Appendix C

Delta Conditions Assessment

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Appendix C
Delta Conditions Assessment

C.1 Background

Hydrologic conditions, climatic variability, and regulatory requirements for operation of water projects commonly affect water supply availability in California. This variability strains water supplies, making advance planning for water shortages necessary and routine. In the past decades, water transfers have become a common tool in water resource planning to supplement available water supplies to serve existing demands.

The United States Department of the Interior, Bureau of Reclamation (Reclamation) manages the Central Valley Project (CVP), which includes storage in reservoirs (such as Shasta, Folsom, and Trinity reservoirs) and diversion pumps in the Sacramento-San Joaquin Delta (Delta) to deliver water to users in the San Joaquin Valley and San Francisco Bay area. When these users experience water shortages, they may look to water transfers to help reduce potential impacts of those shortages.

A water transfer involves an agreement between a willing seller and a willing buyer. To make water available for transfer and conveyance to the Buyer Service Area for beneficial use, the willing seller must take an action to reduce the consumptive use of water or reduce reservoir storage. Water transfers would only be used to help meet existing demands and would not serve any new demands in the Buyer Service Area.

Reclamation and the San Luis & Delta-Mendota Water Authority (SLDMWA) are completing a joint Environmental Impact Statement/Environmental Impact Report (EIS/EIR), in compliance with the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA), for water transfers from 2015 through 2024. Reclamation is serving as the Lead Agency under NEPA and SLDWMA is the Lead Agency under CEQA. Reclamation would facilitate transfers proposed by buyers and sellers. The SLDMWA, consisting of federal and exchange water service contractors in western San Joaquin Valley, San Benito, and Santa Clara counties, helps negotiate transfers in years when the member agencies could experience shortages.

This EIS/EIR evaluates water transfers that originate from entities located upstream of the Delta. Purchasing agencies are in areas south of the Delta or in the San Francisco Bay Area. Water transfers are subject to federal and state law.

This EIS/EIR analyzes transfers to CVP contractors, using CVP or SWP facilities to deliver these transfers.

C.2 Purpose of Delta Conditions Analysis

An analysis of Delta conditions is necessary to assist in evaluation of potential environmental impacts associated with Long-Term Water Transfers within the Delta. Water transfers have the potential to affect both the natural system and operation of the CVP and State Water Project (SWP). The purpose of this analysis is to simulate the hydrodynamics and water quality within the Delta when transfer water is made available by various sellers to determine how and where within the Delta the effects are likely to occur under the alternatives. Output from the Delta conditions analysis for parameters such as water level (stage), water quality, and environmental flows under D-1641 and the biological opinions (BOs) provides a basis for environmental assessment.

C.3 Analytical Approach

The Delta Conditions analysis is performed with the Delta Simulation Model 2 (DSM2). DSM2 setup relies on the output of three additional tools for this Project: CalSim II, the Transfer Operations Model (TOM), and the Delta Island Consumptive Use model (DICU model). CalSim II outputs simulating California's water delivery system to the Delta are used to supply inflow and export boundary conditions to DSM2. Within DSM2, agricultural influences and the effect of meteorological conditions are modeled by boundary conditions supplied by the DICU, model. DSM2 boundary conditions affected by the assumptions under the alternatives are supplied by TOM.

DSM2 model results of a baseline (Base) alternative, the No Action/No Project Alternative without proposed water transfers, as developed in CALSIM II, are compared to model results with proposed water transfers under each alternative supplied by TOM to determine the extent and significance of any differences resulting from the transfers.

A distinction needs to be made between the uses of models for *absolute* versus *comparative* analyses. In an *absolute analysis,* the model is run once to predict an outcome – for example, the outcome could be the concentration of EC at one of the Delta water intakes. In a *comparative analysis*, the model is run twice, once with conditions representing a baseline and another run with an alternative representing some specific changes to Delta operations and/or bathymetry in order to assess the change in modeled outcome due to the given change in model configuration. The assumption is that while the model might not produce results reflecting these changes with absolute certainty, it does produce a reasonably reliable estimate of the relative change in outcome.

For the long-term water transfers analysis, as is customary in most projects using CalSim II planning models combined with DSM2, the analysis is a comparative analysis approach[1]. The Base alternative represents a condition that approximates an operational and regulatory framework that is assumed to determine the hydrodynamics and water quality in the Delta at an Existing Condition time frame. DSM2 was used to determine changes from due to the Alternatives in: EC patterns in the Delta; water level changes in the south Delta; changes in X2, the location of the 2 ppt salinity isohaline; and, changes in the magnitude of the combined flow in Old and Middle Rivers (OMR flow).

C.4 Model Descriptions

Models used in the Delta conditions analysis are described briefly in the following sections – DSM2, CALSIM II, the TOM and the DICU model. Appendix B supplies detail on the assumptions and logic used in CalSim II and TOM. For these studies, the modeled time frame is restricted to water years 1970 – 2003.

C.4.1 DSM2

DSM2 is a one-dimensional (1-D) hydrodynamic and water quality simulation model used to represent conditions in the Sacramento-San Joaquin Delta. The model was developed by the Delta Modeling Section (DMS) of the Department of Water Resources (DWR) and is used to model impacts associated with projects in the Delta. DSM2 has been used extensively to model hydrodynamics and salinity in the Delta, as well as Dissolved Organic Carbon (DOC). Salinity is modeled as electrical conductivity (EC), which is assumed to behave as a conservative constituent. DOC was not modeled in the current study.

DSM2 contains three separate modules, a hydrodynamic module (HYDRO), a water quality module (QUAL), and a particle tracking module (PTM). QUAL uses the hydrodynamics simulated in HYDRO as the basis for its transport calculations. PTM was not used in the current study. Detailed descriptions of the mathematical formulation implemented in the hydrodynamic module, DSM2-HYDRO and for EC in the water quality module, DSM2-QUAL, the data required for simulation, and the calibration of HYDRO and QUAL are documented in a series of reports available at: http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/annualreports.cfm .

The calibration of DSM2 has primarily focused on hydrodynamics and the conservative transport of salinity (EC). The DSM2 network used for the HYDRO hydrodynamic and QUAL water quality simulations in this study was updated in 2009 (Chilmakuri, 2009), The version of the model (V 8.1.2) used in

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[1] 2003, http://sacramentoriverportal.org/modeling/CALSIM-Review.pdf

this study implements the NAVD88 datum in the formulation of the grid and the development of boundary conditions, a change from previous versions of the model.

C.4.2 DICU

The Delta Island Consumptive Use Model, or DICU[2] model, was developed by the Planning Division of DWR to estimate agricultural diversions and return flows to Delta channels. The DICU model is used in DSM2 to estimate historical agricultural flows and to estimate project planning model agricultural volumes and the salinity of return flows. These volumes and the associated concentration of water quality parameters are assigned to numerous DSM2 nodes. In this report, the term "DICU" is used to refer both to the conceptual model and to the associated computer program.

The values calculated for consumptive use in the conceptual model include the following parameters:

- Evapotranspiration – includes climatic conditions, soil type and plant type and associated acreage
- Precipitation – spatially distributed using Delta weather station values
- Surface runoff
- Soil moisture
- Irrigation – water diverted from channels, estimated by season
- Seepage – water used by plants flows from channels to Delta islands
- Drainage – return flows from irrigation and leaching to channels from Delta islands
- Leach water – heavy applications of water in winter months used to leach salts from soils.

The DICU model as a whole is most sensitive to changes in irrigation efficiency (a constant factor applied to irrigation withdrawals) and to leaching water estimates. Calculations for water diversions and returns are most sensitive to changes in efficiency of irrigation and in evapotranspiration. Changes in seepage values can cause changes in irrigation demands and in return flows, although they only have a small impact on return flows. Studies have indicated that DICU seepage estimates are probably low.

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[2] http://modeling.water.ca.gov/delta/reports/misc/EstDICU.pdf

The DICU model provides time series of values that are applied as boundary conditions on a monthly average basis[3],[4] (DWR, 1995a; DWR 2002) in DSM2 at 257[5] locations throughout the Delta – these locations are subdivided into 142 regions. There are three components to DICU flows – diversion, drainage and seepage. The total monthly diversions incorporate agricultural use, evaporation and precipitation, drains incorporate agricultural returns, and seeps incorporate channel depletions. These flows are distributed as boundary conditions that vary by region and by Water Year Type. Acreages for land use categories and crop type are varied by two categories of water year type, critical and non-critical. The critical years in the DICU model include the D-1485 (same as D-1641) water year classification types of Critical and Dry; non-critical years include the remaining Water Year classification types.

The concentration of EC in agricultural return flows, the Drain flows in DSM2, are also applied on a monthly average basis using the same monthly averages in every year regardless of water year type. The estimation of water quality concentrations in return flows in the DICU model is documented in DWR publications available online[6].

C.4.3 CALSIM II

CalSim is a model that was developed by the California Department of Water Resources to simulate California State Water Project (SWP) and Central Valley Project (CVP) operations in planning studies. CalSim II is the latest version of CalSim available for general use. It represents the Central Valley with a node and link structure to simulate natural and managed flows in rivers and canals. It generates monthly flows showing the effect of land use, potential climate change, and water operations on flows throughout the Central Valley.

CalSim II is a simulation by optimization model which simulates operations by solving a mixed-integer linear program to maximize an objective function for each month of the simulation. CalSim II simulates the operation of the CVP and SWP systems for defined physical conditions and a set of regulatory requirements. The model simulates these conditions using up to 82 years of historical hydrology from Water Year (WY) 1922 through WY 2003.

The system objectives and constraints are specified as input to the model, and CalSim II then utilizes optimization techniques to route water through a network representing the California water system given user-defined priority weights. A linear programming (LP)/mixed integer linear programming (MILP) solver determines an optimal set of decisions for each time period given this set

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[3] http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/dicu.cfm

[4] http://www.iep.ca.gov/dsm2pwt/reports/DSM2FinalReport_v07-19-02.pdf,
http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/DICU_Dec2000.pdf

[5] note that Byron-Bethany irrigation district is included as a DICU flow in Clifton Court Forebay, so there are actually 258 DICU nodes

[6] http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dicu/DICU_Dec2000.pdf

of weights and system constraints. The CalSim II model has been designed to separate the physical and operational criteria from the actual process of determining the allocations of water to competing interests. Thus, CalSim II provides quantitative hydrologic-based information to those responsible for planning, managing and operating the SWP and CVP. As the official model of those projects, CalSim II is the default system model for the analysis of water in the Central Valley of California.[7]

C.4.4 Transfer Operations Model (TOM)

TOM was developed to analyze effects of Long-Term Water Transfers on the CVP, SWP, major rivers, and the Delta by tracking: the water made available from various sellers as it moves through the system; the effects on CVP and SWP operations; and, the diversion of transfer water by buyers. TOM simulates operations on a monthly time-step for the same 34-year period as CalSim II, and its output is used is supply a subset of the boundary conditions used in DSM2 to model the Alternatives. (See Appendix B for more details.)

In real-time operations, tracking transfer water requires an increased level of coordination between CVP and SWP operators as it affects accounting under the Coordinated Operation Agreement (COA) between the CVP and SWP, and can require COA accounting adjustments. Transfer water can change the timing of when CVP and SWP Project water is moved. A portion of transfer water is typically used as carriage water to maintain Delta water quality when transfer water is moved through the Delta. This requires initial estimates for carriage water that must later be verified and adjusted. TOM was developed in consultation with Reclamation and with an understanding of both actual operations and CalSim II model assumptions. Rules used in TOM to simulate operational responses to water transfers and changes in stream-aquifer interaction were reviewed with CVP operations staff.

C.4.5 Level of Development

The Long-Term Water Transfers EIS/EIR is intended to provide environmental assessment for water transfers occurring over a ten-year period. Because of the relatively short horizon, it is anticipated that the existing Level of Development (LOD) would not substantially change, although reasonably foreseeable projects that may be constructed over the next ten years have been incorporated into the model. CalSim II existing LOD simulations depict how the modeled water system might operate with an assumed physical and institutional configuration imposed on a long-term hydrologic sequence, assuming that current land use, facilities, and operational objectives are in place for each year of simulation (water years 1970 through 2003). The results are a depiction of the current environment which provides a basis for comparison of alternatives effects for the impact analysis under CEQA. The ten-year period allows simulation of a

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[7] http://sacramentoriverportal.org/modeling/CALSIM-Review.pdf, Section 6.1

single level of development under the assumptions that conditions are not likely to change significantly over such a short time horizon.

C.5 Modeling Methodology and Analysis Limitations

C.5.1 DSM2 Scenario Development

DWR-DMS has developed a series of computer applications, called preprocessors, to automate the generation of DSM2 model inputs and boundary conditions. These applications produce input time series for DSM2 flows from CalSim II output, as well as time series for the timing of operations for certain gates and barriers, for example, the gates at the entry of Clifton Court Forebay (CCFB) and the gates in the Delta Cross Channel (DCC). The time series, as well as the time series for DICU flows and EC concentrations, are copied into a single input file in the DSS data format that is read directly into DSM2. Boundary conditions for the Base case come solely from CalSim II output, while boundary conditions defining the alternatives come from TOM. As mentioned previously, these alternatives depict an Existing, or Current Conditions, LOD.

C.5.2 Inflow, Export and EC Boundary Conditions

Boundaries that define the movement of water into and out of the Delta, and thus also the transport of water quality constituents, consist of inflow boundaries, outflow boundaries and a stage boundary set at Martinez. In Figure C-1 (left), the main inflow boundary locations are denoted by blue dots as is the stage boundary at Martinez. The inflow boundaries are found at the each of the major rivers (Sacramento, San Joaquin, Calaveras, Mokelumne and Cosumnes), and at the Yolo Bypass. The stage boundary at Martinez is also an outflow boundary. In Figure C-1 (right), the approximate positions of Delta export/ diversion locations (water intakes) are shown.

CalSim II and EXCEL files were converted to DSM2 input. CalSim II output was developed as boundary conditions by running the preprocessors for DSM2. Time series in EXCEL files representing TOM model output were transferred to DSS format using the CalSim II file as a template, and then run through the DSM2 preprocessors. Similarly, the stage boundary at Martinez was obtained from a standardized time series under direction of the preprocessor logic. The EC boundary condition at Martinez is calculated in a DSM2 preprocessor using the NDO (Net Delta Outflow) value from CalSim II DSS file output and an equation defining an NDO-EC relationship at Martinez. The EC time series at the San Joaquin River location at Vernalis was supplied by MBK staff, either in the original CalSim II DSS file or in the EXCEL file with TOM model output. EC values at the other major inflow boundaries are set as standard constants for use in QUAL.

C.5.3 Limitations of the Analysis

There are limitations in the ability of models to accurately address all of the intricacies of complex water management operations. Professional judgment is required to interpret results and determine benefits and impacts. Analysis of Delta Conditions for the Long-Term Water Transfers is based on several models each with their own simplifications, idiosyncrasies and limitations. The overall analysis is therefore subject to the individual and combined limitations of these models. While it is important to recognize and acknowledge the limitations of models as they are applied for this analysis, these three models represent the best available tools for performing the analysis to serve as the basis for determining environmental impacts. The regular and continued use of DSM2, in particular, for planning studies and environmental assessment by Reclamation, DWR, and others indicates DSM2 is adequate for the purposes of this EIS/EIR.

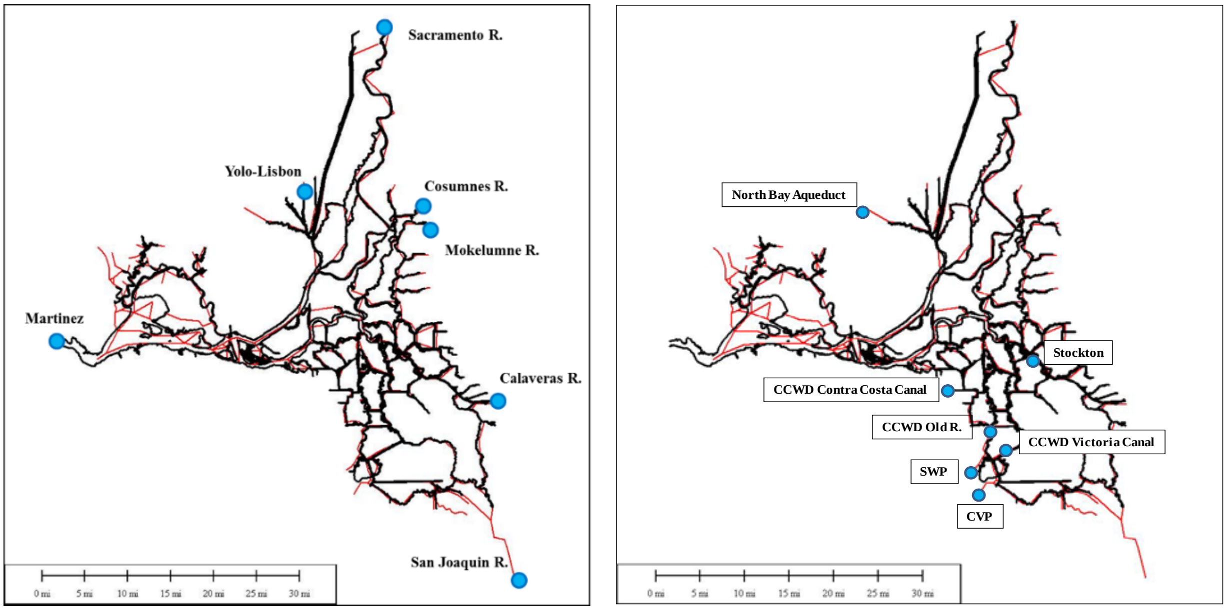


Figure C-1. Approximate Location (Blue Circles) Of: (Left) the Main Model Inflow Boundaries and the Stage Boundary At Martinez; and, (Right) the Water Intakes (Export Locations).

C.6 Description of Project Alternatives

C.6.1 Alternative 1: No Action/No Project Alternative

CEQA requires an EIR to include a No Action/No Project Alternative which allows for a comparison between the impacts of the action alternatives with Base case conditions. The No Action/No Project Alternative may include some reasonably foreseeable changes in existing conditions and changes that would be reasonably expected to occur in the foreseeable future if transfers were not approved.

Under the No Action/No Project Alternative, CVP related water transfers through the Delta would not occur from 2015-2024. However, other transfers that do not involve the CVP could occur under the No Action/No Project Alternative. Additionally, CVP transfers within basins could continue and would still require Reclamation’s approval. Some CVP entities may decide that they are interested in selling water to buyers in export areas under the No Action/No Project Alternative; however, they would need to complete individual NEPA and Endangered Species Act (ESA) compliance for each transfer to allow Reclamation to complete the evaluation of the transfers for approval.

C.6.2 Alternative 2/Proposed Action: Full Range of Transfers

Alternative 2 would involve transfers from potential sellers upstream from the Delta to buyers in the Central Valley and Bay Area. Alternative 2 includes transfers under all potential transfer measures: groundwater substitution, reservoir release, conserved water, and cropland idling and crop shifting.

C.6.3 Alternative 3: No Cropland Modifications

Alternative 3 would include transfers through groundwater substitution, stored reservoir release, and conservation. It would not include any cropland idling or shifting transfers.

C.6.4 Alternative 4: No Groundwater Substitution

Alternative 4 would include transfers through cropland idling, crop shifting, stored reservoir release, and conservation. It would not include any groundwater substitution transfers.

C.6.5 Nomenclature Used in the DSM2 Analysis of Delta Conditions

The following descriptive nomenclature was used in headings and/or captions for Tables and Plots depicting model results for the Alternatives, and in the text of this document:

- Alternative 1 = (Existing Condition) Base
- Alternative 2 = All Transfers
- Alternative 3 = No Crop Idle
- Alternative 4 = No Groundwater Substitution

C.7 Comparison of Boundary Conditions for the Alternatives

Alternative 1, the Base condition, was simulated in DSM2 with the conditions defined by the baseline CalSim II output. These results represent reasonably foreseeable conditions for the 2015-2024 period and are used for comparison with results from each of the project alternatives. Selected boundary conditions for Alternatives 2 – 4 differed from CalSim II baseline conditions – the Base conditions and the monthly average differences are depicted in Figure C-2 through Figure C-10. Tables show computations of monthly average differences, average monthly differences and average monthly percent differences – the Attachment to this Appendix contain the full set of tabular results. In general, the Proposed Action has the greatest change from Base among the Alternatives.

Conditions for all other boundary conditions (not shown), including DICU flows and EC concentrations, were used by all four Alternatives. For the All Transfers and No Crop Idle alternatives, diversions of water for Banta Carbona Water District were specified downstream of Vernalis. These diversions were incorporated in the San Joaquin River inflow boundary instead of at their geographic location as they were small in volume, totaling 54 cfs in increments of 4 cfs over the simulation period (water years 1970 through 2003), and the diversion location would not affect any of parameters tracked for the Delta conditions analysis.

Table C-1 document the change from Base for Sacramento River inflow as shown in Figure C-2, while Table C-2 through Table C-4 show computation of the average monthly percent difference results. These tables show that the period July to September in Dry and Critical water years account for the increases in Sacramento River inflow for each of the water transfer alternatives, and that most other months and years have variable levels of decrease in inflow. The timing of the increases in inflow are in line with the release of transfer water from storage in upstream dams discussed in Appendix B. Percent decreases in inflow are less than 2% in all other months and year types.

Table C-1. Monthly Average Difference in Sacramento River Inflow (Cfs) between the All Transfers and Base Alternatives, (All Transfers – Base). The Lower Table Computes Average Monthly Differences.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1970	-0.5	-0.2	0.0	-0.2	0.3	0.0	0.2	-0.5	-0.4	-0.4	0.2	0.1
1971	0.5	-0.5	0.2	-0.4	-0.1	-0.3	0.2	0.0	0.3	-0.3	0.0	0.4
1972	-0.1	0.4	0.3	0.4	0.4	-0.1	-0.4	0.3	-0.4	-0.4	0.0	0.4
1973	0.5	0.3	-0.3	0.2	-0.4	0.1	0.3	0.0	0.0	-0.1	0.3	0.2
1974	-0.5	-0.3	0.4	-0.5	0.3	0.4	0.1	0.3	0.4	-0.4	-0.3	0.3
1975	0.2	-0.1	0.0	-0.1	0.1	-0.3	-0.5	0.2	-0.4	-0.2	0.1	-0.1
1976	0.3	-0.5	-0.1	-0.5	-0.3	0.2	-2.9	-4.6	-45.0	1279.9	2802.7	693.4
1977	-180.2	-167.5	-155.3	-155.8	-148.7	-146.2	-127.1	-120.2	-97.1	2118.5	826.0	471.0
1978	-146.4	-160.4	-162.1	-961.7	-849.3	-464.5	-123.7	-92.9	-58.4	0.3	-0.4	-0.3
1979	-0.1	-0.2	0.0	-84.7	-239.3	-76.8	-65.9	-49.4	-0.1	-0.1	-0.5	0.0
1980	-12.6	-30.7	-69.9	-196.4	-291.8	-48.9	-34.5	-27.9	-0.2	-0.3	0.2	0.1
1981	0.3	-13.8	0.5	-43.6	-29.2	-28.5	-22.5	-19.9	-37.8	66.8	1740.4	-102.3
1982	-153.3	62.5	-817.2	-198.8	-218.7	-100.8	-84.4	-199.9	-40.5	0.5	-0.1	-0.1
1983	-84.4	-150.4	-64.7	-50.0	-56.6	-63.2	-56.8	-49.4	-40.9	-30.8	-27.6	-25.6
1984	-23.7	-37.0	-37.2	-35.0	-31.4	-29.6	-20.3	-17.7	0.0	-13.7	0.0	0.3
1985	-0.1	-76.3	-20.9	-16.3	-20.8	-16.5	-13.1	-12.1	-10.6	-12.3	-11.7	-9.7
1986	-9.0	-9.1	-22.2	-16.1	-77.5	-19.9	-18.1	-11.2	-0.2	-0.2	0.4	-0.3
1987	0.3	-9.4	-8.9	-8.9	-12.0	-17.4	-46.0	-77.8	-106.5	1818.7	2956.2	659.8
1988	-216.7	-182.1	-276.8	-384.3	-82.3	-173.0	-165.1	-158.5	-126.5	2939.3	1189.0	567.7
1989	-237.4	-229.1	-222.9	-213.6	-204.0	-1104.4	-698.7	-210.6	-196.1	59.1	959.5	-30.2
1990	-186.6	-179.8	-168.8	-189.9	-409.6	-227.7	-85.6	-144.3	-96.6	2801.2	1042.1	616.0
1991	-197.1	-113.6	-91.9	-111.1	-114.4	-620.4	-240.6	-177.9	-198.1	2186.9	856.5	463.1
1992	-209.3	-186.1	-200.7	-193.7	-674.1	-286.3	-234.3	-198.9	-235.7	2889.0	1185.5	443.6
1993	-85.7	-218.3	-298.0	-1265.1	-1190.4	-1136.9	-226.0	-595.1	-184.2	-0.4	-0.5	0.1
1994	0.3	0.0	0.3	-90.1	-216.4	-110.4	-73.6	-64.5	-43.6	142.6	2682.3	503.4
1995	-157.6	-176.8	-189.7	-1176.5	-837.8	-282.3	-183.1	109.2	-311.7	-108.4	-100.0	-0.4
1996	-0.4	0.5	-129.0	-397.0	-117.1	-109.6	-102.4	-97.9	-66.3	0.3	0.5	0.2
1997	-0.3	0.3	-406.3	-92.0	-83.7	-75.8	-54.0	-49.2	0.3	-33.7	0.0	-30.4
1998	-29.6	-37.9	-48.2	-90.0	-272.1	-81.4	-74.2	-67.1	-59.2	-46.1	-41.5	-38.6
1999	0.5	-89.5	-46.6	-39.1	-53.5	-47.8	-46.0	-38.5	-30.0	-0.1	-0.1	-0.1
2000	0.1	0.4	-14.2	-110.9	-69.3	-109.4	-39.8	-31.3	-0.1	-18.3	-0.5	0.1
2001	-0.2	0.3	-22.5	-38.5	-33.9	-31.9	-28.8	-82.3	-112.7	3053.6	1524.6	657.0
2002	-185.6	-220.9	-236.8	-692.3	-440.7	-176.1	-335.0	-76.7	-61.3	-15.9	-49.0	-25.5
2003	-2.7	-24.0	-264.7	-165.5	-81.9	-77.7	-75.4	-137.2	-133.2	800.8	55.0	46.6
Average	-62.3	-66.2	-116.9	-206.4	-201.7	-166.6	-96.4	-79.5	-67.4	584.6	517.3	142.9
Critical	-141.3	-118.5	-127.6	-160.8	-235.1	-223.4	-132.8	-124.1	-120.4	2051.0	1512.0	536.9
Dry	-70.4	-91.6	-85.3	-168.9	-123.4	-229.1	-190.7	-79.9	-87.5	828.3	1186.7	191.5
BN	-0.1	0.1	0.2	-42.1	-119.4	-38.5	-33.1	-24.5	-0.2	-0.3	-0.3	0.2
AN	-41.1	-72.1	-134.8	-449.9	-413.8	-306.2	-83.2	-147.4	-62.7	130.3	9.0	7.8
Wet	-35.2	-33.7	-135.4	-161.2	-134.4	-62.4	-49.2	-32.4	-42.2	-18.0	-12.9	-7.3

Table C-2. Average Monthly Percent Difference in Sacramento River Inflow Between the All Transfers and Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.8	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.6	-0.5	4.3	5.2	1.8
Critical	-1.9	-1.5	-1.4	-1.1	-1.3	-1.5	-1.2	-1.5	-1.2	15.7	15.8	7.0
Dry	-1.0	-0.8	-0.5	-0.6	-0.8	-0.6	-1.1	-0.7	-0.7	5.6	11.1	2.3
BN	0.0	0.0	0.0	-0.2	-0.4	-0.2	-0.2	-0.2	0.0	0.0	0.0	0.0
AN	-0.6	-1.0	-0.7	-1.0	-0.9	-0.8	-0.3	-0.6	-0.3	0.5	0.1	0.0
Wet	-0.3	-0.2	-0.4	-0.3	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0

Table C-3. Average Monthly Percent Difference in Sacramento River Inflow between the No Groundwater Substitution and Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.4	-0.3	-0.2	-0.2	-0.3	-0.2	-0.2	0.0	-0.2	2.4	2.4	0.8
Critical	-0.8	-0.6	-0.5	-0.3	-0.6	-0.5	-0.6	0.1	-0.8	9.2	7.3	3.7
Dry	-0.4	-0.3	0.0	-0.3	-0.4	-0.3	-0.7	-0.2	-0.2	2.4	5.0	0.5
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.4	-0.4	-0.2	-0.4	-0.6	-0.1	0.0	-0.1	0.0	0.2	-0.2	-0.1
Wet	-0.1	0.0	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-4. Average Monthly Percent Difference in Sacramento River Inflow between the No Crop Idle and Base Alternatives.

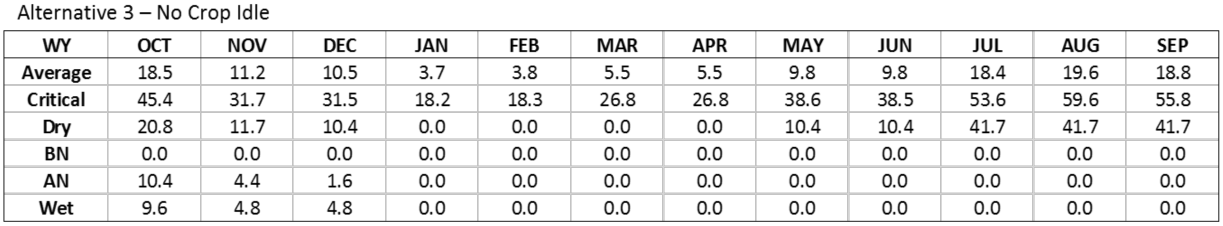
WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.8	-0.7	-0.6	-0.6	-0.7	-0.6	-0.5	-0.6	-0.4	2.9	3.1	1.0
Critical	-1.9	-1.5	-1.4	-1.1	-1.3	-1.5	-1.2	-1.5	-1.1	9.9	8.4	3.6
Dry	-1.0	-0.8	-0.5	-0.6	-0.8	-0.6	-1.1	-0.7	-0.6	4.4	7.7	1.3
BN	0.0	0.0	0.0	-0.2	-0.4	-0.2	-0.2	-0.2	0.0	0.0	0.0	0.0
AN	-0.6	-1.0	-0.7	-1.0	-0.9	-0.8	-0.3	-0.6	-0.3	0.5	0.1	0.0
Wet	-0.3	-0.2	-0.4	-0.3	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0

The East Bay Municipal Utility District (EBMUD) transfer water occur as exports on the upper Sacramento River near Freeport. Table C-5, Table C-6 and Figure C-3 illustrate these results. The flow volumes are small in comparison with Sacramento River flows. The exports of transfer water occur mainly in Critical and Dry water years, although some transfer also occurs in a few Above Normal or Wet water years.

Table C-5. Monthly Average Difference in EBMUD Export (cfs) for the All Transfers Alternative, (All Transfers – Base). The Lower Table Computes Average Monthly Differences.

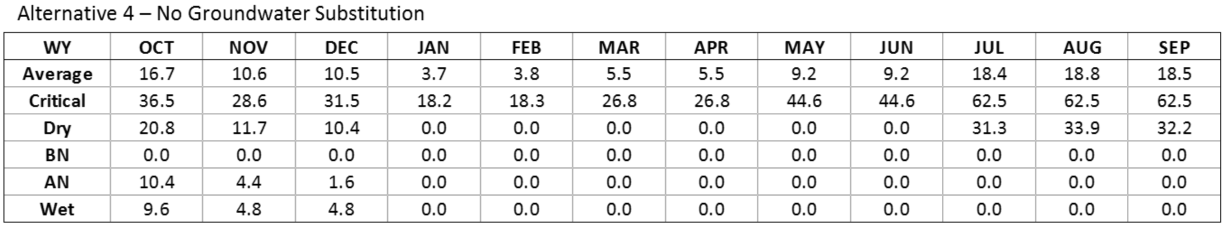
WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.5	62.5	62.5
1977	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
1978	62.5	19.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.5	62.5	62.5
1982	62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.5	62.5	62.5
1988	62.5	62.5	62.5	62.5	65.3	62.5	62.5	62.5	62.5	62.5	62.5	62.5
1989	62.5	7.5	0.0	0.0	0.0	0.0	0.0	62.5	62.5	62.5	62.5	62.5
1990	62.5	34.5	33.0	0.9	0.0	0.0	0.0	62.5	62.5	62.5	62.5	62.5
1991	67.9	0.0	0.0	0.0	0.0	62.5	62.5	62.5	62.5	62.5	62.5	62.5
1992	62.5	62.5	62.5	1.2	0.0	0.0	0.0	62.5	62.5	62.5	62.5	62.5
1993	0.0	6.8	9.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.5	62.5	62.5
1995	62.5	62.5	62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.5	62.5	62.5
2002	62.5	62.5	62.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	18.5	11.2	10.5	3.7	3.8	5.5	5.5	11.0	11.0	20.2	20.2	20.2
Critical	45.4	31.7	31.5	18.2	18.3	26.8	26.8	44.6	44.6	62.5	62.5	62.5
Dry	20.8	11.7	10.4	0.0	0.0	0.0	0.0	10.4	10.4	41.7	41.7	41.7
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	10.4	4.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	9.6	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-6. Average Monthly Difference in EBMUD Exports (cfs) for Alternatives 3 and 4.



Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	18.5	11.2	10.5	3.7	3.8	5.5	5.5	9.8	9.8	18.4	19.6	18.8
Critical	45.4	31.7	31.5	18.2	18.3	26.8	26.8	38.6	38.5	53.6	59.6	55.8
Dry	20.8	11.7	10.4	0.0	0.0	0.0	0.0	10.4	10.4	41.7	41.7	41.7
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	10.4	4.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	9.6	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

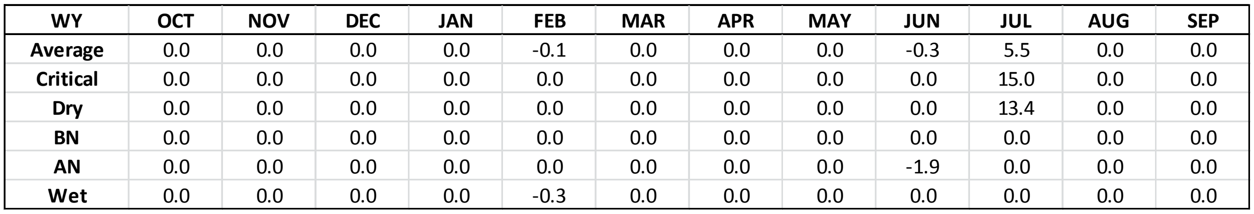


Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	16.7	10.6	10.5	3.7	3.8	5.5	5.5	9.2	9.2	18.4	18.8	18.5
Critical	36.5	28.6	31.5	18.2	18.3	26.8	26.8	44.6	44.6	62.5	62.5	62.5
Dry	20.8	11.7	10.4	0.0	0.0	0.0	0.0	0.0	0.0	31.3	33.9	32.2
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	10.4	4.4	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	9.6	4.8	4.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

On the San Joaquin River (Figure C-4), Table C-7 shows that the average monthly percent change from Base inflow is less than +/- 2% for all months, water year types and alternatives except for July in Dry and Critical water years in the No Groundwater Substitution alternative, Alternative 3, whose results for average monthly percent difference results are shown in Table C-7. As can be seen in Figure C-3, the increased flow of approximately 500 cfs in this alternative occurred in exactly three water years (1981, 1992 and 2001). Figure C-5, San Joaquin River inflow EC for Base and change from Base for the Alternatives, illustrates that the upstream changes on the San Joaquin make little difference to inflow EC, as increases and decreases were infrequent and small in magnitude. Thus, the changes in San Joaquin River inflow and EC in Alternatives 2 through 4 have very little influence on the model results in the Delta.

Table C-7. Average Monthly Percent Difference in San Joaquin River Inflow between the No Groundwater Substitution and Base Alternatives



WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	-0.3	5.5	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.9	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0

South Delta exports at the SWP-Banks and CVP-Jones locations, Figure C-6 and Figure C-7 respectively, show a similar pattern to Sacramento R. inflow in monthly average percent difference increases and decreases, shown in Table C-8 and Table C-9 for Alternative 2. Increases in export flow occur July and August in Dry and Critical years at SWP, and July – September in Dry and Critical years at CVP. The patterns of percent increases and decreases of exports at these locations are similar for Alternatives 3 and 4, but the percentages are smaller (see the Attachment Section on Export Boundary Conditions for monthly average table details).

Table C-8. Average Monthly Percent Difference in SWP Export Flow between the All Transfers and Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.3	-1.0	-0.3	-0.5	-0.2	-0.2	-0.1	-0.2	-0.6	11.2	7.3	-1.1
Critical	-3.6	-2.1	-1.4	-2.4	-0.2	-0.7	0.0	0.0	-1.6	35.3	33.7	-3.9
Dry	-2.9	-0.4	0.0	-0.3	-0.7	0.0	-0.6	-0.9	-1.7	21.2	2.3	-1.4
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.1	-2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0
Wet	-0.1	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-9. Average Monthly Percent Difference in CVP Export Flow between the All Transfers and Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.8	-0.7	-0.3	-0.4	1.6	-0.4	-0.2	-1.2	-0.9	14.6	15.0	5.4
Critical	-1.7	-1.6	-1.5	-1.6	-0.4	-1.7	-0.8	-3.3	-2.6	67.4	43.3	20.4
Dry	-0.8	-0.5	-0.1	-0.4	-0.5	0.0	-0.5	-3.0	-2.2	3.5	34.5	7.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.6	-0.8	-0.1	0.0	9.8	0.0	0.0	0.0	0.0	0.8	0.0	0.0
Wet	-0.5	-0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.1

The export volumes are much smaller at each of the three Contra Costa Water District (CCWD) export locations, shown in Figure C-10 through Figure C-8. For each of these transfer water buyers, all changes in exports are increases for each of the alternatives, unlike the SWP and CVP which also experience decreases in export flow in the Alternatives. The three locations have different patterns of increases in the export of transfer water – although all exports occur in Critical and Dry water years, the Old River location (Table C-10) only exports transfer water in August and September, while the other two locations also export water in July (Table C-11 and Table C-12).

Table C-10. Average Monthly Change from Base for CCWD Old River Exports (cfs) for the Alternatives.

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	6.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	11.1
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4	21.6
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	6.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	11.1
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4	21.6
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	5.5
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	11.1
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.4	18.4
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-11. Average Monthly Change from Base for CCWD Rock Slough Exports (cfs) for the Alternatives.

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	8.5	10.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.1	41.2	36.9
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.7	0.0	13.9
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	8.5	10.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.1	41.2	36.9
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.7	0.0	13.9
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.7	8.5	8.2
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.1	41.2	36.9
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.1	0.0	3.1
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-12. Average Monthly Change from Base for CCWD Victoria Canal Exports (cfs) for the Alternatives.

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	8.3	6.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	23.1	24.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	6.5
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	8.3	6.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	23.1	24.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	6.5
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	6.0	6.1
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.6	23.1	24.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.7	6.5
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-13 illustrates the percent change from Base Net Delta Outflow (NDO) for the alternatives – NDO is the sum of all inflow and outflows set as boundary conditions in DSM2 as calculated in CalSim II. NDO percent changes in the table reflect the changes in Sacramento inflow with the largest increases occurring July through September in Critical and Dry water years for all alternatives in comparison with Base With a few exceptions, the rest of the differences from Base are relatively small percent decreases. Figure C-11 illustrates the plot of Base NDO and the change from Base NDO for the alternatives. The Martinez EC boundary condition, illustrated in Figure C-12 as a monthly average, is calculated in a preprocessor from NDO for each of the Alternatives.

Table C-13. Average Monthly Percent Change from Base Net Delta Outflow (cfs) for the Alternatives.

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	-0.1	-0.4	-0.4	-0.5	-0.5	-0.4	-0.3	-0.3	3.3	2.6	1.5
Critical	0.0	0.0	-0.2	-0.4	-1.0	-0.8	-0.6	-0.4	-0.3	12.3	7.7	5.1
Dry	0.0	-0.5	-0.6	-0.3	-0.5	-0.6	-0.9	-0.3	0.0	4.3	5.5	2.6
BN	0.0	0.0	0.0	-0.2	-0.3	-0.1	-0.2	-0.1	0.0	0.0	0.0	0.0
AN	0.0	-0.1	-0.8	-0.7	-0.8	-0.9	-0.2	-0.5	-1.0	0.1	0.3	0.1
Wet	-0.1	0.0	-0.3	-0.2	-0.2	-0.1	-0.1	-0.1	-0.2	-0.1	-0.1	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	-0.1	-0.4	-0.4	-0.5	-0.5	-0.4	-0.3	-0.3	2.2	1.7	1.1
Critical	0.0	0.0	-0.2	-0.4	-1.0	-0.8	-0.6	-0.5	-0.3	7.9	4.9	3.4
Dry	0.0	-0.5	-0.6	-0.3	-0.5	-0.6	-0.9	-0.3	0.0	3.5	4.0	2.0
BN	0.0	0.0	0.0	-0.2	-0.3	-0.1	-0.2	-0.1	0.0	0.0	0.0	0.0
AN	0.0	-0.1	-0.8	-0.7	-0.8	-0.9	-0.2	-0.5	-1.0	0.1	0.3	0.1
Wet	-0.1	0.0	-0.3	-0.2	-0.2	-0.1	-0.1	-0.1	-0.2	-0.1	-0.1	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	-0.1	-0.2	-0.1	-0.1	0.3	0.0	1.9	1.1	0.7
Critical	0.0	0.0	0.0	0.0	-0.3	-0.1	0.0	1.6	0.2	7.1	3.7	2.6
Dry	0.0	0.0	0.2	-0.1	-0.2	-0.2	-0.6	0.0	0.0	2.4	1.8	1.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	-0.3	-0.4	-0.1	0.0	-0.1	-0.4	0.0	0.0	0.0
Wet	0.0	0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

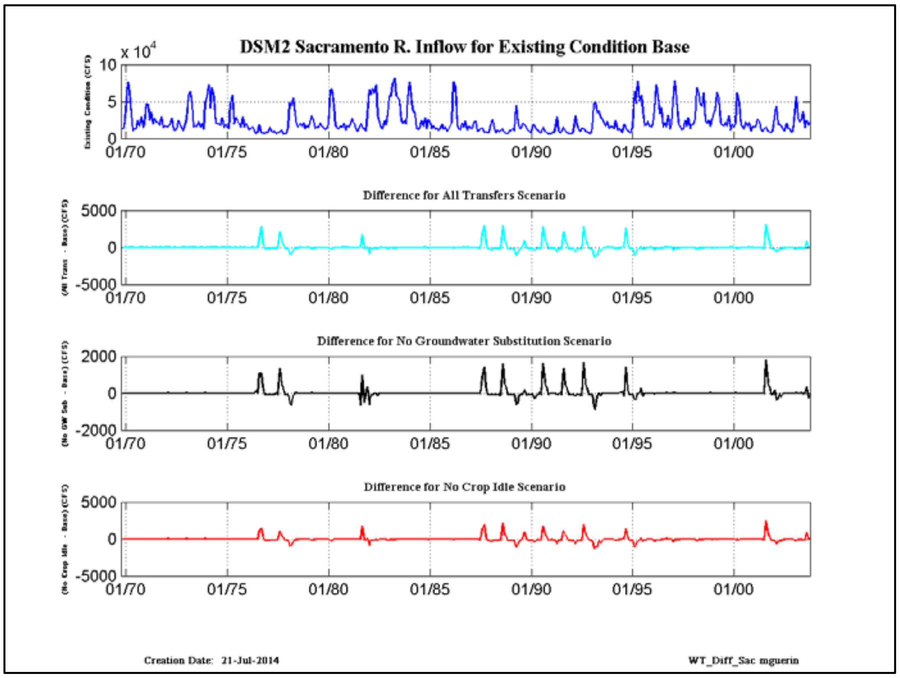


Figure C-2. Sacramento River Inflow for the Base Condition and Change from Base for the Alternatives.

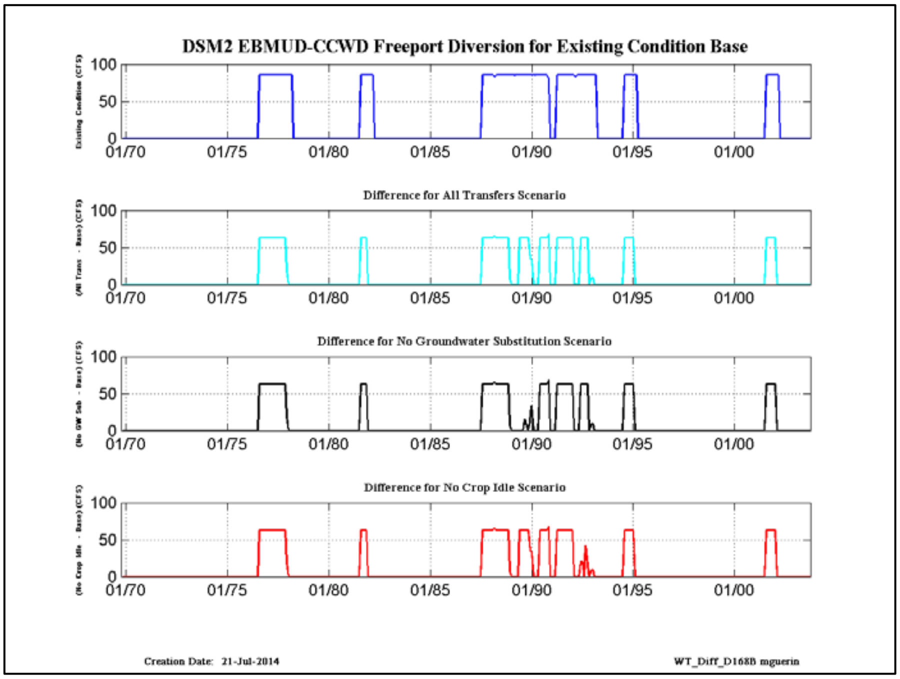


Figure C-3. EBMUD Freeport Diversion for the Base Condition and Change from Base for the Alternatives.

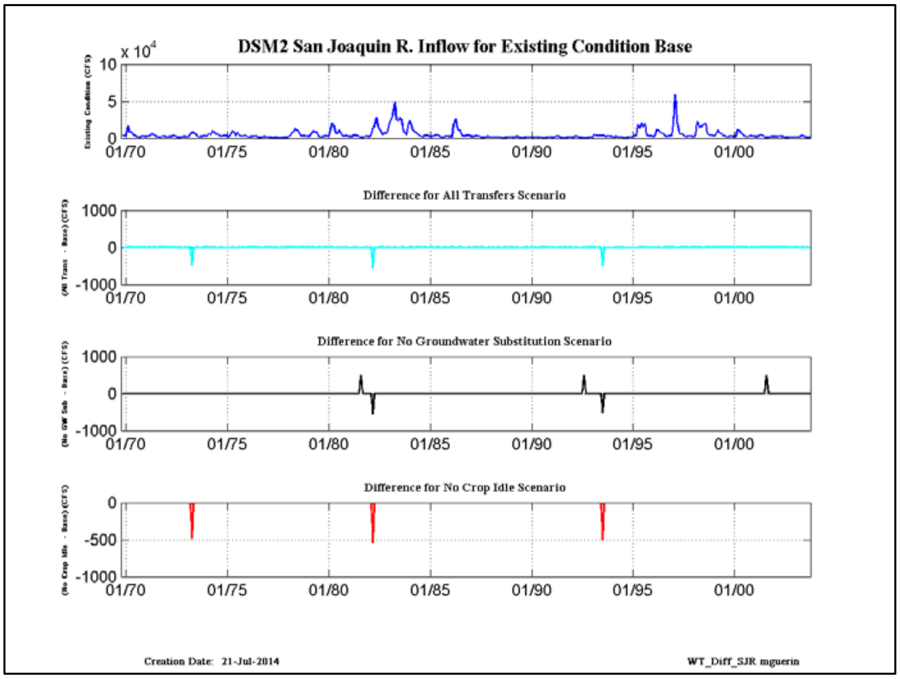


Figure C-4. San Joaquin R. inflow for Existing Base Condition and Change from Base for the Alternatives.

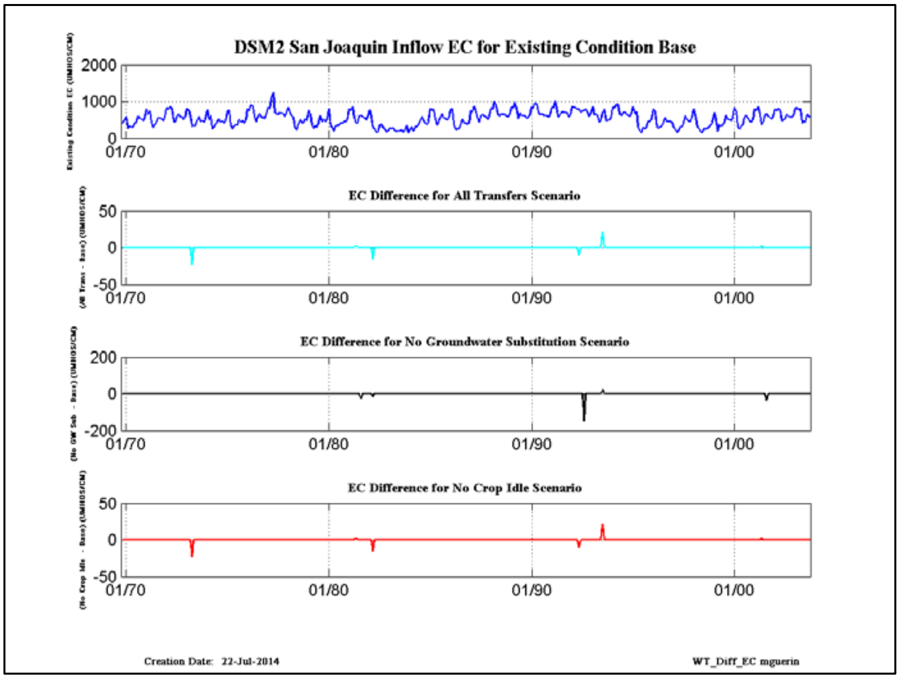


Figure C-5. San Joaquin inflow EC for Existing Base Condition and Change from Base for the Alternatives.

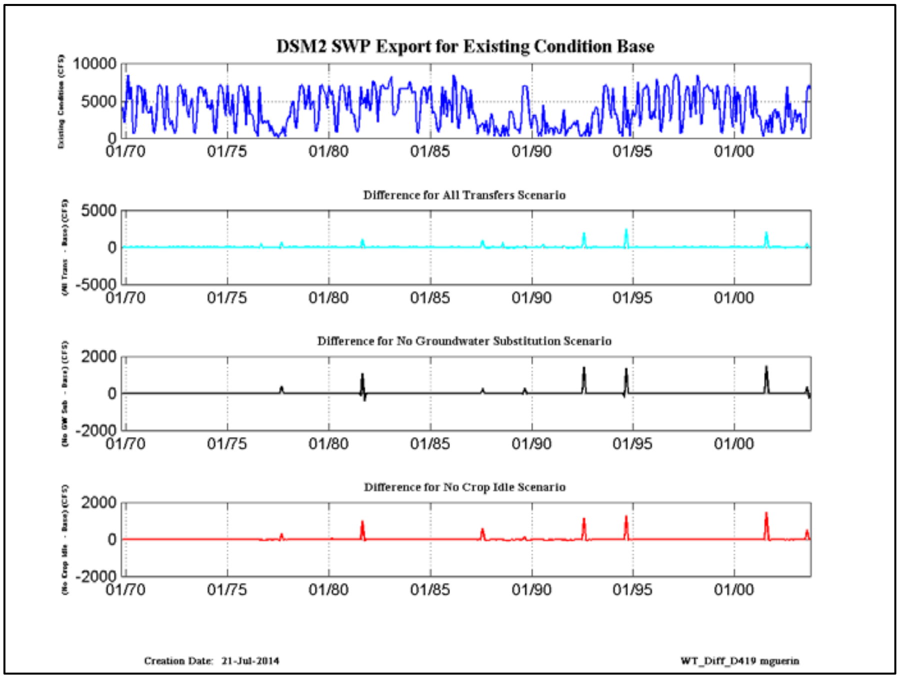


Figure C-6. SWP Export for the Base Condition and Change from Base for the Alternatives.

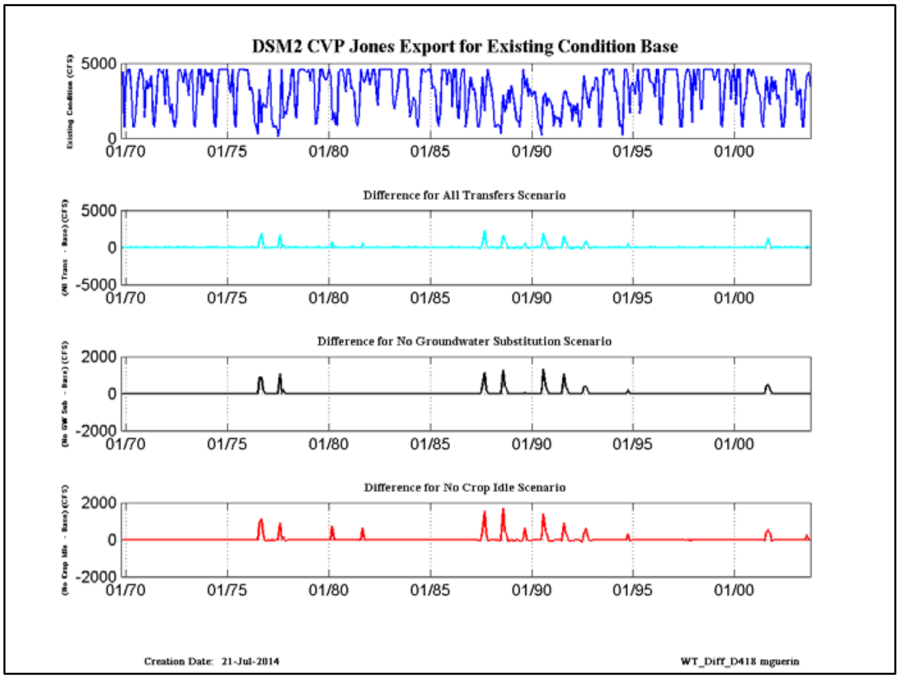


Figure C-7. CVP Export for the Base Condition and Change from Base for the Alternatives.

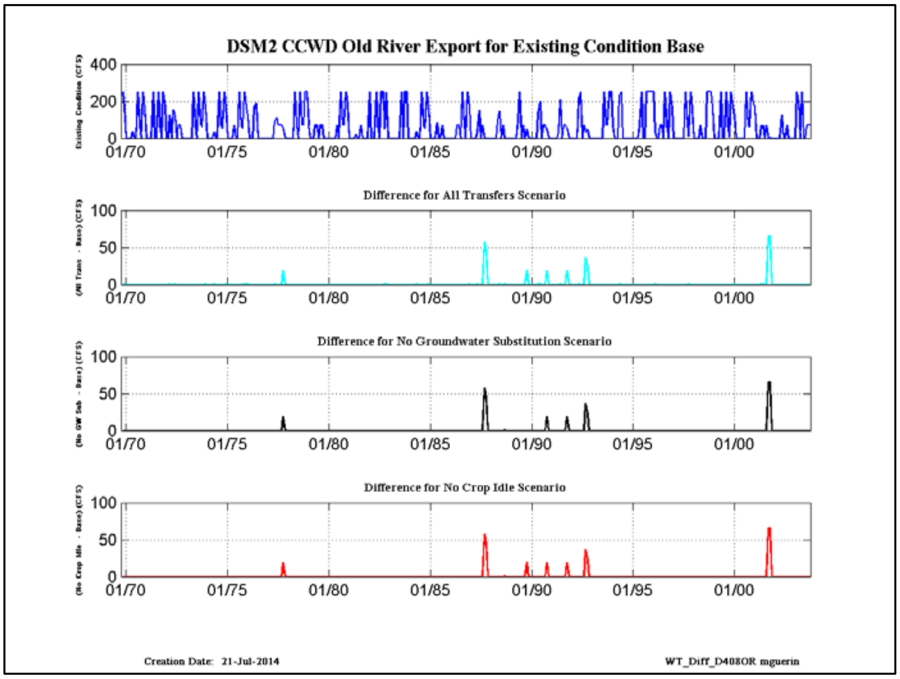


Figure C-8. CCWD Old River Export for the Base Condition and Change from Base for the Alternatives.

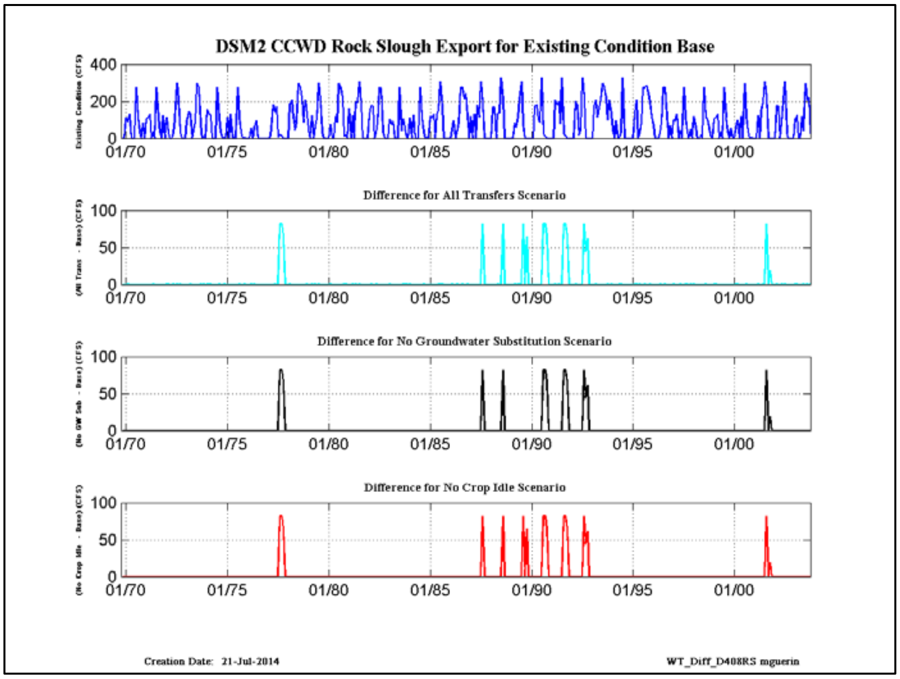


Figure C-9. CCWD Rock Slough Export for the Base Condition and Change from Base for the Alternatives.

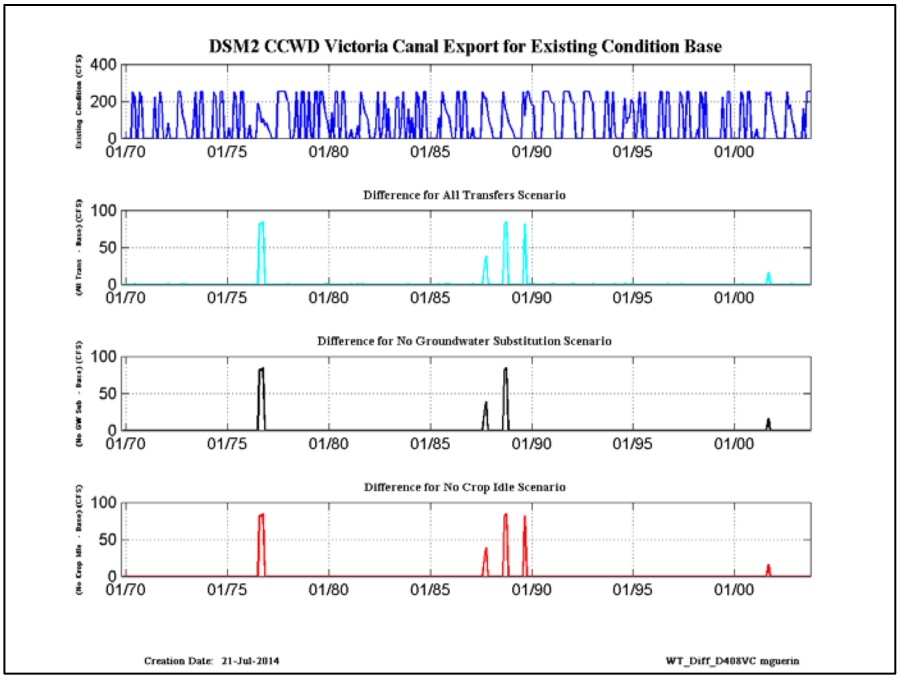


Figure C-10. CCWD Victoria Canal Export for the Base Condition and Change from Base for the Alternatives.

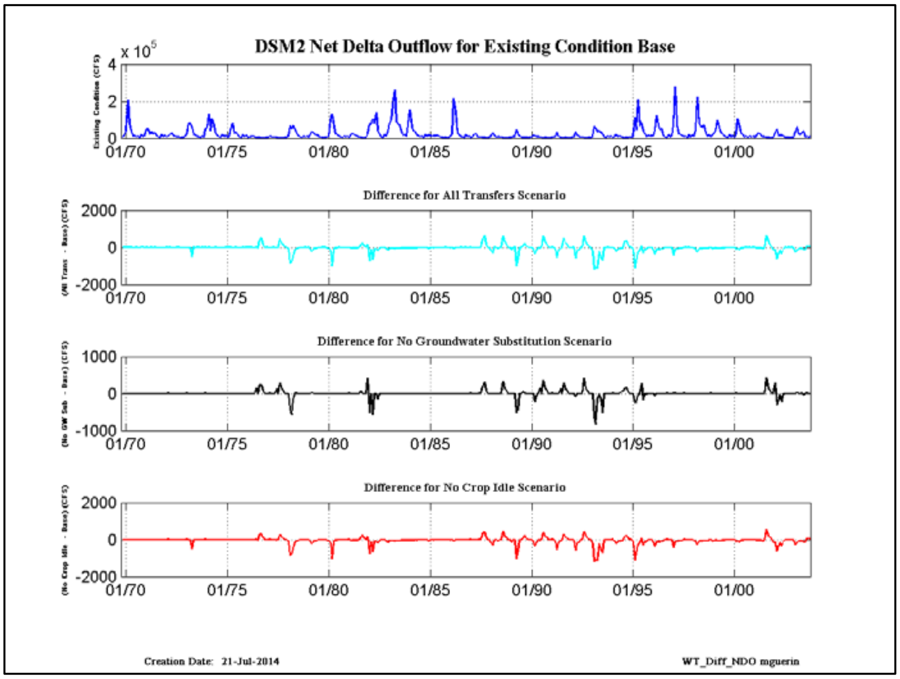


Figure C-11. Net Delta Outflow for the Base Condition and Change from Base for the Alternatives.

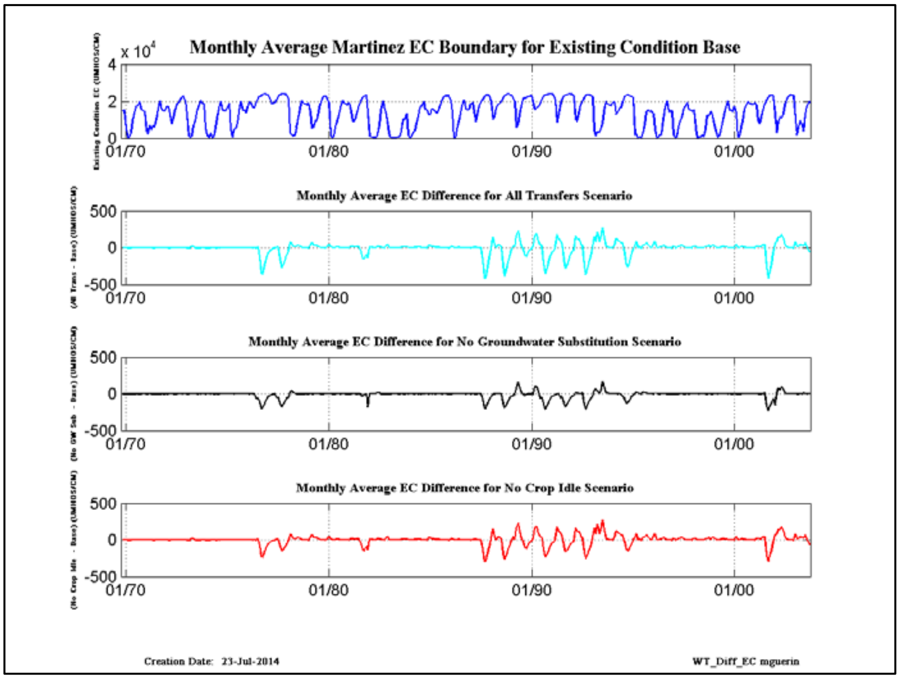


Figure C-12. Monthly Average Martinez EC for the Base Condition and Change from Base for the Alternatives.

C.8 Comparison of Salinity (EC) Results

The change in EC for Alternatives 2 – 4 in large part reflects the changes in flow for the Sacramento River and the SWP and CVP exports as these volumes were by far the largest in magnitude in comparison with the Base, Alternative 1. The largest changes in EC should reflect the balance between these two flows for the alternatives, as Sacramento inflow increases tend to reduce EC in the Delta while SWP+CVP export increases tend to increase EC. If export increases dominate locally, EC increases due to increased intrusion of Martinez EC, and if Sacramento inflow increases dominate locally, EC will decrease. In addition, when the Delta Cross Channel is open, low EC Sacramento River water reaches the central Delta, mainly through Middle River – increases in this flow are facilitated by increases in SWP and CVP export pumping. Table C-14 illustrates that on average, flow through the DCC was greater than Base flow July - September in Critical and Dry water years for all alternatives while in almost all other months and water year types, Base flow through the DCC was greater.

In this section, modeled EC results are presented at selected D-1641 locations that showed a change from Base EC (illustrated in figures) and/or average monthly percent change from Base EC (illustrated in tables) values that differed notably from Base monthly average or average monthly values. At most locations, the change or percent change from base EC was negligible. Plots and tables for locations not covered in this section are found in the Attachment.

Sacramento River (inflow) and SWP and CVP (export) increases in volume occurred mainly July – September in Critical and Dry water years, with the largest increases in the All Transfers alternative, with decreases in volume occurring in most other months with few exceptions. Of the three alternatives, the All Transfers alternative had the greatest changes and percent changes in comparison with the Base alternative.

Figure C-13 and Table C-15 illustrate that the largest changes in modeled EC at the intake to Clifton Court Forebay (for SWP exports) occur in the All Transfers alternative. For all alternatives, the largest EC percent increases occur in July and August of Critical and Dry water years, and the largest decreases occur in September and October of Critical water years. The No Groundwater Substitution alternative has a different pattern for EC percent decreases in Dry water years than the other two alternatives, as the percent differences are smaller in magnitude in September and October for this alternative.

Figure C-14 and Table C-16 illustrate the changes in modeled EC for CVP exports for the three alternatives. The pattern of EC increases and decreases is the same as those for the SWP exports, but the magnitudes are smaller at the CVP location.

Table C-14. Delta Cross Channel Average Monthly Percent Change from Base flow (cfs).

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.5	-0.5	-0.3	0.0	0.0	0.0	0.0	0.0	-0.4	3.8	5.6	2.5
Critical	-1.2	-1.1	-0.8	0.0	0.0	0.0	0.0	-0.2	-1.0	14.3	17.5	9.3
Dry	-0.7	-0.5	-0.2	0.0	0.0	0.0	0.0	0.4	-0.6	4.7	11.7	3.3
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
AN	-0.2	-0.7	-0.2	0.0	0.0	0.0	0.0	-0.2	-0.2	0.4	0.0	0.0
Wet	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1	-0.1	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	2.2	2.8	1.4
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.4	8.9	8.7	5.6
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	-0.1	2.2	5.7	1.3
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	-0.2	-0.1
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.5	-0.5	-0.3	0.0	0.0	0.0	0.0	0.0	-0.4	2.6	3.4	1.5
Critical	-1.2	-1.1	-0.8	0.0	0.0	0.0	0.0	-0.1	-0.8	9.3	9.9	5.5
Dry	-0.7	-0.5	-0.2	0.0	0.0	0.0	0.0	0.3	-0.6	3.7	8.1	2.1
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
AN	-0.2	-0.7	-0.2	0.0	0.0	0.0	0.0	-0.2	-0.2	0.4	0.0	0.0
Wet	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1	-0.1	0.0

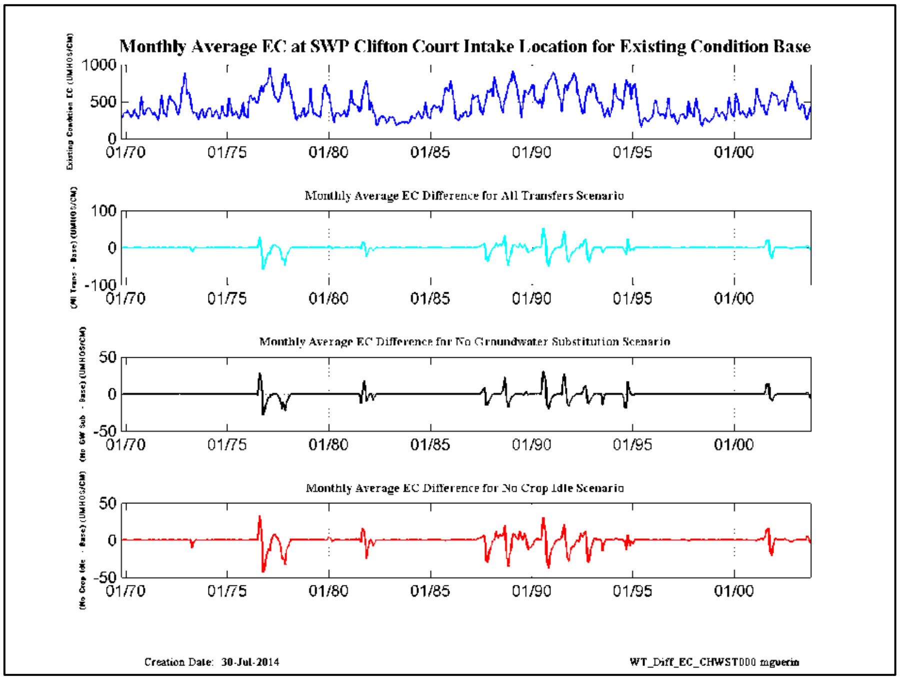


Figure C-13. Monthly Average EC at the SWP-Banks intake to Clifton Court Forebay for the Base Condition and Change from Base for the Alternatives.

Table C-15. SWP Intake to Clifton Court Forebay Average Monthly Percent Change from Base EC for the Alternatives.

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.6	-0.9	-0.4	-0.1	0.0	0.0	0.1	0.2	0.1	1.1	0.6	-1.2
Critical	-3.8	-2.2	-1.1	-0.7	-0.1	0.4	0.3	0.6	0.6	4.2	1.0	-4.3
Dry	-1.9	-0.9	-0.2	0.1	0.2	0.1	0.2	0.6	0.6	1.2	1.9	-1.6
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.8	-1.0	-0.3	0.1	0.0	-0.5	0.0	0.0	-0.6	0.0	0.1	-0.2
Wet	-0.3	-0.2	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.2	-0.7	-0.3	-0.1	0.0	0.0	0.1	0.2	0.1	0.7	0.4	-1.0
Critical	-3.0	-1.7	-0.9	-0.6	-0.1	0.4	0.3	0.6	0.5	2.7	0.6	-3.6
Dry	-1.4	-0.7	-0.1	0.2	0.2	0.1	0.2	0.6	0.6	0.8	1.5	-1.3
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.4	-0.7	-0.2	0.1	0.0	-0.5	0.0	0.0	-0.6	0.0	0.1	-0.2
Wet	-0.3	-0.2	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.6	-0.4	-0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	0.5	0.4	-0.4
Critical	-1.5	-0.8	-0.4	-0.2	-0.1	0.0	0.0	0.0	-0.2	2.2	1.1	-1.6
Dry	-0.7	-0.4	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.3	1.0	-0.2
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-0.7	-0.4	-0.2	0.0	0.0	0.0	0.1	0.0	-0.6	-0.2	0.0	-0.2
Wet	-0.1	-0.1	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

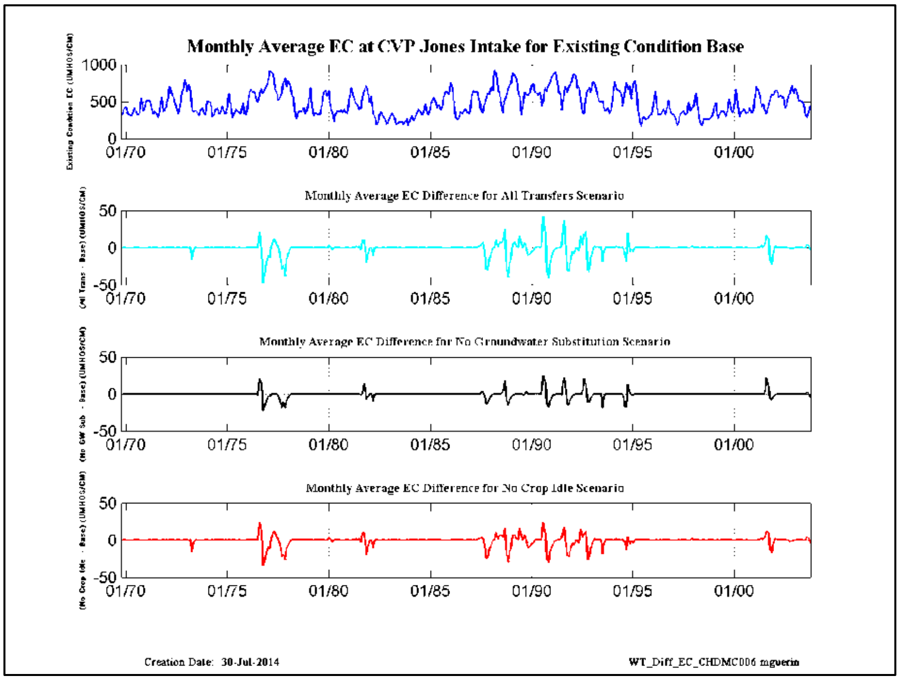


Figure C-14. Monthly Average CVP-Jones Intake EC for the Base Condition and Change from Base for the Alternatives.

Table C-16. CVP Intake at Delta Mendota Canal Average Monthly Percent Change from Base EC for the Alternatives.

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.3	-0.7	-0.3	-0.1	-0.1	0.0	0.1	0.2	0.1	0.9	0.3	-1.1
Critical	-3.2	-1.8	-0.8	-0.5	0.0	0.4	0.2	0.7	0.6	3.3	0.8	-3.9
Dry	-1.6	-0.8	-0.2	0.1	0.2	0.0	0.2	0.6	0.5	1.0	0.7	-1.4
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.6	-0.8	-0.2	0.0	-0.1	-0.7	-0.1	0.0	-0.6	0.1	0.1	-0.1
Wet	-0.3	-0.2	-0.1	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.1	-0.5	-0.2	-0.1	-0.1	0.0	0.1	0.2	0.1	0.5	0.2	-0.9
Critical	-2.5	-1.4	-0.6	-0.4	0.0	0.4	0.2	0.7	0.6	2.1	0.5	-3.2
Dry	-1.2	-0.5	-0.1	0.1	0.2	0.0	0.2	0.6	0.5	0.6	0.6	-1.1
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.2	-0.6	-0.1	0.0	-0.1	-0.7	-0.1	0.0	-0.6	0.1	0.1	-0.1
Wet	-0.3	-0.1	-0.1	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.5	-0.3	-0.1	0.0	-0.1	0.0	0.0	0.0	-0.1	0.6	0.2	-0.4
Critical	-1.3	-0.7	-0.3	-0.1	0.0	0.0	0.0	0.0	-0.1	2.0	0.9	-1.5
Dry	-0.6	-0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.3	-0.2
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-0.6	-0.4	-0.2	0.0	0.0	0.0	0.1	0.0	-0.6	-0.1	0.0	-0.1
Wet	-0.1	-0.1	0.0	0.0	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure C-15. SWP and CVP Monthly Average Chloride for the Alternatives.

D-1641 standards require that all export locations maintain chloride concentration less than 250 mg/L. Figure C-15 shows chloride concentration at SWP and CVP, and Figure C-16 shows chloride at CCWD's Old River and Victoria Canal locations. Each location used the following conversion (DWR, 2001) calculated from monthly average EC:

$$Chloride\ (mg/L) = (EC - 160.6)/3.66$$

Figure C-16. CCWD's Old River (OR) and Victoria Canal (VC) monthly Average Chloride for the Alternatives.

At CCWD's intake in the Contra Costa Canal, denoted in this document as the Rock Slough Intake, a different conversion is used to calculate chloride from EC:

$$Chloride\ (mg/L) = (EC - 89.6)/3.73$$

The D-1641 criteria at this location specifies the minimum number of days that mean daily chloride should be less than 150 mg/L. For Critical water years this is 155 days, and for Dry water years this is 165 days. Results in Table C-17 indicate that several Critical and one Dry water year have greater percent differences (bold font).

Table C-17. Monthly Average Percent Change from Base EC at CCWD Rock Slough Location for the All Transfers Alternative.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	-0.7	-2.2	-0.4	-0.1	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	4.2	-0.8	-8.5
1977	-7.8	-5.1	-2.9	-2.1	-1.2	0.0	0.4	0.3	0.4	1.7	-0.3	-1.0
1978	-4.8	-4.1	-2.0	-0.3	0.2	0.1	0.0	0.0	0.1	0.1	0.1	0.0
1979	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.4	0.6	1.0	2.2	0.2	0.1	0.0	0.0	0.0	0.0
1981	0.0	0.0	-0.1	0.0	0.1	0.0	0.0	0.1	0.2	-0.9	1.1	4.0
1982	-3.6	-2.6	-0.8	0.0	-1.7	-1.4	-0.2	-0.1	-0.1	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.1	-0.1	-0.1	-0.1
1986	-0.1	-0.1	-0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	-0.1	0.0	0.0	0.6	0.9	0.5	**4.3**	**6.8**	-4.3
1988	-6.6	-4.6	-2.7	-0.3	0.0	0.6	0.7	1.0	0.8	**7.8**	**9.0**	-4.9
1989	-7.2	-4.9	-2.9	0.7	0.7	0.7	0.3	1.2	0.5	2.7	1.3	-1.5
1990	-3.0	-2.2	-1.6	-1.2	0.0	0.7	0.7	0.4	0.6	**17.2**	**2.0**	-5.7
1991	-6.2	-4.7	-2.8	-2.1	-0.7	-0.1	0.1	0.2	1.4	**13.1**	**1.3**	-5.0
1992	-5.5	-4.0	-2.5	-2.0	-1.2	0.0	0.1	0.8	0.6	**8.2**	**7.3**	-3.0
1993	-5.5	-3.9	-1.7	0.6	0.3	0.3	0.2	0.2	-1.6	-1.1	0.3	0.2
1994	0.1	0.0	0.0	0.0	0.6	0.4	0.3	0.2	0.3	-0.9	-2.2	5.1
1995	-1.2	-1.1	-1.5	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.1	0.2
1996	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1
1997	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
1998	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
1999	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0
2000	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
2001	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.2	0.6	**9.5**	**8.2**	-1.1
2002	-4.7	-3.6	-0.1	0.3	0.2	0.1	0.1	0.0	0.3	0.0	-0.1	-0.3
2003	-0.3	-0.1	-0.1	0.2	0.0	0.0	0.0	0.0	0.1	2.7	0.8	-1.4
Average	-1.7	-1.2	-0.6	-0.2	0.0	0.1	0.1	0.2	0.2	2.0	1.0	-0.8
Critical	-4.1	-2.9	-1.8	-1.1	-0.4	0.2	0.3	0.4	0.6	**7.3**	**2.3**	-3.3
Dry	-2.0	-1.4	-0.5	0.1	0.2	0.2	0.2	0.4	0.4	**2.6**	**2.9**	-0.6
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-1.8	-1.4	-0.6	0.2	0.3	0.3	-0.3	0.0	-0.3	0.3	0.2	-0.2
Wet	-0.4	-0.3	-0.2	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

For these years, mean daily chloride was calculated from EC model output for the four Alternatives, and the number of days that chloride was greater than 150.5 mg/L was tabulated – results are shown in Table C-18. Although D-1641 specifies 14-day durations for mean daily chloride concentration, since most DSM2 boundary conditions are specified as monthly values, it is not sensible to account for this constraint herein.

Table C-18. Check on D-1641 Chloride Standard at the CCWD Rock Slough Intake Location – Number Days Mean Daily Chloride < 150 mg/L.

Water Year	Base	All Transfers	No Crop Idle	No GW Sub
1988 (Crit)	272	264	278	275
1990 (Crit)	201	193	195	195
1991 (Crit)	180	176	177	177
1992 (Crit)	194	183	185	186
2001 (Crit)	338	338	338	338

The model results for the three CCWD intake locations are also presented by comparing the monthly average percent difference tables by alternative. Table C-19 through Table C-21 illustrates the results for all three locations for the All Transfers, No Groundwater Substitution and No Crop Idle alternatives, respectively. For each alternative, the CCWD-Victoria Canal intake location has a different pattern of monthly average percent increases and decreases than the other two alternatives (not shown), as the path for much of the water exported is through Middle River which is more heavily influenced by the operations of the DCC than the other two locations. In August of Critical water years, Victoria Canal sees a decrease in EC while the other locations saw an increase – this is likely due to the increased flow through the DCC (Table C-14) combined with the increased exports (Table C-8 and Table C-9) in comparison with the Base alternative.

The pattern of EC changes at CCWD’s Rock Slough and Old River intake locations is similar to the pattern at the SWP location, with the largest EC increases occurring in July and August of Critical and Dry water years, with Rock Slough showing greater increases than Old River as it receives a greater proportion of higher EC water from the Martinez boundary than the Old River location.

Table C-19. CCWD Intakes –Average Monthly Percent Change from Base EC for the All Transfers Alternative.

CCWD Victoria Canal location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.3	-0.5	-0.3	-0.1	0.1	0.0	0.1	0.2	0.1	0.0	-0.4	-1.5
Critical	-3.1	-1.3	-0.9	-0.6	-0.2	0.2	0.3	0.4	0.4	0.5	-1.9	-5.9
Dry	-1.5	-0.6	-0.2	0.1	0.2	0.1	0.2	0.3	0.5	-0.3	0.0	-1.8
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.8	-0.7	-0.3	0.0	1.1	-0.3	-0.1	0.1	-0.6	-0.3	0.1	-0.1
Wet	-0.2	-0.1	-0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

CCWD Old River location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.6	-0.9	-0.5	-0.1	0.0	0.0	0.1	0.2	0.1	1.3	0.5	-1.2
Critical	-4.0	-2.3	-1.5	-0.9	-0.3	0.3	0.3	0.6	0.6	4.9	0.5	-4.4
Dry	-2.0	-1.0	-0.2	0.2	0.2	0.2	0.2	0.5	0.5	1.7	2.4	-1.5
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.9	-1.1	-0.4	0.1	0.5	-0.4	-0.1	0.0	-0.4	0.2	0.1	-0.2
Wet	-0.3	-0.2	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

CCWD Rock Slough location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.7	-1.2	-0.6	-0.2	0.0	0.1	0.1	0.2	0.2	2.0	1.0	-0.8
Critical	-4.1	-2.9	-1.8	-1.1	-0.4	0.2	0.3	0.4	0.6	7.3	2.3	-3.3
Dry	-2.0	-1.4	-0.5	0.1	0.2	0.2	0.2	0.4	0.4	2.6	2.9	-0.6
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-1.8	-1.4	-0.6	0.2	0.3	0.3	-0.3	0.0	-0.3	0.3	0.2	-0.2
Wet	-0.4	-0.3	-0.2	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table C-20. CCWD Intakes –Average Monthly Percent Change from Base EC for the No Groundwater Substitution Alternative.

CCWD Victoria Canal location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.6	-0.3	-0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	0.0	-0.1	-0.7
Critical	-1.4	-0.6	-0.4	-0.2	-0.1	0.0	0.0	0.0	-0.2	-0.1	-0.7	-2.8
Dry	-0.6	-0.3	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.2	-0.4
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-0.8	-0.4	-0.2	0.0	0.0	0.0	0.0	0.1	-0.6	-0.3	0.0	-0.1
Wet	-0.1	-0.1	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

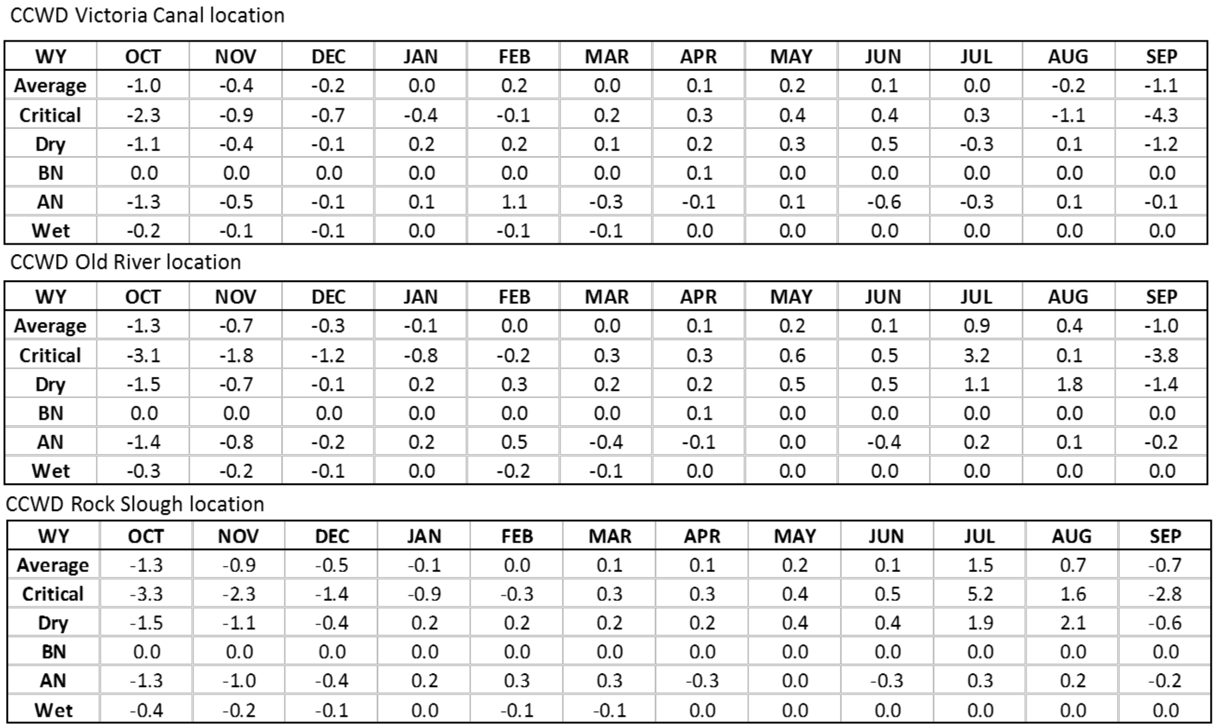
CCWD Old River location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.6	-0.4	-0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	0.6	0.4	-0.4
Critical	-1.5	-0.9	-0.5	-0.3	-0.1	0.0	0.0	0.0	-0.3	2.7	0.8	-1.7
Dry	-0.7	-0.4	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.4	1.2	-0.1
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-0.8	-0.5	-0.2	-0.1	0.0	0.0	0.0	0.1	-0.4	-0.1	-0.1	-0.2
Wet	-0.1	-0.1	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

CCWD Rock Slough location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.5	-0.5	-0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	1.0	0.6	-0.1
Critical	-1.5	-1.1	-0.6	-0.3	-0.1	0.0	0.0	0.0	-0.4	4.7	2.1	-0.7
Dry	-0.6	-0.5	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.7
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.6	-0.6	-0.3	-0.1	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	-0.2
Wet	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table C-21. CCWD Intakes –Average Monthly Percent Change from Base EC for the No Crop Idle Alternative.



CCWD Victoria Canal location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.0	-0.4	-0.2	0.0	0.2	0.0	0.1	0.2	0.1	0.0	-0.2	-1.1
Critical	-2.3	-0.9	-0.7	-0.4	-0.1	0.2	0.3	0.4	0.4	0.3	-1.1	-4.3
Dry	-1.1	-0.4	-0.1	0.2	0.2	0.1	0.2	0.3	0.5	-0.3	0.1	-1.2
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.3	-0.5	-0.1	0.1	1.1	-0.3	-0.1	0.1	-0.6	-0.3	0.1	-0.1
Wet	-0.2	-0.1	-0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

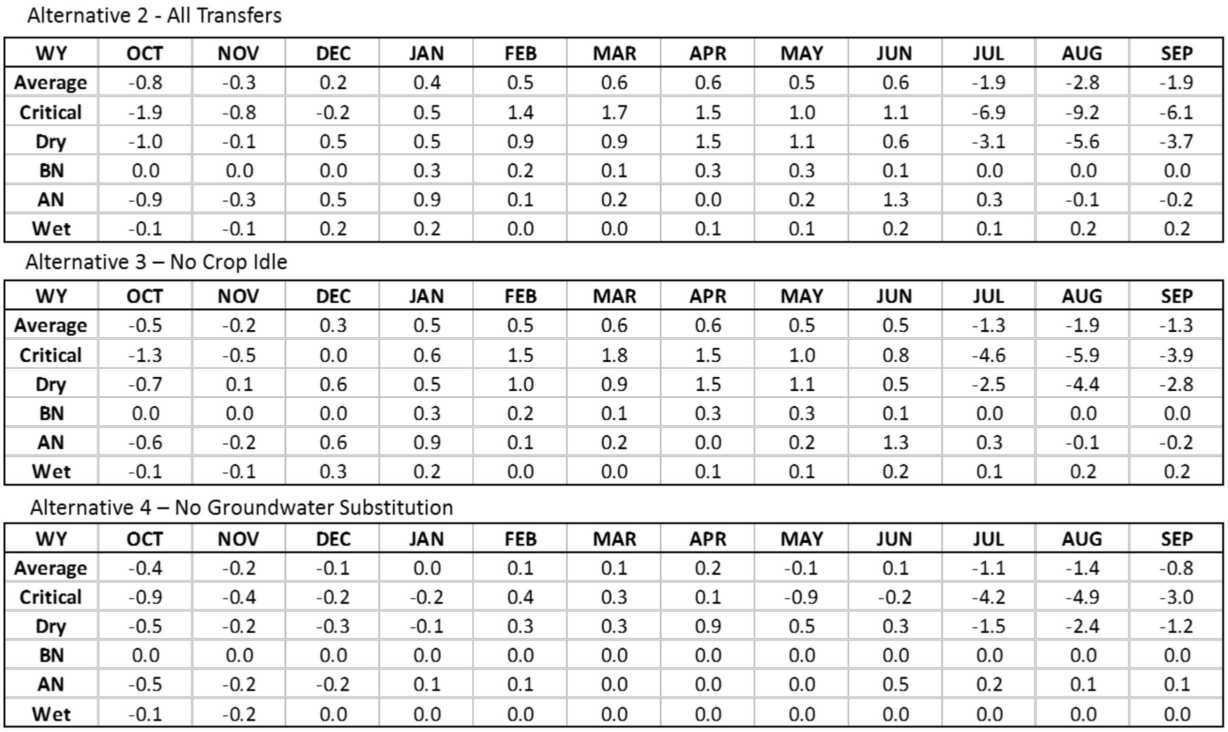
CCWD Old River location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.3	-0.7	-0.3	-0.1	0.0	0.0	0.1	0.2	0.1	0.9	0.4	-1.0
Critical	-3.1	-1.8	-1.2	-0.8	-0.2	0.3	0.3	0.6	0.5	3.2	0.1	-3.8
Dry	-1.5	-0.7	-0.1	0.2	0.3	0.2	0.2	0.5	0.5	1.1	1.8	-1.4
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-1.4	-0.8	-0.2	0.2	0.5	-0.4	-0.1	0.0	-0.4	0.2	0.1	-0.2
Wet	-0.3	-0.2	-0.1	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

CCWD Rock Slough location

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.3	-0.9	-0.5	-0.1	0.0	0.1	0.1	0.2	0.1	1.5	0.7	-0.7
Critical	-3.3	-2.3	-1.4	-0.9	-0.3	0.3	0.3	0.4	0.5	5.2	1.6	-2.8
Dry	-1.5	-1.1	-0.4	0.2	0.2	0.2	0.2	0.4	0.4	1.9	2.1	-0.6
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-1.3	-1.0	-0.4	0.2	0.3	0.3	-0.3	0.0	-0.3	0.3	0.2	-0.2
Wet	-0.4	-0.2	-0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0

Table C-22. RSAC081 location (Collinsville) Average Monthly Percent Change from Base EC for the Alternatives.



Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.8	-0.3	0.2	0.4	0.5	0.6	0.6	0.5	0.6	-1.9	-2.8	-1.9
Critical	-1.9	-0.8	-0.2	0.5	1.4	1.7	1.5	1.0	1.1	-6.9	-9.2	-6.1
Dry	-1.0	-0.1	0.5	0.5	0.9	0.9	1.5	1.1	0.6	-3.1	-5.6	-3.7
BN	0.0	0.0	0.0	0.3	0.2	0.1	0.3	0.3	0.1	0.0	0.0	0.0
AN	-0.9	-0.3	0.5	0.9	0.1	0.2	0.0	0.2	1.3	0.3	-0.1	-0.2
Wet	-0.1	-0.1	0.2	0.2	0.0	0.0	0.1	0.1	0.2	0.1	0.2	0.2

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.5	-0.2	0.3	0.5	0.5	0.6	0.6	0.5	0.5	-1.3	-1.9	-1.3
Critical	-1.3	-0.5	0.0	0.6	1.5	1.8	1.5	1.0	0.8	-4.6	-5.9	-3.9
Dry	-0.7	0.1	0.6	0.5	1.0	0.9	1.5	1.1	0.5	-2.5	-4.4	-2.8
BN	0.0	0.0	0.0	0.3	0.2	0.1	0.3	0.3	0.1	0.0	0.0	0.0
AN	-0.6	-0.2	0.6	0.9	0.1	0.2	0.0	0.2	1.3	0.3	-0.1	-0.2
Wet	-0.1	-0.1	0.3	0.2	0.0	0.0	0.1	0.1	0.2	0.1	0.2	0.2

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.4	-0.2	-0.1	0.0	0.1	0.1	0.2	-0.1	0.1	-1.1	-1.4	-0.8
Critical	-0.9	-0.4	-0.2	-0.2	0.4	0.3	0.1	-0.9	-0.2	-4.2	-4.9	-3.0
Dry	-0.5	-0.2	-0.3	-0.1	0.3	0.3	0.9	0.5	0.3	-1.5	-2.4	-1.2
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.5	-0.2	-0.2	0.1	0.1	0.0	0.0	0.0	0.5	0.2	0.1	0.1
Wet	-0.1	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

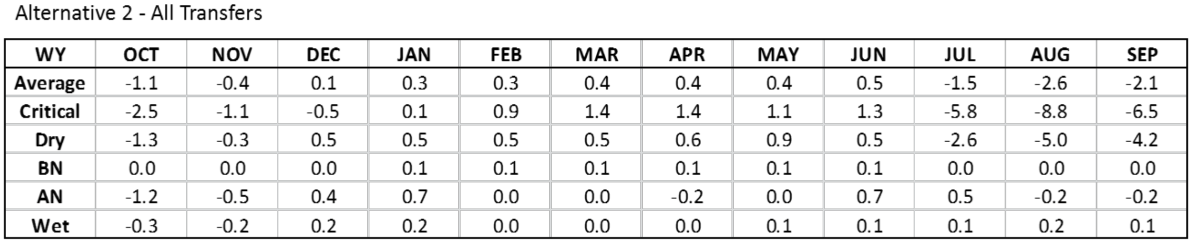
Table C-22 illustrates results for average monthly percent change from Base EC at Collinsville, RSAC081, on the Sacramento River. The increases and decreases in percent change from Base EC at RSAC081 reflect the boundary conditions changes in NDO (Figure C-11). EC results at locations in Suisun Marsh show a similar pattern.

Table C-23 and Table C-24 illustrate EC results as percent change from Base at RSAN007, near Antioch, and RSAN018, Jersey Point, respectively, on the San Joaquin River. The model results for EC at RSAN007 are similar to those at RSAC081, as they are both strongly influenced by the increases in Sacramento River outflow, as reflected in the changes in NDO flow in comparison with Base. The results at RSAN018 (Table C-24), Jersey Point, are somewhat different than those at RSAN007 (Table C-23). The Jersey Point location has a more complicated set of influences on EC, as local antecedent conditions, such as the EC in Franks Tract, of higher or lower EC waters can serve as reservoirs that mix locally near RSAN018. However, the largest increases (June – July) and decreases (August – November) in EC occur in Critical water years for all alternatives.

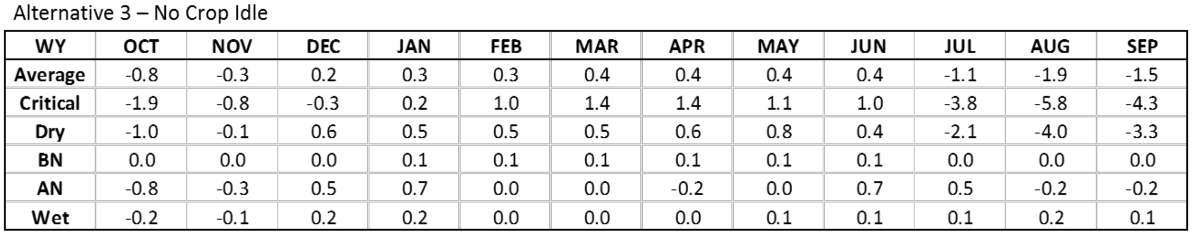
Both RSAN018 and RSAC092 on the Sacramento River at Emmaton have D-1641 have constraints for EC specified by water year type. Examining the average monthly percent change from Base at RSAN018 in Table C-24, large changes in EC are seen in Critical (Cr) June and July periods and in Above Normal (AN) July's (i.e., the values indicate individual years may be influencing results). Monthly average Tables (not shown, see the Attachment) indicate that for RSAN018 the AN water year 2003 and the Cr water years 1990 and 1991 can serve as indicators for adherence to D-1641 criteria for RSAN018, and that water years 2003 (AN) and 1976, 1977 and 1991 (Cr) can serve as indicators for RSAC092.

Using the maximum EC constraints at RSAC092 for AN and Cr water years (the plotted constants), Figure C-17 shows that there are only minor differences between the Base Alternative 1 and the other Alternatives (2-4) . Similarly, for RSAN018 (Figure C-18) the difference in Base alternative in increase in EC amounts to a shift in EC increases of a few days. These differences could be accounted for in real operations by delaying exports and/or reservoir releases by a few days to adhere more closely to D-1641 standards.

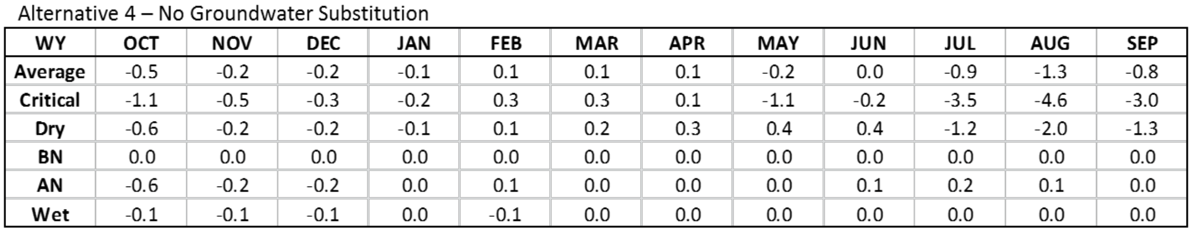
Table C-23. RSAN007 Location (Near Antioch) Average Monthly Percent Change from Base EC for the Alternatives.


Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.1	-0.4	0.1	0.3	0.3	0.4	0.4	0.4	0.5	-1.5	-2.6	-2.1
Critical	-2.5	-1.1	-0.5	0.1	0.9	1.4	1.4	1.1	1.3	-5.8	-8.8	-6.5
Dry	-1.3	-0.3	0.5	0.5	0.5	0.5	0.6	0.9	0.5	-2.6	-5.0	-4.2
BN	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
AN	-1.2	-0.5	0.4	0.7	0.0	0.0	-0.2	0.0	0.7	0.5	-0.2	-0.2
Wet	-0.3	-0.2	0.2	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1

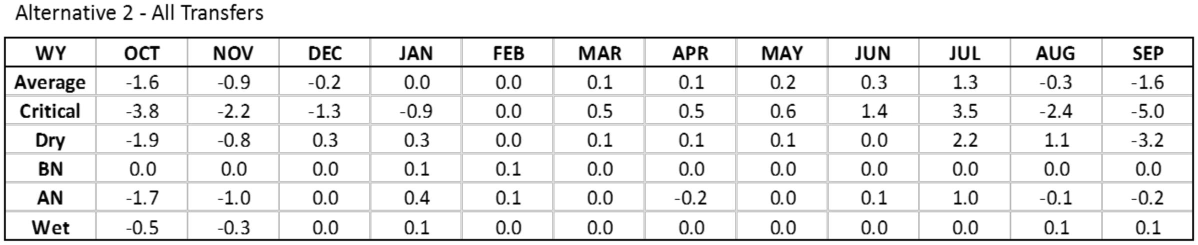

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.8	-0.3	0.2	0.3	0.3	0.4	0.4	0.4	0.4	-1.1	-1.9	-1.5
Critical	-1.9	-0.8	-0.3	0.2	1.0	1.4	1.4	1.1	1.0	-3.8	-5.8	-4.3
Dry	-1.0	-0.1	0.6	0.5	0.5	0.5	0.6	0.8	0.4	-2.1	-4.0	-3.3
BN	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
AN	-0.8	-0.3	0.5	0.7	0.0	0.0	-0.2	0.0	0.7	0.5	-0.2	-0.2
Wet	-0.2	-0.1	0.2	0.2	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1

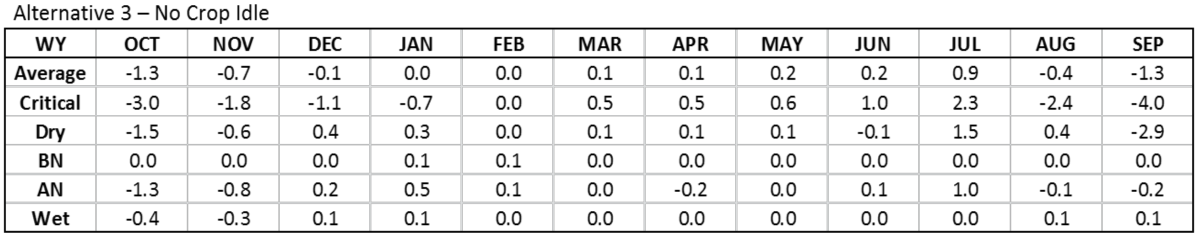

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.5	-0.2	-0.2	-0.1	0.1	0.1	0.1	-0.2	0.0	-0.9	-1.3	-0.8
Critical	-1.1	-0.5	-0.3	-0.2	0.3	0.3	0.1	-1.1	-0.2	-3.5	-4.6	-3.0
Dry	-0.6	-0.2	-0.2	-0.1	0.1	0.2	0.3	0.4	0.4	-1.2	-2.0	-1.3
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.6	-0.2	-0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.2	0.1	0.0
Wet	-0.1	-0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

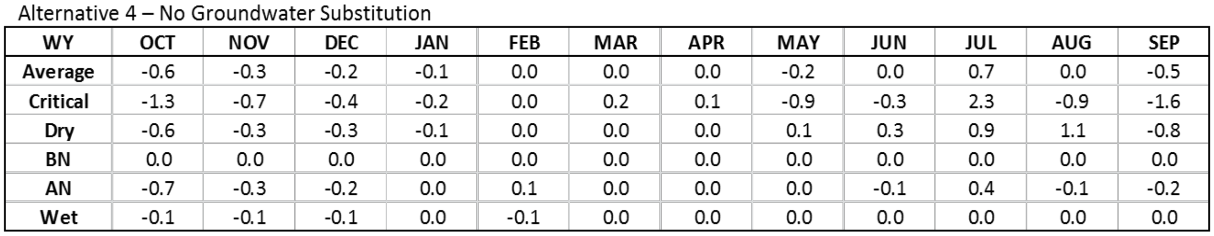
Table C-24. RSAN018 Location (Jersey Point) Average Monthly Percent Change from Base EC for the Alternatives.


Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.6	-0.9	-0.2	0.0	0.0	0.1	0.1	0.2	0.3	1.3	-0.3	-1.6
Critical	-3.8	-2.2	-1.3	-0.9	0.0	0.5	0.5	0.6	1.4	3.5	-2.4	-5.0
Dry	-1.9	-0.8	0.3	0.3	0.0	0.1	0.1	0.1	0.0	2.2	1.1	-3.2
BN	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-1.7	-1.0	0.0	0.4	0.1	0.0	-0.2	0.0	0.1	1.0	-0.1	-0.2
Wet	-0.5	-0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1


Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-1.3	-0.7	-0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.9	-0.4	-1.3
Critical	-3.0	-1.8	-1.1	-0.7	0.0	0.5	0.5	0.6	1.0	2.3	-2.4	-4.0
Dry	-1.5	-0.6	0.4	0.3	0.0	0.1	0.1	0.1	-0.1	1.5	0.4	-2.9
BN	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-1.3	-0.8	0.2	0.5	0.1	0.0	-0.2	0.0	0.1	1.0	-0.1	-0.2
Wet	-0.4	-0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1


Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.6	-0.3	-0.2	-0.1	0.0	0.0	0.0	-0.2	0.0	0.7	0.0	-0.5
Critical	-1.3	-0.7	-0.4	-0.2	0.0	0.2	0.1	-0.9	-0.3	2.3	-0.9	-1.6
Dry	-0.6	-0.3	-0.3	-0.1	0.0	0.0	0.0	0.1	0.3	0.9	1.1	-0.8
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.7	-0.3	-0.2	0.0	0.1	0.0	0.0	0.0	-0.1	0.4	-0.1	-0.2
Wet	-0.1	-0.1	-0.1	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure C-17. Comparison of 14-Day Running Average EC at RSAC092 for Selected Time Frames Pertinent to D-1641.

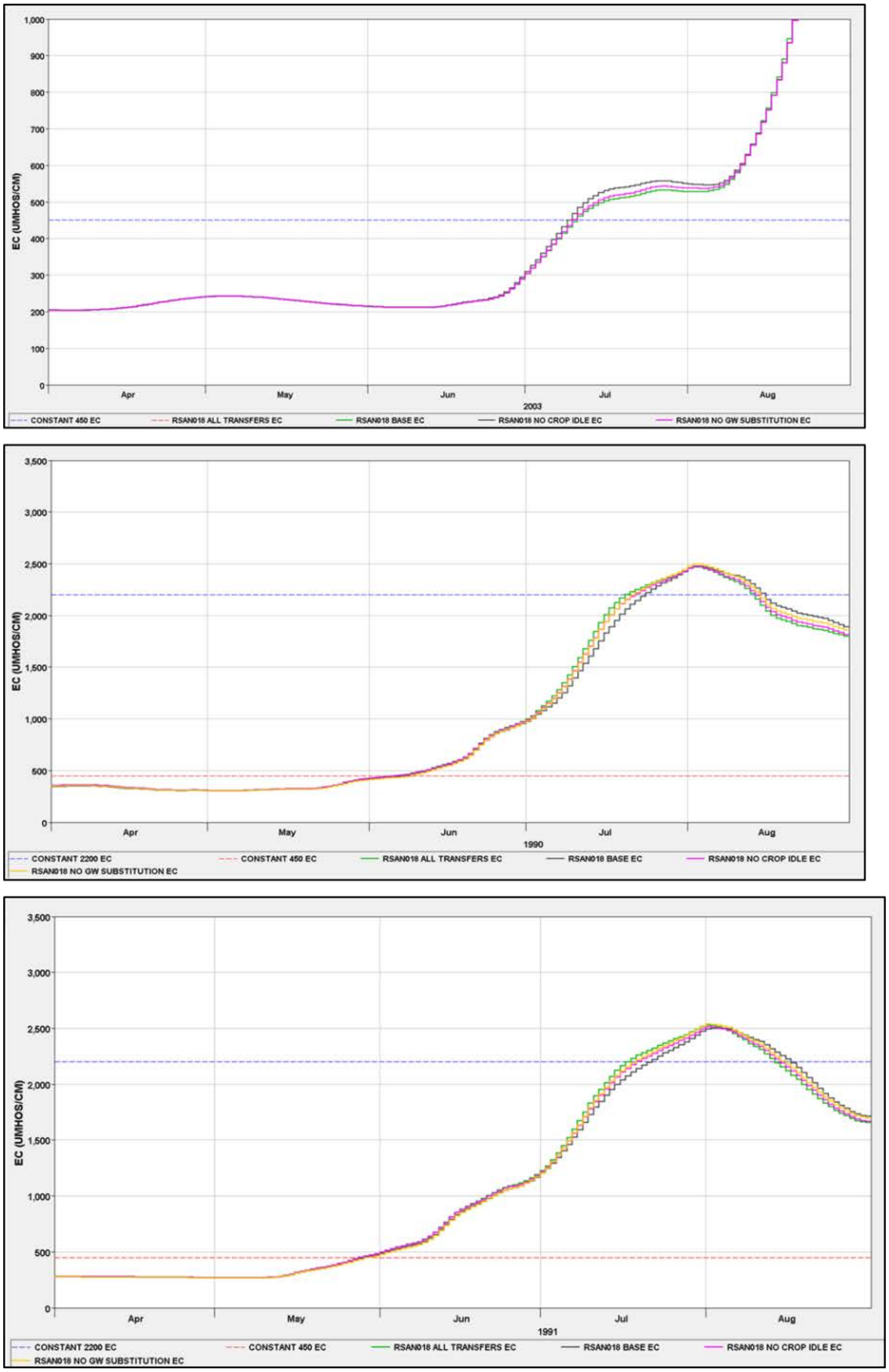


Figure C-18. Comparison of 14-Day Running Average EC at RSAN018 for Selected Time Frames Pertinent to D-1641.

C.9 Comparison of Stage Results

The potential exists for decreases in water level elevation due operational changes in the three Alternative that might affect agricultural withdrawals of water in the south Delta, a conservative estimate of stage changes was calculated as follows at each relevant D-1641 location in HEC DSSVue:

1. the daily minimum stage was calculated for all the Base and three Alternative from the 15-minute model output
2. daily change from Base stage was calculated (Daily Alternative Min Stage – Daily Base Min Stage)
3. monthly average stage was calculated from the results at step 2.

Step 2, the difference in daily minimum stage is a conservative estimate of potential decreases in stage since changes in exports and/or inflows can shift the timing of stage potentially resulting in overly optimistic or pessimistic stage differences when calculated with 15-minute output data. As CalSim II model outputs are calculated on a monthly time step and input as boundary conditions for DSM2, the final calculation of stage changes as a monthly average is appropriate.

Stage changes were calculated upstream and downstream of agricultural barrier locations in Old and Middle Rivers, in Grant Line Canal, and in three additional locations: Old River near Middle River, Old River near Tracy, and RMID040 in Middle River. Results are shown as monthly average tables of difference in stage (Alternative – Base), with Average monthly results separated by water year type at the bottom of each Table.

A selection of results for three of these locations are shown in this section to illustrate the general results the complete set of stage results is found in the Attachment. The largest differences from Base stage occurred for the All Transfers alternative, as this alternative had the greatest increases over Base exports for SWP and CVP in the south Delta. Figure C-19 shows the monthly averaged minimum daily Base stage calculation and change from minimum Base stage for each the alternatives downstream of the Old River agricultural barrier. This location was chosen for the All Transfers alternative as it had the largest decreases in monthly average of daily minimum stage difference, -0.2 ft., of any of the agricultural barrier locations, as shown in Table C-25. All seven of these occur in July or August of Dry or Critical water years. For the No Crop Idle Alternative, June 1993 had a difference of -0.2 ft. upstream of the barrier in Old River as did July 1987 downstream of this barrier. All other decreases in monthly average of daily minimum stage were -0.1 ft. or less at both the upstream and downstream locations of the Grant Line Canal and Middle River agricultural barrier locations for all of the alternative. The stage difference results in Grant Line Canal upstream of the agricultural barrier are plotted in Figure C-20 for all of the alternatives, and the monthly average results for the All Transfers alternative are shown in Table C-26. Each of Old River near Middle River, Old River near Tracy, and RMID040 in Middle River had exactly one stage decrease of -0.2 ft., occurring in June 1993, an Above Normal water year, for all three of the alternative. These results are shown for the Old River near Middle River location in Figure C-21, and monthly average calculation for the All Transfers alternative in Table C-27.

Table C-25. Difference in Minimum Stage (ft) at Old River Downstream of Barrier for All Transfers minus Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	0.0
1982	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	0.0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	0.0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

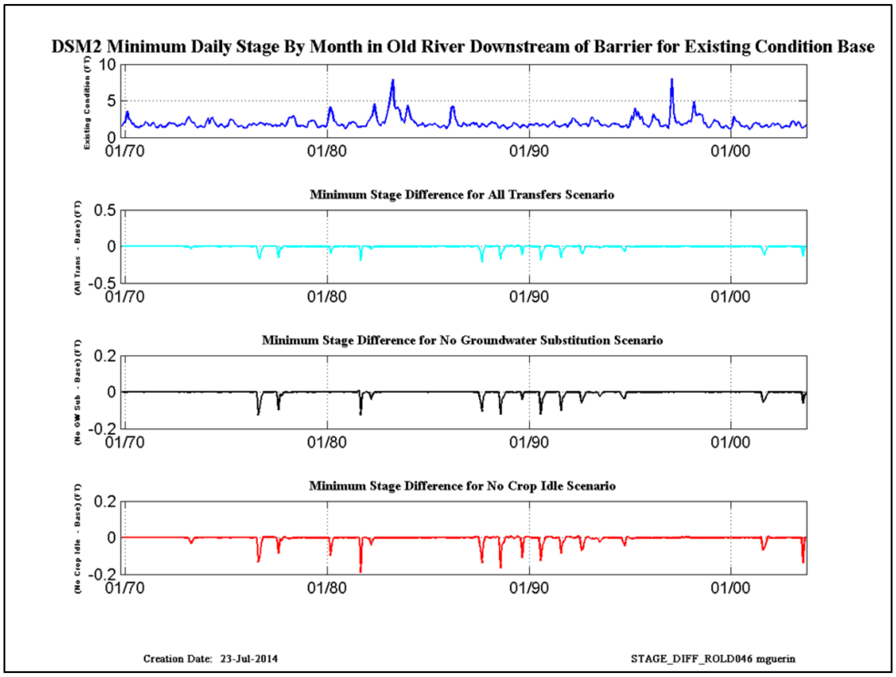


Figure C-19. Minimum stage at Old River Downstream Barrier and Minimum Stage Differences Alternative – Base.

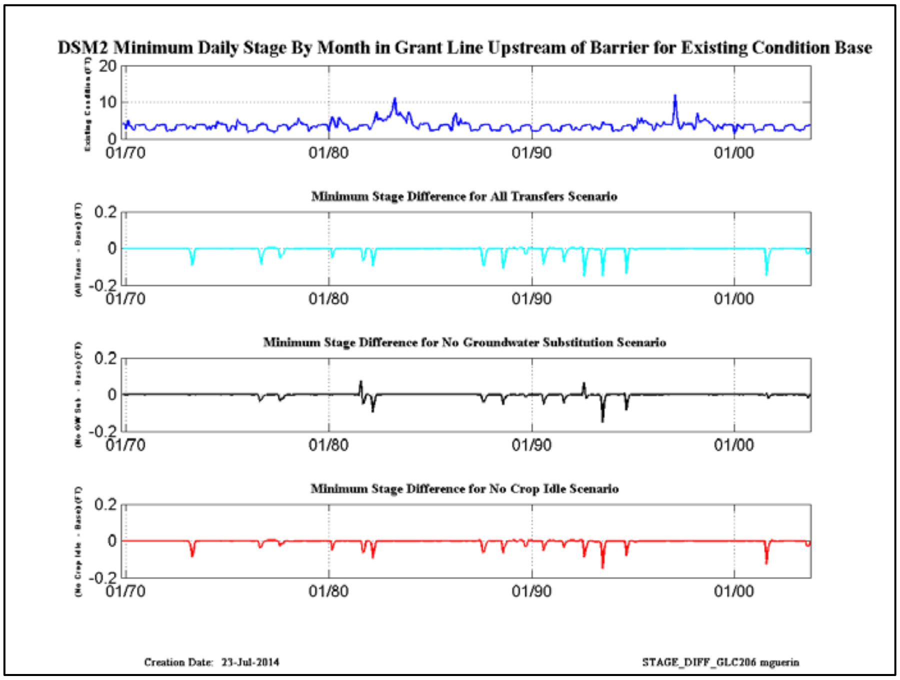


Figure C-20. Minimum Stage At Grant Line Upstream Barrier and Minimum Stage Differences Alternative – Base.

Table C-26. Difference in Minimum Stage (ft) at Grant Line Canal Upstream of Barrier for All Transfers minus Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
1982	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-27. Difference in Minimum Stage (ft) at Old River near Middle River Location for All Transfers Minus Base Alternatives.

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1970	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1971	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1972	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1973	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1979	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
1982	0.0	0.0	0.0	0.0	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1983	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.1	0.0	0.0
1994	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Critical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	0.0
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

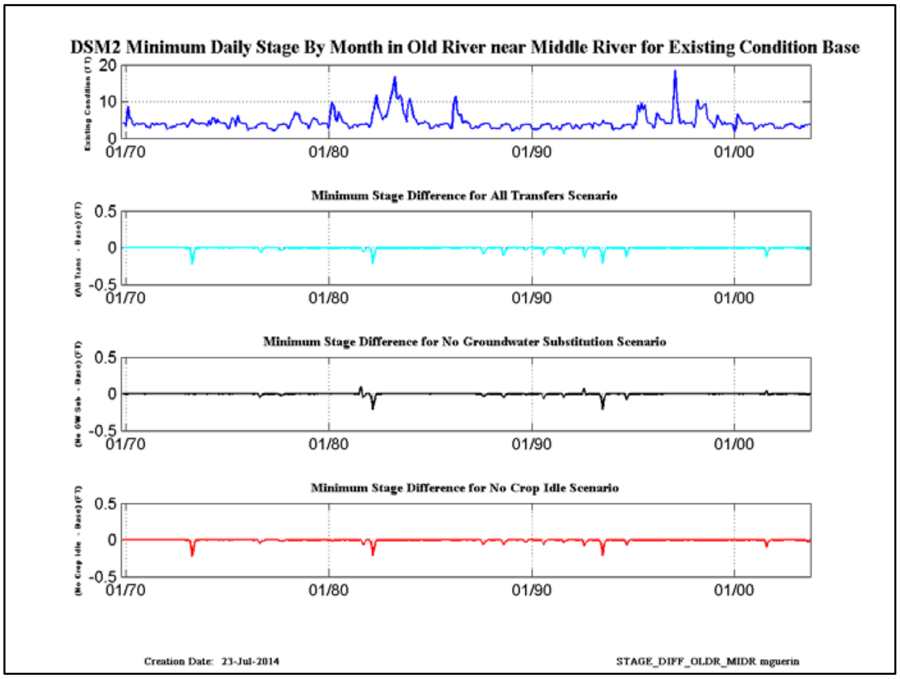


Figure C-21. Minimum Stage at Old River Near Middle River Location and Minimum Stage Differences Alternative – Base.

C.10 Comparison OF X2 Results

Figure C-22 and Table C-28 illustrate the monthly average and average monthly, respectively, model results for the alternatives for the location of X2 in kilometers (km) from the Golden Gate. Westward changes, negative values, are considered beneficial as higher outflow is thought to expand the volume of habitat region available to fish species. Specification of X2 is part of the D-1641 compliance standards February – June. Changes in inflow and export operations will result in a change in X2 location. According to criteria specified in (SWRCB, 1999), eastward changes in monthly average X2 position (positive values in our analysis) of 1.1 km are not significant in general, and in Critically Dry years an eastward movement of 3.0 km is not significant. It can be seen in Figure C-22 that changes in X2 are insignificant for each of the alternative, as all monthly average differences are less than 1.1 km. Alternative 3, No Groundwater Substitution, has the smallest differences in comparison with the Base X2 location.

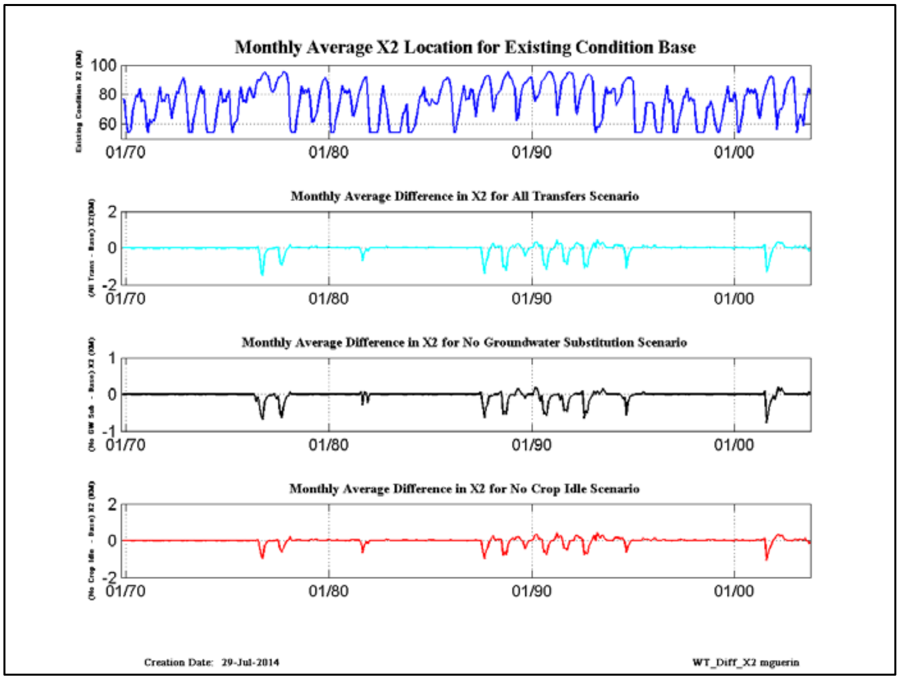


Figure C-22. Monthly Average X2 Location for Existing Condition Base and the Differences Alternative – Base.

Table C-28. X2 Monthly Average Change from Base Location (km).

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	-0.2	-0.3	-0.3
Critical	-0.2	-0.1	0.0	0.1	0.2	0.2	0.1	0.1	0.1	-0.8	-1.1	-1.1
Dry	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	-0.4	-0.7	-0.4
BN	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	-0.2	-0.2	-0.2
Critical	-0.2	0.0	0.0	0.1	0.2	0.2	0.1	0.1	0.1	-0.5	-0.7	-0.7
Dry	-0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	-0.3	-0.5	-0.3
BN	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
AN	-0.1	0.0	0.1	0.2	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2	-0.1
Critical	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	-0.5	-0.6	-0.5
Dry	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.2	-0.3	-0.1
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wet	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

C.11 Comparison of OMR results

Under National Marine Fisheries Service and California Fish and Wildlife Service Biological Opinions (BOs), CVP and SWP operations are mandated to maintain exports at levels to minimize entrainment of delta smelt, steelhead, and winter-run salmon between December and June. Entrainment protection is currently met via prescriptions for OMR flow using measurements supplied by the US Geological Survey (USGS). This prescription is called into play when delta smelt are found in locations believed to put them at risk for entrainment. Restrictions to OMR flow, and therefore to export levels, are considered to be an “adaptive management” process in which decisions on changes in Delta operations are made after assessing current conditions and data. The period December – March is used to protect pre-spawning delta smelt adults along with turbidity or export salvage triggers, and the period through June is used to protect larval smelt along with water temperature triggers.

The 15-minute DSM2 flow results at ROLD024 and at RMID015 were daily averaged, added together then smoothed with a 14-day running average – the final step was to monthly average the running average results and then calculate change from Base and percent change between each alternative and the Base alternative. Percent change from Base of the monthly averaged OMR flow for the alternatives was then used to gauge the effect of alternative Delta operations found in the alternatives. Note that negative percent difference numbers indicate that a negative OMR flow in the alternative was smaller in magnitude than the Base.

The change from Base results (Figure C-23) show that all alternative tend to increase the magnitude of negative OMR flow. The December – June percent change from Base values (Table C-29) of OMR flow are similar for the All Transfers and No Crop Idle alternatives, with positive percent changes in April and June of Above Normal water years, while the No Groundwater Substitution alternative has a positive percent change in June of Above Normal water years.

The Biological Opinions (FWS, 2008; NOAA, 2009) prescribing OMR flow values for the protection of delta smelt are complicated by additional triggers used to specify the “adaptive” actions to restrict negative OMR flows, such as turbidity, water temperature, and the presence of delta smelt at certain locations or times.

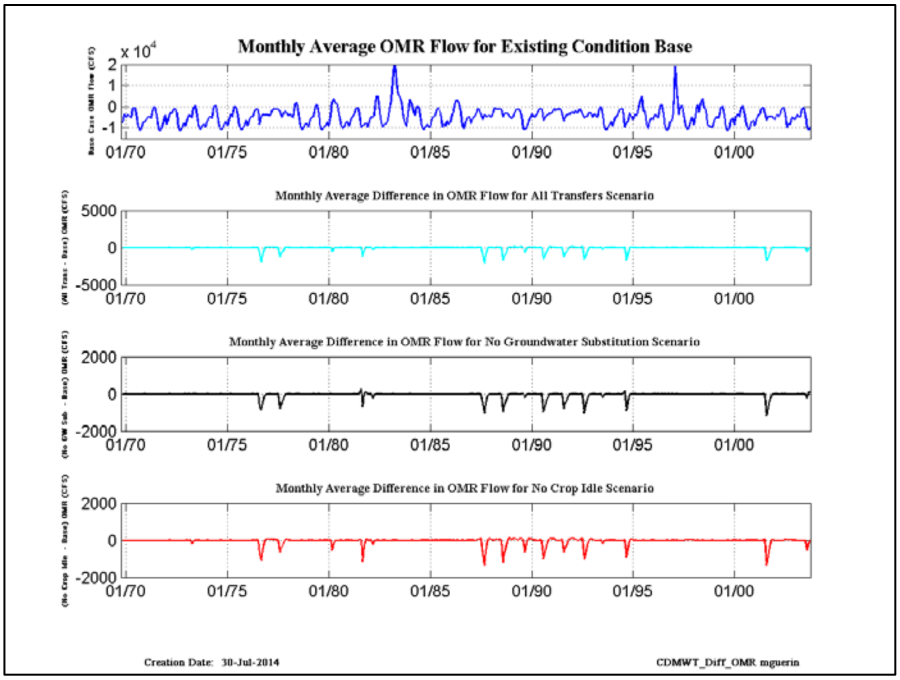


Figure C-23. Monthly Average OMR Flow (Cfs) and Flow Differences Alternative – Base.

Table C-29. OMR Monthly Average Percent Change from Base Flow (cfs)

Alternative 2 - All Transfers

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.1	-0.7	-0.4	-0.5	-0.9	-0.3	0.2	-0.8	-0.4	6.5	8.3	4.0
Critical	0.0	-1.7	-1.6	-1.9	-0.7	-1.3	-0.7	-1.8	-1.3	24.6	25.4	14.0
Dry	0.1	-0.6	-0.1	-0.3	-0.7	-0.3	-0.5	-1.5	-1.7	7.2	17.0	6.3
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.5	-0.9	-0.2	0.0	-4.0	-0.1	2.5	-1.2	0.7	1.0	0.2	0.0
Wet	0.0	-0.2	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 3 – No Crop Idle

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	-0.2	-0.7	-0.4	-0.5	-0.9	-0.3	0.2	-0.8	-0.4	4.2	5.1	2.2
Critical	-0.6	-1.7	-1.6	-1.9	-0.7	-1.3	-0.7	-1.8	-1.3	15.1	14.3	7.3
Dry	-0.3	-0.6	-0.1	-0.3	-0.7	-0.3	-0.5	-1.5	-1.7	5.4	11.8	4.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.0	-0.9	-0.2	0.0	-4.0	-0.1	2.5	-1.2	0.7	1.0	0.2	0.0
Wet	-0.1	-0.2	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0

Alternative 4 – No Groundwater Substitution

WY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Average	0.4	0.0	0.0	0.0	0.1	0.0	0.0	-0.2	0.1	4.0	4.3	2.2
Critical	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	13.6	8.1
Dry	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	8.7	3.0
BN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN	0.6	0.0	0.0	0.0	0.0	0.0	0.0	-1.3	0.7	0.5	-0.2	-0.2
Wet	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0

C.12 Summary of Results

The Delta Conditions analysis of DSM2 alternatives examined regulated parameters to determine the magnitude of changes to these parameters that could occur if the system operations defined by any of the Alternatives were implemented instead of Base operations. The pertinent parameters are:

- salinity (EC) changes at D-1641 locations
- changes in south Delta stage heights identified in D-1641, as decreases in stage might affect agricultural diversion operations
- changes in the location of X2, the 2 ppt salinity isohaline, as regulated by D-1641
- changes in the magnitude in the combined Old River plus Middle River flow (OMR) December – June as regulated by the NMFS and FWS BOs

Alternative 1 is the Base condition, and all analyses of the regulated parameters for the Alternatives are defined *via* a change from the Base conditions using the "comparative analysis" approach discussed above. The model time span is 09/1969 – 10/2003, i.e., water years 1970 through 2003. As DSM2 boundary conditions are specified as monthly values, defined either by CalSim II or TOM model output, all comparisons are made using either monthly average (one value per month modeled) or average monthly (one value per month, averaged over the modeled years) calculations.

The Proposed Project, Alternative 2 or the "All Transfers" alternative, has boundary conditions with the greatest changes to Base conditions among the alternatives. Although both the Sacramento and San Joaquin Rivers change under the alternatives, increases in Sacramento River inflow in the months July – September of Critical and Dry water years dominate the changes and are greatest in the All Transfers alternative and smallest in the No Groundwater Substitution alternative, Alternative 3. Export changes are the greatest at the SWP and CVP export locations, as expected, and the increases generally mirror the increases in Sacramento River inflow, although increases in SWP exports end in August while increases in CVP exports end in September. In the other months, exports generally decrease as average monthly values. These results reflect the changes discussed in Appendix B (Water Operations Assessment).

Changes in the EC regime were calculated for each Alternative in comparison with Base at all D-1641 locations, and the entire set of results are compiled in the Attachment to this Appendix. It was found that results at many locations were either small (had average monthly percent differences around +/- 1% or less) or were characteristic of a region (e.g., Suisun Marsh), so they are not discussed in this document. Instead, only those results that reflect general trends or occur at export locations were included herein.

As expected, the All Transfers alternative, the Proposed Project, exhibits the largest increases in EC in July – August of Critical and Dry water years at SWP and CVP export locations, with the No Groundwater Substitution alternative showing the smallest average monthly EC increases over all water years. At these locations, EC decreases in Critical and Dry water years September - December even though exports have increased over Base in September. Note that the EBMUD exports were not covered herein for EC, as only low EC Sacramento River water is exported at this location.

The model results for the three CCWD intake locations are differ by location. The CCWD-Victoria Canal intake location has a different pattern of increases and decreases than the other two locations. In August of Critical water years, Victoria Canal sees a decrease in EC while the other locations saw an increase – this is likely due to the increased flow of low EC Sacramento River water through the DCC and then through Middle River as Victoria Canal is more heavily influenced by DCC operations than the other two locations. The pattern of EC changes at CCWD’s Rock Slough and Old River intake locations is similar to the pattern at the SWP location, with the largest EC increases occurring in July and August of Critical and Dry water years, with Rock Slough showing greater increases than Old River as it receives a greater proportion of water from the Martinez boundary than the Old River location.

In general, the All Transfers alternative sees the largest increases in EC when exports are the greatest, with Critical water years in July seeing the largest percent difference of 4.2% at the SWP location and 3.3 % at the CVP location. In terms of D-1641 criteria for chloride concentration, all export locations regulated by the 250 mg/L standard were in compliance on a monthly average basis – spot checks at SWP showed the compliance was also maintained with daily average chloride. At the Contra Costa Canal location (CCWD’s intake modeled at Rock Slough), the chloride standard was in compliance for the requisite number of days for all alternatives.

At locations RSAN007 and RSAC081, near the confluence of the Sacramento and San Joaquin Rivers, the influence of Sacramento River increases result in EC decreases during the increased export periods. The increases in EC during other periods are less than 2% on an average monthly. RSAN018, Jersey Point, and RSAC092, Emmaton were checked for D-1641 EC compliance and it was found that only in June/July of one Above Normal (2003) and a selection of Critical water years had the potential to violate standards. In comparison with the Base, the potential exists for the Critical water year standards to be exceeded in the Alternatives by EC increases occurring a few days sooner than in the Base, which could be changed with a minor variation in export timing.

Changes in the south Delta stage were calculated for each Alternative in comparison with Base at all D-1641 locations, and discussed only at representative locations - the entire set of results are compiled in the Attachment to this Appendix. Stage changes were assessed via a conservative calculation that compared the monthly average of differences in daily minimum stage. The analyses consider a stage difference of -0.2 ft. to indicate a potentially significant result. Stage decreases were greatest for the Proposed Project/All Transfers alternative at the Old River downstream of agricultural barrier location, but changes of this magnitude only occurred in seven of the 408 months simulated. These decreases occurred in July and August of Dry or Critical water years, when south Delta exports increased in comparison with Base. Monthly average decreases in stage were sparse in all other locations and alternatives, with few instances when stage changes reached -0.2 ft. (e.g., in June 1993 in several locations for each of the alternatives).

Changes in X2 were evaluated as the change from monthly average Base values. The No Groundwater Substitution alternative, Alternative 3, had the smallest changes in X2. According to the criteria specified in (SWRCB, 1999), none of the changes in X2 are considered significant.

The Biological Opinions (FWS, 2008; NOAA, 2009) prescribing December – June OMR flow values for the protection of delta smelt are complicated by additional triggers used to specify the “adaptive” actions to restrict the magnitude of negative OMR flows, such as turbidity, water temperature, and the presence of delta smelt at certain locations or times. These adaptive constraints make it difficult to assess the significance of a change in OMR flow due to the alternatives. However, all of the Alternatives tend to increase the magnitude of negative OMR flow (positive percent values indicate a result to be avoided). The December – June average monthly percent change from Base values of OMR flow are similar for the All Transfers and No Crop Idle alternatives, with positive percent changes in April and June of Above Normal water years, while the No Groundwater Substitution alternative has a positive percent change in June of Above Normal water years.

C.13 References

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Appendix D

Groundwater Model Documentation

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Appendix D
Groundwater Model Documentation

Implementation of conjunctive water management within the Sacramento Valley is one strategy being used to enhance the reliability of the existing water supply, as well as potentially improve water quality, within the San Francisco Bay-Delta. However, the operation of conjunctive water management, or groundwater substitution projects, can result in adverse impacts on water resources within the valley. The two most critical potential impacts of additional groundwater production are depression of local groundwater levels, with associated impacts on well yields from nearby water supply wells, and changes in the hydraulic relationship between the surface water and groundwater systems in the area. To support the evaluation of these potential impacts, a high-resolution, numerical groundwater modeling tool was developed to estimate the impacts of potential future conjunctive water management projects on surface water and groundwater resources within the Sacramento Valley. This model, known as the Sacramento Valley Finite Element Groundwater Model (SACFEM2013), is described herein.

D.1 Model Code Description

MicroFEM (Hemker 1997), a finite-element based, three-dimensional, integrated groundwater modeling package developed in The Netherlands, was chosen to simulate the groundwater flow systems in the Sacramento Valley Groundwater Basin. The current version of the program (4.10) has the ability to simulate up to 25 layers and 250,000 surface nodes. MicroFEM is capable of modeling saturated, single-density groundwater flow in layered systems. Horizontal flow is assumed in each layer, as is vertical flow between adjacent layers.

MicroFEM was the chosen modeling platform for the following reasons:

- The finite-element scheme allowed the construction of a model grid covering large geographic areas (over 5,960 square miles in the Sacramento Valley Groundwater Basin) with coarse node spacing outside of the simulated project areas and finer node spacing in areas of interest (e.g., near potential project areas). The finer node spacing near simulated production wells provides greater resolution of simulated groundwater levels and stream impacts.

- The graphical interface allows rapid assignment of aquifer parameters and allows proofing of these values by graphical means.

- The flexible post-processing tools allow for rapid evaluation of transient water budgets for model simulations and identification of changes to stream discharges and other water fluxes across the model domain.

D.2 Sacramento Valley Groundwater Basin

The following briefly summarizes the geology and hydrology of the Sacramento Valley Groundwater Basin.

D.2.1 Geologic Setting

The Sacramento Valley Groundwater Basin is a north-northwestern trending asymmetrical trough filled with as much as ten miles of both marine and continental rocks and sediment (Page 1986). On the eastern side, the basin overlies basement bedrock that rises relatively gently to form the Sierra Nevada; and on the western side, the underlying basement bedrock rises more steeply to form the Coast Ranges. Marine sandstone, shale, and conglomerate rocks that generally contain brackish or saline water overlie the basement bedrock. The more recent continental deposits, overlying the marine sediments, contain fresh water. These continental deposits are generally 2,000 to 3,000 feet thick (Page 1986). The depth (below ground surface) to the base of fresh water typically ranges from 1,000 to 3,000 feet (Bertoldi et al. 1991).

In the Sacramento Valley Groundwater Basin, groundwater users pump primarily from deeper continental deposits. Groundwater is recharged by deep percolation of applied water and rainfall, infiltration from streambeds, and lateral inflow along the basin boundaries. The quantity and timing of snowpack melt are the predominant factors affecting the surface water and groundwater hydrology, and peak runoff in the basin typically lags peak precipitation by one to two months (Bertoldi et al. 1991).

D.2.2 Hydrology

The Sacramento River is the main surface water feature in the Sacramento Valley Groundwater Basin. It has several major tributaries draining the Sierra Nevada, including the Feather, Yuba, and American Rivers. The flow in these tributaries depends heavily on the precipitation in the Sierra Nevada. Stony, Cache, and Putah Creeks drain the Coast Range and are the main west side tributaries to the Sacramento River. The west side tributaries contribute significantly less streamflow than those on the eastside tributaries. The Sacramento River flows south through the center of the valley before heading west to flow out Suisun Bay.

Streamflow data for streams throughout the Sacramento Valley are collected at gaging stations operated by the California Department of Water Resources[1] (DWR) and the U.S. Geological Survey[2] (USGS).

D.3 Model Construction

This section discusses the development of the groundwater model grid and layering, the assignment of groundwater flux boundary conditions, and the basis for assignment of material properties to the aquifers within the model domain.

D.3.1 Spatial Grid

The SACFEM2013 grid used for the groundwater substitution transfer simulations consists of 153,812 nodes and 306,813 elements (see Figure D-1). The current grid was configured to support evaluation of potential conjunctive water management projects associated with the Long-Term Water Transfer Program; however, the SACFEM2013 model was designed to be grid independent, and geographic information system (GIS)-based tools have been developed to build a similar model of the valley on any grid developed to support a particular application. The nodal spacing of the current grid varies from as large as approximately 3,300 feet (1,000 meters) near the model boundary and in areas where long-term water transfer projects are not being evaluated, to as small as 410 feet (125 meters) in areas where long-term water transfer groundwater production is being evaluated. Nodal spacing of approximately 1,640 feet (500 meters) is included along streams and flood bypasses included in SACFEM2013. The finer node spacing near proposed project areas allows for more refined estimates of the effects of groundwater pumping on groundwater levels and groundwater/surface water interaction in the potential project areas. The model domain boundary coincides with the lateral extent of the freshwater aquifer within the Sacramento Valley Groundwater Basin.

D.3.2 Vertical Layering

The total model thickness is defined by the thickness of the freshwater aquifer (less than 3,000 micromhos), as defined by Berkstresser (1973) and subsequently refined in the northern portion of the valley by DWR (DWR 2002). For the southern portion of the model area, defined by Berkstresser data, elevation contour lines of the base of fresh water, along with information from boring locations (point measurements of the elevation of the base of fresh water), were digitized and used to generate a three-dimensional surface defining the elevation of the base of fresh groundwater. For the northern portion of the model area, the locations of geologic cross sections developed by DWR Northern District staff were plotted, along with the estimated base of freshwater elevations obtained from the cross section information; and a base of freshwater

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[1] http://cdec.water.ca.gov/
[2] http://waterdata.usgs.gov/nwis

elevation contour map was constructed. These data sets were then merged to yield a single interpretation of the structural contour map of the base of freshwater across the Sacramento Valley (see Figure D-2).

D.3.2.1 Total Aquifer Thickness

The uppermost boundary of the SACFEM2013 model is defined at the water table. To develop a total saturated aquifer thickness distribution and, therefore, a total model thickness distribution, it was necessary to construct a groundwater elevation contour map and then subtract the depth to the base of freshwater from that groundwater elevation contour map. Average calendar year groundwater elevation measurements were obtained from the DWR Water Data Library. These measurements were primarily collected biannually, during the spring and fall periods; and these values were averaged at each well location to compute an average water level for each location. These values were then contoured, considering streambed elevations for the gaining reaches of the major streams included in the model, to develop a target groundwater elevation contour map for the year 2000. As described above, the distribution of the elevation of the base of freshwater was subtracted from this groundwater elevation contour map to provide an estimate of the distribution of the total saturated aquifer thickness across the model domain.

D.3.2.2 Model Layer Thickness

The strategy used to develop the overall layering of the SACFEM2013 model was to develop a tool that provided sufficient layers to assess the effects of groundwater pumping on shallow features such as wetlands and streams, but also to provide sufficient vertical resolution to allow assignment of pumping stresses to appropriate depths within the aquifer that reflect the major producing zones within the aquifer system. Additionally, to facilitate investigation of potential future conjunctive water management projects using the lower Tuscan aquifer, the layering strategy also provided for two layers explicitly representing this deep aquifer system.

Layer one of the SACFEM2013 model was assigned a maximum thickness of approximately 65 feet (20 meters). The thickness of this layer was limited to provide more accurate shallow groundwater elevations with which to support evaluations of the effects of changing groundwater levels on surface streams and wetland/riparian areas. Layers two through five represent the more regional groundwater-producing zones within the valley. The thicknesses of these layers were assigned using a specified percentage of the available aquifer thickness at a given location, to provide multiple-depth zones within which to assign regional pumping. The assumed layer thicknesses for layers two through five were also selected to reflect typical screened intervals of production wells in the Sacramento Valley. The thicknesses of layers two through four each represent approximately ten percent of the total aquifer thickness (one to 107 meters, three to 350 feet), and the thickness of layer five represents approximately 15 percent of the total aquifer thickness on average (one to 193 meters, three feet to 633 feet).

Where the lower Tuscan aquifer is present (the northeastern and central portions of the valley), the elevation of the top of layer six was defined by the structural contour surface of the top of the lower Tuscan aquifer. Two layers were assigned to represent this unit because in many areas of the model, the depth to the base of fresh water (the base of the model) is as much as 900 feet below the upper surface of the lower Tuscan. Groundwater production wells drilled into the lower Tuscan would almost certainly be screened over a much smaller depth interval. To allow representation of this condition in the model, layer six was assigned a thickness of between 250 to 360 feet (75 to 110 meters) in the central portion of the northern Sacramento Valley Groundwater Basin. The total range in layer six thickness is approximately three to 580 feet (one to 177 meters). The remaining lower Tuscan thickness not apportioned to layer six was assigned to layer 7. The exception to this convention is in the northeastern portion of the model near the City of Chico. The lower Tuscan outcrops in the foothills above Chico; thus, in these areas, all layers of the model represent the lower Tuscan aquifer. Moving west from Chico, a transition zone exists where a decreasing number of layers represent the lower Tuscan until it is limited to layers six and seven, as discussed above. In areas where the lower Tuscan is not present, the thicknesses of layers six and seven represent 18 and 27 percent of the total aquifer thickness, respectively. A contour map of the total saturated aquifer thickness is presented on Figure D-3.

D.3.3 Model Time Discretization

Time is continuous in the physical system, but a numerical model must describe the field problem at discrete time intervals. SACFEM2013 was set up to simulate transient flow conditions between Water Years[3] 1970 and 2010 with monthly stress periods. As such, model stresses (such as stream stage, groundwater pumping, deep percolation, etc.) and model output are assigned/evaluated on a monthly basis.

D.3.4 Boundary Conditions

A combination of no-flow, specified-flux, and head-dependent boundary conditions were used to simulate the groundwater flow system within the Sacramento Valley. Each of these boundary conditions is discussed in more detail below.

D.3.4.1 Head-dependent Boundaries

Surface Water Bodies. A head-dependent boundary condition was chosen to simulate the major streams, flood bypasses, and reservoirs within the Sacramento Valley. The MicroFEM wadi system was used to implement streams within the model domain. MicroFEM's wadi package is a two-way head-dependent boundary condition (that is, it can act as a source of groundwater recharge or as a groundwater sink) that calculates the magnitude and direction of nodal fluxes by using the relative values of the user-specified

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[3] A water year runs from October 1 of the previous calendar year through September 30 of the current calendar year (for example, water year 1970 includes the period of October 1, 1969 through September 30, 1970).

stream stage (wh1) and the calculated head in the upper aquifer (h1), but is limited by a critical depth (wl1). When calculated groundwater elevations fall below this critical depth, it is assumed that the water table de-couples from the river system, and the leakage rate from the river to the aquifer becomes constant. The equations that govern operation of the wadi package are as follows:

Groundwater discharge to a stream is simulated if $h1 > wh1$:

$$Q_{outflow} = a * (h1 - wh1) / | wc1 | \qquad (1)$$

In coupled streams (groundwater elevation is above the stream bottom elevation), groundwater recharge from a stream is simulated if $h1 < wh1$:

$$Q_{inflow} = a * (wh1 - h1) / | wc1 | \qquad (2)$$

In decoupled streams (groundwater elevation is below the stream bottom elevation), groundwater recharge from a stream is simulated if:

$$Q_{inflow} = a * (wh1 - wl1) / | wc1 | \qquad (3)$$

Where:

Q = volumetric flux

a = nodal area

h1 = simulated groundwater elevation in layer 1

wh1 = simulated stream stage

wl1 = stream bottom elevation

wc1 = resistance across the streambed

Nodal area is a grid-dependent parameter that can be automatically calculated within MicroFEM. In general, the nodal area around a node that represents a discrete reach of a stream is greater than the surface area of that stream along the reach in the field. The effective resistance term (wc1) incorporates an areal correction factor to account for this discrepancy the wadi resistance term (wc1) is a measure of the resistivity of the streambed sediments. The resistances are calculated as follows:

$$wc1 = Dr/Kv))* (a/LW) \qquad (4)$$

Where:

Dr = thickness of streambed sediments

Kv = vertical hydraulic conductivity of streambed sediments

L = stream length represented by the model node

W = field width of the wetted river channel within the stream reach represented by L. Fifty individual streams are simulated with MicroFEM's wadi package in the current version of SACFEM2013.

Stream locations were digitized from existing base maps and USGS topographic quadrangle sheets, and imported into the model domain. Stream length within a given node is a grid-dependent variable calculated by MicroFEM at each river node. The stream-length term is generally overestimated by MicroFEM at stream confluences. Manual corrections of this term were made where necessary. Streambed thickness was assumed to be 3.28 feet (one meter) for all river nodes. Assumptions of streambed Kv were based on the type of streambed deposits expected given stream size. Streams draining the Sierra Nevada were generally assigned lower streambed Kv's, with all streams except the Bear River and Big Chico Creek having values of two meters per day (m/d) (0.0023 centimeters per second [cm/s]) or less. Westside streams were assigned higher values, with most being at or above five m/d (0.0058 cm/s). Wetted stream width was calculated from aerial photographs at two locations along each stream. Few streams showed greater variability in width such that it was necessary to develop a continuously variable distribution along the stream length. This was accomplished by estimating wetted stream width at several points via examination of aerial photographs and fitting a polynomial to the data points.

Streambed elevations (wl1) were estimated using data from 10-meter Digital Elevation Model (DEM) data. It was assumed that the minimum DEM elevation that at/near a given stream node represented the streambed elevation at that location. Polynomials were fitted to the distribution of streambed elevations and cumulative distance along each stream. These polynomials provided relationships that were used to both "smooth" the distribution of streambed elevations and populate values for nodes where the SACFEM2013 nodal resolution was finer than the DEM spacing.

As previously discussed, SACFEM2013 simulates transient conditions from water years 1970 through 2010 on a monthly basis. Monthly varying distributions of stream stage were developed for all streams included in SACFEM2013. Further historical measured stream stage data for model streams was analyzed to determine the timing and location of streams that experience seasonal drying. During months where a given stream is interpreted as experiencing no surface water flow, the SACFEM2013 nodes are converted from a MicroFEM wadi boundary condition to a MicroFEM drainage boundary condition, discussed in more detail below.

The current version of SACFEM2013 incorporates additional recharge from the major flood bypasses in the Sacramento Valley during wet periods. These include the Butte Bypass, the Sutter Bypass, and the Yolo Bypass. Historical weir data were evaluated to determine the timing and location of flood bypass inundation. During periods of bypass flow, the interpreted water surface elevation was compared to the DEM data to determine the spatial distribution of bypass inundation. Active flood bypass nodes were simulated using MicroFEM's wadi boundary condition. The wh1 value for each active flood node was assigned the interpreted water surface elevation (which varied on a monthly basis). The wc1 value was assumed to be ten for all active bypass nodes. During dry periods (and non-inundated bypass nodes), flood bypasses were simulated as groundwater sinks using MicroFEM's drainage package.

The final surface water bodies simulated in SACFEM2013 using MicroFEM's wadi package are the major reservoirs located within the interior of the Sacramento Valley Groundwater Basin, Black Butte Reservoir and Thermalito Afterbay. The lake bottom elevations were assumed to be constant for both reservoirs, and were simulated as 100 feet below the average DEM elevation (assumed to represent lake stage) for Black Butte reservoir and 40 feet below the average DEM elevation for Thermalito Afterbay. The wc1 values were assumed to be one for both reservoirs. The lake stage elevation was assumed to be constant spatially across each reservoir; however, historical data were evaluated to develop monthly-variable lake stage datasets for the SACFEM2013 simulation period.

Drains. MicroFEM's drainage package was used to simulate boundary conditions across the top surface of the model, excluding nodes where wadi boundaries exist. Drainage boundary conditions are one-way head-dependent boundaries that allow the transfer of water out of the model domain only. The elevation of the drain boundaries were set at the land surface. The drain boundaries were included in the model to represent a combination of surficial processes that occur in areas of shallow groundwater, including evapotranspiration and groundwater discharge to the surface. Additionally, as discussed above, specific streams and flood bypasses were converted from wadi boundary conditions to drain boundary conditions during periods when a given surface water body was interpreted as being dry.

Groundwater discharge to a drain is simulated if $h1 > dh1$:

$$Q_{outflow} = a * (h1 - dh1) / | dc1 | \text{ (where } a = \text{nodal area)} \quad (5)$$

Groundwater discharge to a drain is simulated if $h1 < dh1$:

$$Q_{outflow} = 0 \quad (6)$$

The parameter dc1 represents the drain conductance and is a measure of the resistance to flow across the drain boundary. The dc1 was assumed to be 500 throughout the model domain.

Specified-flux Boundaries. Three sets of specified-flux boundary conditions were implemented in the SACFEM2013 model. These conditions are as follows: (1) deep percolation of applied water and precipitation along with agricultural pumping, (2) mountain-front recharge, and (3) urban pumping. Each is discussed in more detail below.

Deep Percolation of Applied Water, and Precipitation and Agricultural Pumping. The first set of specified-flux boundary conditions reflects the deep percolation of precipitation and applied water across the valley, as well as the regional agricultural pumping. The deep percolation flux values were applied to every surface node in the model. The pumping stresses due to agricultural pumping were applied at selected locations in model layers two through four (the depths of the regional producing zones across the valley). The spatial distribution and magnitudes of these fluxes were derived from the surface water budget calculations described in full detail in the Surface Water Budget section below.

Mountain-front Recharge. The second set of specified-flux boundary conditions represents the subsurface inflow of precipitation falling within the Sacramento River watershed but outside the extent of the model domain. To estimate these flux values, the USGS 10-meter DEM along with GIS-based hydrography coverages for the Sacramento Valley were used to delineate the drainage areas that are tributary to the model domain but fall outside of the watersheds of the rivers explicitly represented in the model. It is these areas that can contribute water to the model domain but are not accounted for in the wadi boundary conditions defined in the model. After the extents of these watershed areas were defined, they were intersected with monthly Parameter – elevation Relationships on Independent Slopes Model (PRISM)[4] rainfall datasets using GIS tools, and the volume of precipitation falling on the watershed was computed. On the basis of the computed total volume of precipitation, the deep percolation to the groundwater system was calculated using the following empirical relationship developed by Turner (1991):

$$DP = (PPT-2.32)*(PPT)^{0.66} \quad (7)$$

Where:

DP	=	average annual deep percolation of precipitation (inches per year)
PPT	=	annual precipitation (inches per year)

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[4] http://prism.oregonstate.edu/

A summary of the process that was used to estimate the quantity of subsurface inflow, otherwise known as mountain-front recharge, is as follows:

1. The area of each drainage basin tributary to the model domain that is not represented by streams explicitly simulated in SACFEM2013 was computed using a GIS-based analysis of the land surface topography. The extent of these smaller watersheds is shown on Figure D-1.

2. Each drainage area polygon was then intersected with a GIS coverage of annual total rainfall estimated using the PRISM model for each year of the simulation period. This distribution of annual average rainfall was then used to calculate the total volume of rainfall falling on the small watershed areas, and an overall average rainfall rate was computed (inches per year).

3. The total annual rainfall rate was then used to compute a deep percolation quantity using the relationship between annual rainfall and deep percolation rate developed by Turner (1991) and described above.

4. The annual volume of deep percolation computed in Step three was then converted into monthly values that were based on the monthly distribution of streamflow measured in ungauged sections of Deer Creek. These monthly deep percolation quantities were then introduced at the model domain boundary of each small watershed polygon using injection wells into layer one. The quantity applied to each model boundary node was proportional to boundary length of each element divided by the total boundary length of the drainage polygon.

5. The deep percolation rates for individual drainage basins were adjusted during SACFEM2013 calibration to improve the match between simulated and measured groundwater elevations. Final factors applied to the deep percolation rates range from 0.5 to 1.5.

Urban Pumping. The final set of specified-flux boundary conditions applied in the SACFEM2013 model reflects urban pumping within the model domain. The distribution of agricultural pumping that was developed using the surface water budgeting methodologies described below do not include urban pumping. As a first step to estimate the quantity of urban pumping to apply to the model, the year 2010 U.S. Census data were evaluated. Each municipal area with a population greater than 5,000 that used groundwater as a source of municipal supply was further assessed. For municipalities where urban water management plans were available, the reported annual groundwater use was simulated in SACFEM2013. For cities that do not have a current water management plan, a pumping volume that was based on an annual average per capita value of 271 gallons/capita/day was simulated. Further, municipalities in the northern Sacramento area pumping rates were assigned consistent with the Sacramento County Integrated Groundwater and Surface Water Model (SacIGSM) model.

Urban pumping was assigned spatially to all SACFEM2013 nodes within a given city area and was apportioned equally to model layers two through four. The monthly variability in urban pumping quantity was distributed on the basis of typical seasonal trends for municipal water use.

D.3.4.2 No-flow Boundaries

A no-flow boundary was specified across the bottom boundary of the model, representing the freshwater/brackish water interface.

D.3.5 Surface Water Budget

D.3.5.1 Approach

One of the most critical components to the successful operation of the SACFEM2013 is computation of transient surface water budget components. These water budget components were estimated by using a variety of spatial information including land use, cropping patterns, source of irrigation water, surface water availability in different year types and locations, and the spatial distribution of precipitation. Surface water budget components include deep percolation of applied water, deep percolation of precipitation, and agricultural pumping.

Surface water budgets were developed by intersecting existing GIS data developed by DWR with the groundwater model grid to develop land use for each groundwater model node. Additionally, GIS data on water districts and surrounding areas were used to identify district and non-district areas. The resulting intersection provided land use, water district, and water source information for each of the over 150,000 groundwater model nodes.

D.3.5.2 Methodology

A semi-physically based soil moisture accounting model and historical precipitation data were used to simulate the root zone processes and calculate applied water demand and deep percolation past the root zone for each node. Calculated deep percolation was split between applied water and precipitation depending on the season and the availability of water from each source.

Calculated values for deep percolation were compared to estimated values prepared by DWR’s Northern District for the year 2000. Northern District staff calculated detailed water budgets in 2000, which included some of the best available estimates of regional deep percolation. In some areas, soil parameters in the root zone model were adjusted to provide similar volumes of deep percolation. However, considerable uncertainty still exists in any estimate of regional deep percolation because soil conditions vary widely, and it is not possible to measure deep percolation on a regional basis.

The total demand for applied water was used in conjunction with the water source and water district attributes from the GIS intersection to estimate agricultural groundwater pumping. Some areas are supplied solely from groundwater, and calculated total applied water demand represents groundwater pumping. Other areas are supplied by a mix of groundwater and surface water. For these areas, estimates of the availability of surface water each year were made to determine the fraction of applied water demand met from surface water and groundwater. In these areas, additional information on the overlying water district was combined with district water rights and contracts to estimate available surface water. For example, districts within the Tehama-Colusa Canal Authority have water contracts with the Bureau of Reclamation that receive different allocations each year. An estimate of those allocations from an existing level of development simulation of Central Valley Project operations was used to calculate the availability of surface water for groundwater model elements within those districts. Any remaining applied water demand, after consideration of available surface water, is assumed to be met by groundwater pumping.

D.3.6 Aquifer Properties

The distribution of aquifer properties across the Sacramento Valley is poorly understood. In certain areas with significant levels of groundwater production, the collection of aquifer test data and the measurement of historical groundwater-level trends in response to known groundwater production rates have provided valuable information on aquifer properties. However, in the majority of the valley, these data are not available.

To estimate the spatial distribution of aquifer properties across the model domain for this numerical modeling effort, a database of well productivity information was used. In consultation with DWR staff, a database was obtained that included all of the specific capacity yield data that were available from well log records. These data were compiled along with well construction information for each production well to yield a representative data set of well productivity across the valley. Wells that did not have available construction data were omitted from further consideration. To protect owner privacy, the exact location of each well was modified by DWR staff to reflect the center of the section in which each well was located. This modification in well location did not adversely affect the use of the data to estimate the spatial distribution of aquifer properties, given the extremely large area encompassed by the model domain. Approximately 1,000 wells in the database within the model domain were used in this analysis.

The intent of the modeling analysis described herein is to simulate the effects of the operation of high-productivity irrigation wells screened within the major producing zones in the valley to support conjunctive water management projects. Therefore, the aquifer properties that are of primary interest are those of the major aquifer zones tapped by large-diameter irrigation wells. The well database described above was filtered to remove data obtained from tests on low-yield and shallow, domestic-type wells. All test data from wells that reported a well yield below 100 gallons per minute were eliminated from consideration, as were the test data from wells with a total depth of less than

100 feet. The only exception to this second consideration was for wells that were located along the basin margins – where aquifers are thin – that reported what appeared to be valid test results. Data from these wells were considered because they were often the only data available in the basin margin areas.

After the data set for consideration was finalized, the reported specific capacity data for each well were used to estimate an aquifer transmissivity for that location. The relationship used to estimate aquifer transmissivity was the following form of a simplified version of the Jacob non-equilibrium equation:

$$Sc = T/2000 \quad (8)$$

Where:

Sc = specific capacity of an operating production well (gallons per minute per foot of drawdown)

T = aquifer transmissivity (gallons per day per foot)

After a transmissivity estimate was computed for each location, the transmissivity value was then divided by the screen length of the production well to yield an estimate of the aquifer horizontal hydraulic conductivity (Kh). The final step in the process was to smooth the Kh field to provide regional-scale information. Individual well tests produce aquifer productivity estimates that are local in nature, and might reflect small-scale aquifer heterogeneity that is not necessarily representative of the basin as a whole. To average these smaller scale variations present in the data set, a FORTRAN program was developed that evaluated each independent Kh estimate in terms of the available surrounding estimates. When this program is executed, each Kh value is considered in conjunction with all others present within a user-specified critical radius, and the geometric mean of the available Kh values is calculated. This geometric mean value is then assigned as the representative regional hydraulic conductivity value for that location. The critical radius used in this analysis was 10,000 meters, or about six miles. The point values obtained by this process were then gridded using the kriging algorithm to develop a Kh distribution across the model domain. The aquifer transmissivity at each model node within each model layer was then computed using the geometric mean Kh values at that node times the thickness of the model layer. Insufficient data were available to attempt to subdivide the data set into depth-varying Kh distributions, and it was, therefore, assumed that the computed mean Kh values were representative of the major aquifer units in all model layers. The distribution of K used throughout most of the SACFEM2013 model layers is shown in Figure D-4. During model calibration, minor adjustments were made to the Kh of model layer one east of Dunnigan Hills and in model layers six and seven in the northern Sacramento Valley based on qualitative assessment of Lower Tuscan aquifer test data in this area.

MicroFEM computes vertical flow between adjacent model layers based on the simulated head difference between adjacent model layers and the vertical resistance term. The vertical resistance term in MicroFEM is calculated as follows:

$$V = \frac{\left({b_i}/{Kv_i} + {b_{i+1}}/{Kv_{i+1}} \right)}{2} \qquad (9)$$

Where:

V = Vertical resistance to flow between an upper model layer (i) and adjacent lower model layer (i+1) (days^{-1})

b_i = Saturated thickness of model layer i (meters)

b_{i+1} = Saturated thickness of model layer i+1 (meters)

Kv_i = Vertical hydraulic conductivity of model layer i (m/d)

Kv_{i+1} = Vertical hydraulic conductivity of model layer i+1 (m/d)

The ratio of Kh to vertical hydraulic conductivity (Kv) were assumed to be 500:1 in layers two through seven and 50:1 in layer one at all model nodes except those representing bedrock areas. The Kh:Kv in areas of bedrock outcrop (such as the Sutter Buttes, Black Butte, and Dunnigan Hills) was assumed to be 1:1 in all model layers.

The specific yield of model layer one was assumed to be 12 percent throughout the SACFEM2013 model domain. The aquifer storativity of model layers two through seven is 6.5x10^{-5} multiplied by model layer thickness throughout the majority of the model domain, with variations along small portions of the model boundary.

D.4 References

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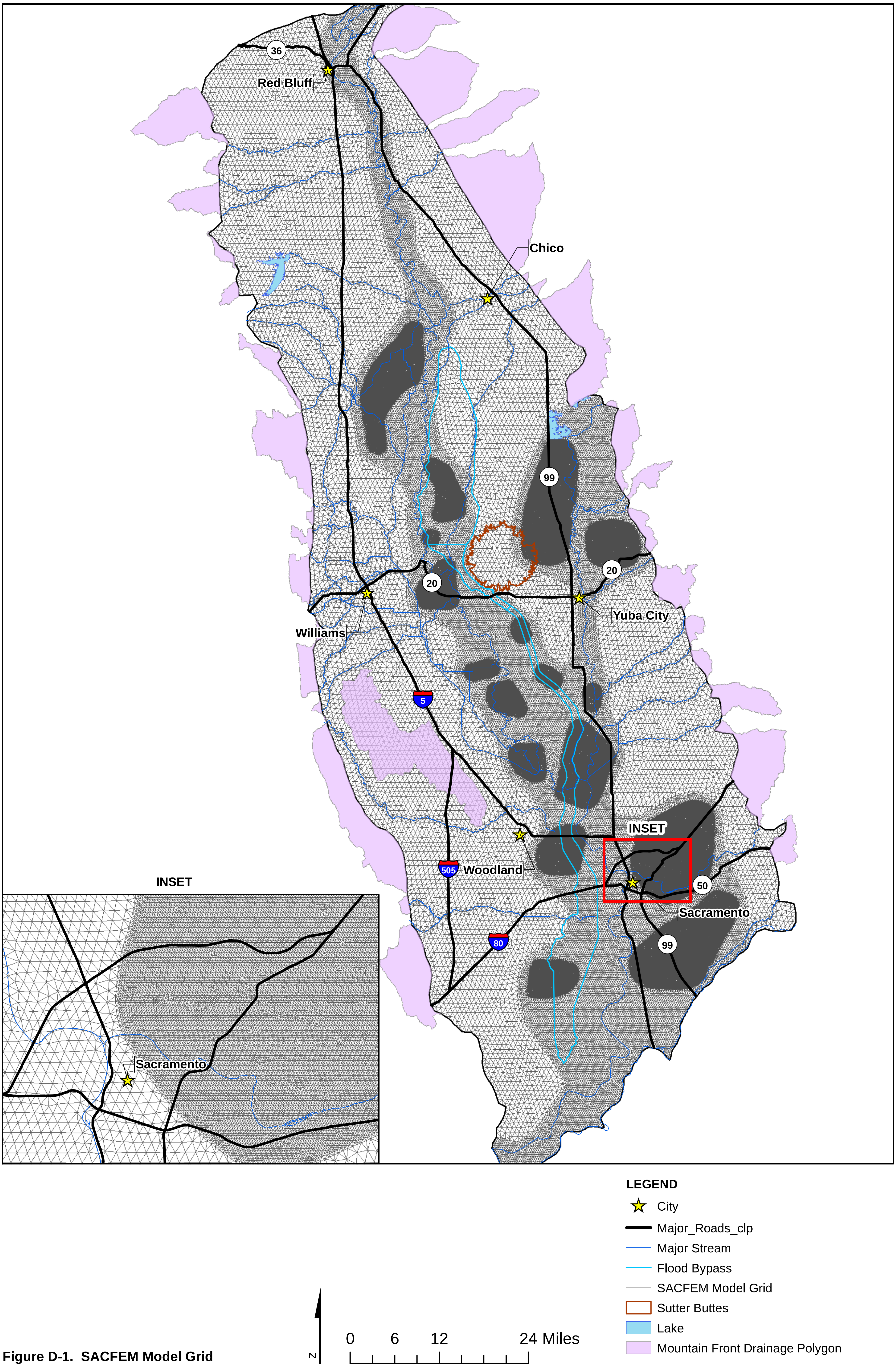

Figure D-1. SACFEM Model Grid

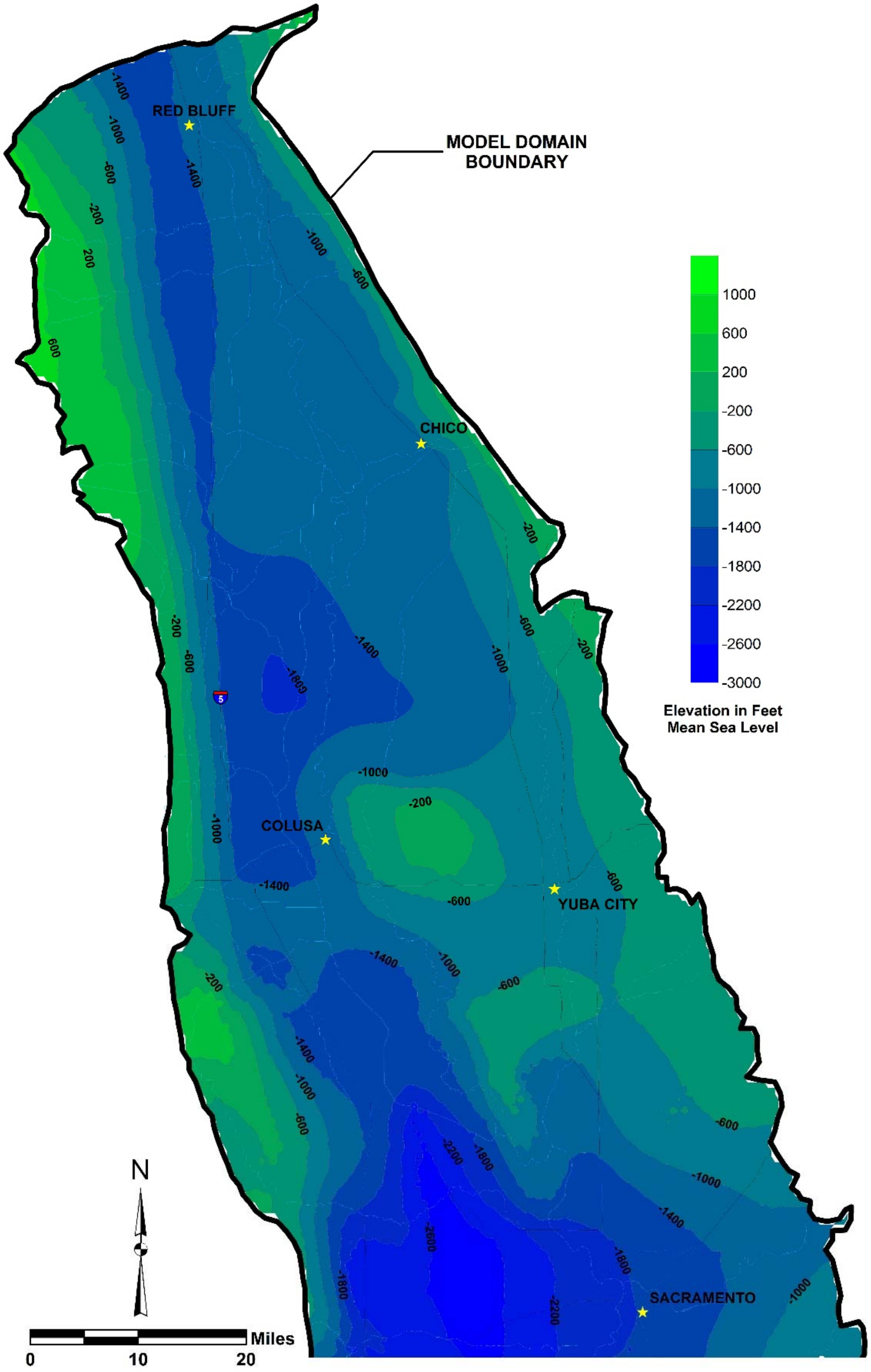

Figure D-2. Elevation of the Base of Fresh Water

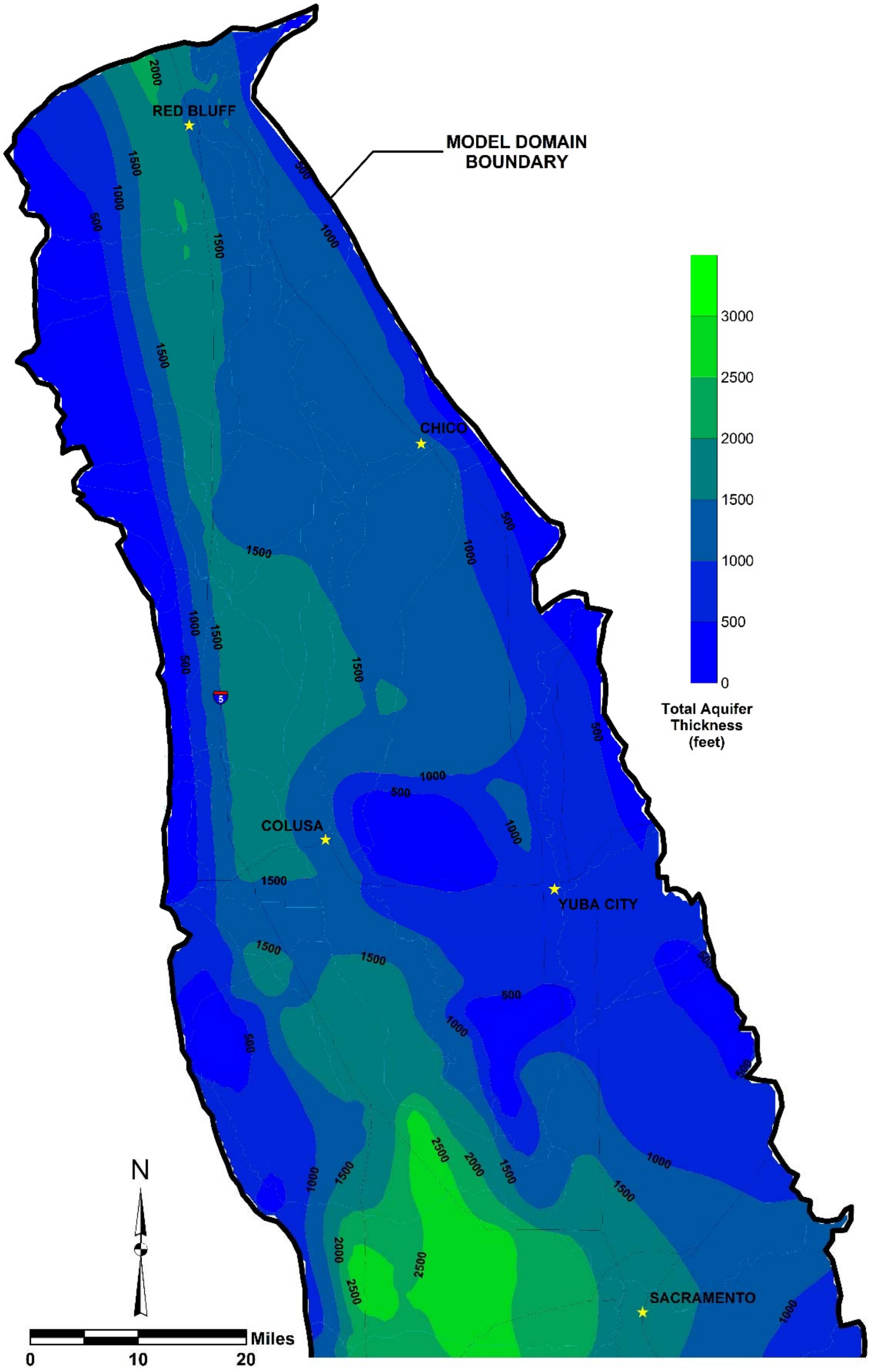

Figure D-3. Total Saturated Aquifer Thickness

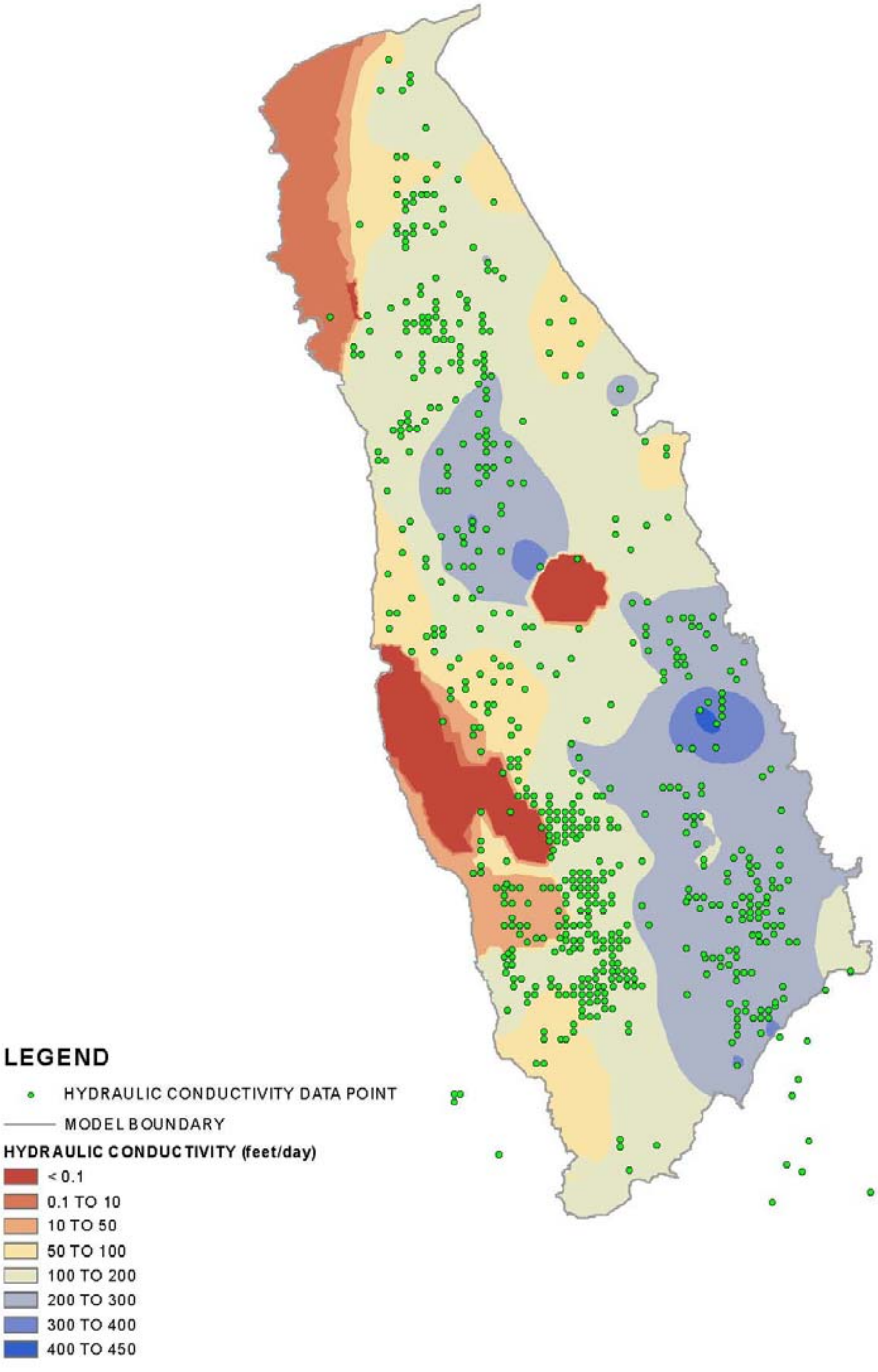

Figure D-4. SACFEM Hydraulic Conductivity Distribution