
	Total[2]	$8.7	$7.4	$8.1	$7.4	$8.1
Statewide ***Long-Term Impacts (average annual over project life)***						
Agricultural Production	Direct	$1.3	$0.7	$0.9	$0.8	$1.3
	Indirect & Induced	$4.5	$3.8	$4.2	$3.6	$5.9
	Total[2]	$5.8	$4.6	$5.2	$4.4	$7.1

Notes:

General: The Southern San Joaquin Valley impact region includes Fresno, Kern, Kings, Madera, Merced, and Tulare counties.

General: The Statewide impact region includes the entire state of California.

[1] Personal income per year results are presented at January, 2013 price levels.

[2] All numbers are rounded for display purposes; therefore, line items may not sum to totals.

Table 11-5. Personal Income Results for the Action Alternatives Under Future Conditions

Impact Region/ Duration of Effects/ Activity Type	Personal Income per Year ($[1] million)	Alternative Plan				
		1	2	3	4	5
Southern San Joaquin Valley ***Short-Term Impacts (average annual over 8-year construction period)***						
Construction Expenditure[3]	**Direct**	$109.4	$109.4	$109.4	$113.2	$109.4
	Indirect & Induced	$54.7	$54.7	$54.7	$56.6	$54.7
	Total[2]	$164.1	$164.1	$164.1	$169.8	$164.1
Southern San Joaquin Valley ***Long-Term Impacts (average annual over project life)***						
Agricultural Production[3]	**Direct**	$1.2	$0.9	$0.9	$0.7	$1.1
	Indirect & Induced	$3.1	$3.0	$3.1	$2.5	$4.1
	Total[2]	$4.3	$3.9	$4.0	$3.2	$5.2
Recreational Visitation[3]	**Direct**	$0.8	$0.8	$0.8	$0.9	$0.5
	Indirect & Induced	$0.3	$0.3	$0.3	$0.3	$0.2
	Total[2]	$1.1	$1.1	$1.0	$1.2	$0.7
Project Operations and Maintenance[4]	**Direct**	$1.9	$1.9	$1.9	$1.9	$1.9
	Indirect & Induced	$0.4	$0.4	$0.4	$0.4	$0.4
	Total[2]	$2.3	$2.3	$2.3	$2.3	$2.3
TOTAL[2]	**Direct**	$3.9	$3.6	$3.6	$3.5	$3.5
	Indirect & Induced	$3.8	$3.7	$3.8	$3.2	$4.7
	Total[2]	$7.6	$7.3	$7.4	$6.7	$8.2
Statewide ***Long-Term Impacts (average annual over project life)***						
Agricultural Production	**Direct**	$1.1	$0.7	$0.7	$0.6	$0.9
	Indirect & Induced	$3.6	$3.5	$3.6	$2.9	$4.8
	Total[2]	$4.7	$4.2	$4.4	$3.5	$5.7

Notes:
General: The Southern San Joaquin Valley impact region includes Fresno, Kern, Kings, Madera, Merced, and Tulare counties.
General: The Statewide impact region includes the entire state of California.
[1] Personal income per year results are presented at January, 2013 price levels.
[2] All numbers are rounded for display purposes; therefore, line items may not sum to totals.

Employment

Employment results are given in Tables 11-6 (existing conditions) and 11-7 (future conditions). Jobs created directly from action alternative construction expenditure were calculated to be between 450 and 460 (existing and future conditions) per year over the 8-year construction period. Over the life time of the project, the action alternatives are projected to directly create between 91 and 235 jobs (existing conditions) and 93 and 235 jobs (future conditions) annually in the San Joaquin Valley. In the statewide model, the action alternatives are project to directly create between 38 and 75 jobs (existing conditions) and 24 and 53 jobs (future conditions) annually over the life time of the project.

Table 11-6. Employment Results for the Action Alternatives Under Existing Conditions

Impact Region/ Duration of Effects/ Activity Type	Employment Effects (Jobs[1] per Year)	Alternative Plan 1	2	3	4	5
Southern San Joaquin Valley ***Short-Term Impacts (average annual over 8-year construction period)***						
Construction Expenditure[3]	**Direct**	450	450	450	460	450
	Indirect & Induced	1,155	1,155	1,155	1,196	1,155
	Total[2]	1,605	1,605	1,605	1,656	1,605
Southern San Joaquin Valley ***Long-Term Impacts (average annual over project life)***						
Agricultural Production	**Direct**	59	46	56	43	86
	Indirect & Induced	94	77	87	74	121
	Total[2]	153	123	143	117	207
Recreational Visitation	**Direct**	27	27	26	29	20
	Indirect & Induced	6	6	6	7	5
	Total[2]	33	33	32	36	25
Project Operations and Maintenance[4]	**Direct**	28	28	28	28	28
	Indirect & Induced	10	10	10	10	10
	Total[2]	38	38	38	38	38
TOTAL[2]	**Direct**	114	100	109	235	91
	Indirect & Induced	110	94	103	179	114
	Total[2]	224	194	212	414	205

Table 11-6. Employment Results for the Action Alternatives Under Existing Conditions (contd.)

Impact Region/ Duration of Effects/ Activity Type	Employment Effects (Jobs[1] per Year)	Alternative Plan 1	2	3	4	5
Statewide ***Long-Term Impacts (average annual over project life)***						
Agricultural Production	**Direct**	54	40	49	38	75
	Indirect & Induced	88	74	82	70	114
	Total[2]	142	114	131	108	189

Notes:
General: The Southern San Joaquin Valley impact region includes Fresno, Kern, Kings, Madera, Merced, and Tulare counties.
General: The Statewide impact region includes the entire state of California.
[1] Jobs per year represent full-time, part-time, and temporary positions.
[2] All numbers are rounded for display purposes; therefore, line items may not sum to totals.
[3] Direct jobs were estimated by the study team.
[4] Direct project operations and maintenance jobs were estimated by the study team for powerhouse, dam, and recreation operations.

Table 11-7. Employment Results for the Action Alternatives Under Future Conditions

Impact Region/ Duration of Effects/ Activity Type	Employment Effects (Jobs[1] per Year)	Alternative Plan 1	2	3	4	5
Southern San Joaquin Valley ***Short-Term Impacts (average annual over 8-year construction period)***						
Construction Expenditure[3]	**Direct**	450	450	450	460	450
	Indirect & Induced	1,155	1,155	1,155	1,196	1,155
	Total[2]	1,605	1,605	1,605	1,656	1,605

Table 11-7. Employment Results for the Action Alternatives Under Future Conditions (contd.)

Impact Region/ Duration of Effects/ Activity Type	Employment Effects (Jobs[1] per Year)	Alternative Plan 1	2	3	4	5
Southern San Joaquin Valley *Long-Term Impacts (average annual over project life)*						
Agricultural Production	**Direct**	35	40	42	28	62
	Indirect & Induced	76	73	76	61	100
	Total[2]	110	113	118	89	162
Recreational Visitation	**Direct**	25	25	25	28	16
	Indirect & Induced	6	6	6	7	4
	Total[2]	31	31	30	35	20
Project Operations and Maintenance[4]	**Direct**	28	28	28	28	28
	Indirect & Induced	10	10	10	10	10
	Total[2]	38	38	38	38	38
TOTAL[2]	**Direct**	88	93	95	235	106
	Indirect & Induced	91	89	91	179	113
	Total[2]	179	182	186	414	220
Statewide *Long-Term Impacts (average annual over project life)*						
Agricultural Production	**Direct**	32	34	36	24	53
	Indirect & Induced	70	67	69	56	92
	Total[2]	102	101	106	80	145

Notes:
General: The Southern San Joaquin Valley impact region includes Fresno, Kern, Kings, Madera, Merced, and Tulare counties.
General: The Statewide impact region includes the entire state of California.
[1] Jobs per year represent full-time, part-time, and temporary positions.
[2] All numbers are rounded for display purposes; therefore, line items may not sum to totals.
[3] Direct jobs were estimated by the study team.
[4] Direct project operations and maintenance jobs were estimated by the study team for powerhouse, dam, and recreation operations.

Chapter 12
Climate Change Modeling

The climate change analysis conducted for the Investigation is described in EIS Chapter 5, “Climate Change.” This chapter provides a summary of existing and potential future climate conditions in the Central Valley, a detailed discussion of the modeling methodology and approach used, and discussion of the performance of a Representative Alternative under climate change. Additional documentation of these efforts is included in the Climate Change Modeling Attachment.

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Chapter 13
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Chapter 12

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