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APPENDIX 5A, SECTION C
MODELING TECHNICAL APPENDIX –
ONE DIMENSIONAL DELTA
HYDRODYNAMICS AND WATER QUALITY
MODELING RESULTS

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Appendix 5A, Section C**Modeling Technical Appendix – One-Dimensional Delta Hydrodynamics and Water Quality Modeling Results**

C.1 Introduction

The Delta Simulation Model 2 (DSM2) is a river, estuary, and land modeling system. It is a mathematical model for dynamic simulation of one-dimensional hydrodynamics, water quality, and particle tracking in a network of riverine or estuarine channels. DSM2 can calculate stage, flows, velocities, mass transport processes for conservative and non-conservative constituents, including salts, water temperature, and transport of individual particles. Thus, DSM2 provides a powerful simulation package for analysis of complex hydrodynamic, water quality, and ecological conditions in riverine and estuarine systems.

C.2 Delta Hydrodynamics and Water Quality

Hydrodynamics and water quality modeling is essential to understand the impact of proposed modifications to the Delta. Changes to the configuration of the Delta and operations of the Central Valley Project (CVP) and State Water Project (SWP) that may result from the Delta Conveyance Project would influence the tidal hydrodynamics and water quality conditions in the Delta. Analyzing the hydrodynamics and water quality changes in the Delta is critical to understanding impacts on habitat, species, and water users that depend on the Delta. The component of the Delta Conveyance Project that can alter the Delta hydrodynamics is the proposed addition of the north Delta intakes. This section describes in detail the methodology used for simulating Delta hydrodynamics and water quality for evaluating the changes under the Delta Conveyance Project. The section briefly describes the primary analytical tool (DSM2) used in this process and specific improvements to DSM2 undertaken for its application in the Delta Conveyance Project.

C.3 Overview of Hydrodynamics and Water Quality Modeling Approach

The proposed north Delta intakes would affect flow through the Delta and thus change the Delta hydrodynamics and salinity transport. There are several tools available to simulate hydrodynamics and water quality in the Delta. Some tools simulate detailed processes with two or three-dimensional representation, however, they are computationally intensive and have long runtimes. Other tools approximate certain processes and have short runtimes, while only compromising slightly on the accuracy of the results. For a long-term planning level analysis of the Delta Conveyance Project, it is ideal to understand the resulting changes that can occur over the span of many years and as such, the simulation period covers a full range of hydrologic and tidal conditions.

1 A tool that can simulate the changed hydrodynamics and water quality in the Delta more accurately
2 and that has short runtimes is desired.

3 DSM2, a one-dimensional hydrodynamics and water quality model serves this purpose. DSM2
4 currently consists of three modules: HYDRO, QUAL, and PTM. DSM2-HYDRO simulates one-
5 dimensional hydrodynamics including flows, velocities, and water surface elevations. DSM2-HYDRO
6 provides the flow input for DSM2-QUAL and DSM2-PTM. DSM2-QUAL simulates one-dimensional
7 fate and transport of conservative and non-conservative water quality constituents given a flow field
8 simulated by DSM2-HYDRO. DSM2-PTM simulates quasi 3-D transport of neutrally buoyant particles
9 based on the flow field simulated by DSM2-HYDRO. DSM2-PTM has multiple applications ranging
10 from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae.

11 The latest calibrated and validated version of the DSM2 was used to simulate Delta hydrodynamics
12 and water quality using boundary inflows and exports determined by CalSim 3 for existing
13 conditions with and without the proposed Delta Conveyance Project facilities and operations.

14 DSM2 has a limited ability to simulate two-dimensional features, such as open waterbodies
15 (reservoir, flooded islands, tidal marshes, etc.) and three-dimensional transport processes, such as
16 gravitational circulation, which is expected to change with sea level rise in the estuaries. DSM2
17 would need to be recalibrated or corroborated based on a dataset that accurately represents the
18 conditions in the Delta with sea level rise. The best available approach to estimate the Delta
19 hydrodynamics under future sea level rise conditions would be a model simulation of the Delta
20 hydrodynamics with higher dimensional models that can resolve the three-dimensional processes
21 well. Such models would generate the datasets needed to corroborate or recalibrate DSM2 to
22 represent the future conditions so that it can simulate the hydrodynamics and salinity transport
23 with reasonable accuracy.

24 Semi-implicit Cross-scale Hydrosience Integrated System Model (SCHISM), a three-dimensional
25 hydrodynamics and water quality model, was used to simulate the sea level rise effects on
26 hydrodynamics and salinity transport under the historical operations in the Delta (see Appendix 5A
27 Section F). The results from SCHISM were used to corroborate DSM2 so that it can simulate the
28 effect of sea level rise consistent with SCHISM, which can better resolve estuarine processes. For
29 evaluating the future conditions (2040) with and without the project, the corroborated DSM2 was
30 used to simulate hydrodynamics and water quality in the Delta by integrating sea level rise effects
31 over a 93-year period (water year 1923–2015), using the boundary inflows and exports determined
32 by CalSim 3 under the projected operations with and without the Delta Conveyance Project facilities.

33 DSM2 was also used to retrain Artificial Neural Networks (ANNs) that can emulate flow-salinity
34 relationships in the Delta for use in CalSim 3 model as described below in Section C.6.3.

35 **C.4 Delta Simulation Model II (DSM2)**

36 DSM2 is a one-dimensional hydrodynamics, water quality and particle tracking simulation model
37 used to simulate hydrodynamics, water quality, and particle tracking in the Delta (Anderson and
38 Mierzwa 2002). DSM2 is appropriate for describing the existing conditions in the Delta, as well as
39 performing simulations for the assessment of incremental environmental impacts caused by future
40 facilities and operations.

DSM2 hydrodynamics and salinity (electrical conductivity [EC]) were initially calibrated in 1997 (California Department of Water Resources 1997). In 2000, a group of agencies, water users, and stakeholders recalibrated and validated DSM2 in an open process, resulting in a model that could replicate the observed data more closely than the 1997 version (DSM2PWT 2001). In 2009, CH2M HILL performed a calibration and validation of DSM2 by including the flooded Liberty Island in the DSM2 grid, which allowed for an improved simulation of tidal hydrodynamics and EC transport in DSM2 (CH2M HILL 2009). In 2013, the California Department of Water Resources (DWR) released DSM2 version 8.1.2, which includes major changes such as updated bathymetric reference to NAVD 88¹ and modified representation of dispersion in DSM2-QUAL. DWR also recalibrated DSM2 given the magnitude of changes in version 8.1.2, and found that the performance of the model in simulating observed hydrodynamics and salinity conditions was very close to the 2009 calibration (Liu and Sandhu 2013). Most recently, DWR released DSM2 v8.2.0 (California Department of Water Resources 2021a) that differs from v8.1.2 mainly in the way the consumptive use and net channel depletion are estimated for the legal Delta. Specifically, v8.1.2 uses the Delta Island Consumptive Use (DICU) model, while v8.2.0 employs the Delta Channel Depletion (DCD) model in deriving Delta channel depletion as well as consumptive use. DICU is a monthly model that divides the Delta into 142 subareas and simulates the water entering, leaving, or being stored in each of these subareas. In comparison, DCD has finer temporal and spatial resolutions that provide simulations on daily scale for 168 subareas in the Delta. DCD also incorporates a number of enhancements including updated parameterization and the addition of physical processes related to Delta channel depletions (Liang and Suits 2017, 2018). In light of this difference, DSM2 v8.2.0 hydrodynamics and EC were calibrated and validated using observed data up to 2017 (California Department of Water Resources 2021a).

Simulation of Dissolved Organic Carbon (DOC) transport in DSM2 was validated in 2001 by DWR (Pandey 2001). The temperature and dissolved oxygen calibration was initially performed in 2003 by DWR (Rajbhandari 2003). In 2010, Resources Management Associates (RMA) further improved the calibration of temperature, dissolved oxygen, and the nutrients transport in DSM2 (Guerin 2010, 2011). Most recently, RMA's water temperature calibration was fine-tuned in that adjustment of wind speed as a fitting parameter is replaced by adjustment of an evaporation coefficient for calibration. The fine-tuning generally leads to improved water temperature simulation (California Department of Water Resources 2021b).

The calibrated DSM2 v8.2.0 (California Department of Water Resources 2021a) was used in modeling the hydrodynamics and salinity transport in the Delta under the proposed project and various project alternatives, including the existing condition and No Project Alternative (2040).

C.4.1 Delta Hydrodynamics (DSM2-HYDRO)

The DSM2-HYDRO module is a one-dimensional, implicit, unsteady, open channel flow model that DWR developed from FOURPT, a four-point finite difference model originally developed by the U.S. Geological Survey (USGS) in Reston, Virginia. DWR adapted the model to the Delta by revising the input-output system, including open water elements, and incorporating water project facilities, such as gates, barriers, and the Clifton Court Forebay. DSM2-HYDRO simulates water surface elevations, velocities, and flows in Delta channels (Nader-Tehrani 1998). DSM2-HYDRO provides the flow input necessary for DSM2-QUAL and DSM2-PTM modules.

¹ North American Vertical Datum of 1988.

The DSM2-HYDRO module solves the continuity and momentum equations fully implicitly. These partial differential equations are solved using a finite difference scheme requiring four points of computation. The equations are integrated in time and space, which leads to a solution of stage and flow at the computational points. DSM2-HYDRO enforces an equal stage boundary condition for all the channels connected to a junction. The model can handle both irregular cross-sections derived from the bathymetric surveys and trapezoidal cross-sections. Though the model formulation includes a baroclinic term, the density is held constant, generally, in the DSM2-HYDRO simulations.

DSM2-HYDRO allows the simulation of hydraulic gates in the channels. A gate may have a number of associated hydraulic structures, such as radial gates, flash boards, and boat ramps, each of which may be operated independently to control flow. Gates can be placed either at the upstream or downstream end of a channel. Once the location of a gate is defined, the boundary condition for the gated channel is modified from equal stage to known flow, with the calculated flow. The gates can be opened or closed in one or both directions by specifying a coefficient of zero or one.

Reservoirs are used to represent open bodies of water that store flow. These reservoirs in the Delta are represented by cylindrical tanks in DSM2, with a known surface area and bottom elevation and are considered instantly well-mixed. The flow interaction between the open water area and one or more of the connecting channels is determined using the general orifice formula. The flow in and out of the reservoir is controlled using the flow coefficient in the orifice equation, which can be different in each direction. DSM2 does not allow the cross-sectional area of the inlet to vary with the water level.

DSM2 version 8.0.6 and later versions include a feature called *operating rules*, by which the gate operations or the flow boundaries can be modified dynamically when the model is running based on the current value of a state variable (flow, stage, or velocity). The change can also be triggered based on a timeseries input to the model (e.g., daily averaged Martinez EC) or based on the current timestep of the simulation (e.g., a change can occur at the end of the day or end of the season). The operating rules include many functions which allow derivation of the quantities to be used as triggers, from the model data or outside timeseries data. Operating rules allow a change or an action to occur when the trigger value changes from false to true.

C.4.2 Delta Water Quality (DSM2-QUAL)

The DSM2-QUAL module is a one-dimensional water quality transport model that DWR adapted from the Branched Lagrangian Transport Model originally developed by USGS in Reston, Virginia. DWR added many enhancements to the DSM2-QUAL module, such as open water areas and gates. A Lagrangian feature in the formulation eliminates the numerical dispersion that is inherent in other segmented formulations, although the tidal dispersion coefficients must still be specified. DSM2-QUAL simulates fate and transport of conservative and non-conservative water quality constituents given a flow field simulated by DSM2-HYDRO. It can calculate mass transport processes for salts, water temperature, nutrients, dissolved oxygen, and trihalomethane formation potential.

The main processes contributing to the fate and transport of the constituents include flow dependent advection and tidal dispersion in the longitudinal direction. Mass balance equations are solved for all quality constituents in each parcel of water using the tidal flows and volumes calculated by the DSM2-HYDRO module. Additional information and the equations used are specified in the 19th annual progress report by DWR (Rajbhandari 1998).

Salinity is the primary conservative constituent simulated using the DSM2-QUAL model. EC is used as a surrogate for salinity in DSM2 given the availability of observed data across the Delta (DSM2PWT 2001). As noted above, DSM2-QUAL version 8.2.0 was recently calibrated for simulating salinity conditions in the Delta (California Department of Water Resources 2021a). DSM2-QUAL was corroborated based on the higher order SCHISM to account for sea level rise effects on Delta salinity conditions as described in Section C.6.2, *Incorporating Sea Level Rise Effects in DSM2 Planning Simulations*.

C.4.3 Delta Particle Tracking Module (DSM2-PTM)

DSM2-PTM simulates quasi-three-dimensional transport of neutrally buoyant particles based on the flows simulated by DSM2-HYDRO. The DSM2-PTM module simulates the transport and fate of individual particles traveling throughout the Delta. The model uses geometry files, velocity, flow, and stage output from the DSM2-HYDRO module to monitor the location of each individual particle using assumed vertical and lateral velocity profiles and specified random movement to simulate mixing. The location of a particle in a channel is determined as the distance from the downstream end of the channel segment (x), the distance from the centerline of the channel (y), and the distance above the channel bottom (z). DSM2-PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae.

The longitudinal distance traveled by a particle is determined from a combination of the lateral and vertical velocity profiles in each channel. The transverse velocity profile simulates the effects of channel shear that occurs along the sides of a channel. The result is varying velocities across the width of the channel. The average cross-sectional velocity is multiplied by a factor based on the particle's transverse location in the channel. The model uses a fourth order polynomial to represent the velocity profile. The vertical velocity profile shows that particles located near the bottom of the channel move more slowly than particles located near the surface. The model uses the Von Karman logarithmic profile to create the velocity profile. Particles also move because of random mixing. The mixing rates (i.e., distances) are a function of the water depth and the velocity in the channel. High velocities and deeper water result in greater mixing.

At a junction the path of a particle is determined randomly based on the proportion of flow. The proportion of flow determines the probability of movement into each reach. A random number based on this determined probability then determines where the particle will go. A particle that moves into an open water area, such as a reservoir, no longer retains its position information. A DSM2 open water area is considered a fully mixed reactor. The path out of the open water area is a decision based on the volume in the open water area, the timestep, and the flow out of the area. At the beginning of a timestep, the volume of the open water area and the volume of water leaving at each opening of the open water area are determined. From that, the probability of the particle leaving the open water area is calculated. Particles entering exports or agricultural diversions are considered lost from the system. Their final destination is recorded. Once particles pass the Martinez boundary, they have no opportunity to return to the Delta (Smith 1998; Wilbur 2001; Miller 2002).

C.4.4 Finger Printing Analysis

The DSM2-QUAL module was also used to simulate source water finger printing, which can determine the relative contributions of water sources to the volume at any specified location. It is also used to simulate constituent finger printing, which determines the relative contributions of

conservative constituent sources to the concentration at any specified location. For fingerprinting studies, six main sources are typically tracked: the Sacramento River, San Joaquin River, Martinez, eastside streams (Mokelumne, Cosumnes, and Calaveras combined), agricultural drains (all combined), and the Yolo Bypass. For source water fingerprinting, a tracer with constant concentration is assumed for each inflow source tracked, while keeping the concentrations at other inflows as zero. For constituent (e.g., EC) finger printing analysis, the concentrations of the desired constituent are specified at each tracked source, while keeping the concentrations at other inflows to zero (Anderson 2003). Results provide, for each timestep, the percent distribution of either water or constituent concentration at any given location in the Delta from each of the six potential sources.

C.4.5 Delta Water Temperature

DSM2-QUAL v8.2.0 was used to simulate water temperatures in the Delta. The module uses the dynamic flow field obtained from the DSM2-HYDRO to perform the advective and dispersive steps of mass transport including net transfer of energy at the air-water interface to simulate the changes in water temperature in the Delta.

Heat exchanges through the air-water interface depend upon both the internal hydromechanical behavior of the waterbody and the physics of its interaction with the overlying air mass. Meteorological factors, such as solar radiation, wind, humidity, atmospheric pressure, and cloudiness figure prominently in the physical processes involved. The principal sources of heat are shortwave solar radiation, longwave atmospheric radiation, and conduction of heat from air to water. The principal sinks of heat are water surface back radiation, evaporation, and conduction from water to atmosphere. These components of heat transfer are coded in DSM2-QUAL to compute the spatial and temporal changes in water temperature in the Delta. Additional information on water temperature model calibration is documented in Rajbhandari (2004) and RMA (2011, 2015a).

DSM2 (v8.2.0) uses the DCD model (See Section 4.8, *DCD (Delta Channel Depletion Model)*) for the estimation of consumptive use in the Delta, replacing the DICU model used in earlier versions of DSM2. Water temperature corresponding to the agricultural drains is specified as timeseries data that vary by months but are repeated annually. However, the flows vary by year type and do not repeat annually. Assumptions on water temperature at these inflow locations are the same as those used in the California WaterFix studies (ICF 2016).

The memorandum (California Department of Water Resources 2021b) included with the v8.2.0 release documents describes minor updates in v8.2.0 water temperature modeling in relation to the earlier version of the model (v8.1.2) used in Bay Delta Conservation Plan (BDCP) studies (Resources Management Associates 2015b). The memorandum describes an adjustment on water temperature calibration. Based on the comparison of simulated water temperature at a few channels in the Delta, DSM2 v8.2.0 performed at least as well as DSM2 v8.1.2 in predicting the observed field data. The difference in model performance may be attributed to the updated calibration of DSM2 hydrodynamics and water quality resulting in changes in Manning's roughness coefficients, dispersion coefficients, and the use of the DCD model in v8.2.0. Additional changes in v8.2.0 are provided in the memorandum documenting limited recalibration of DSM2 with the purpose of ensuring that the model can be used for evaluating Delta Conveyance Project scenarios (California Department of Water Resources 2021c).

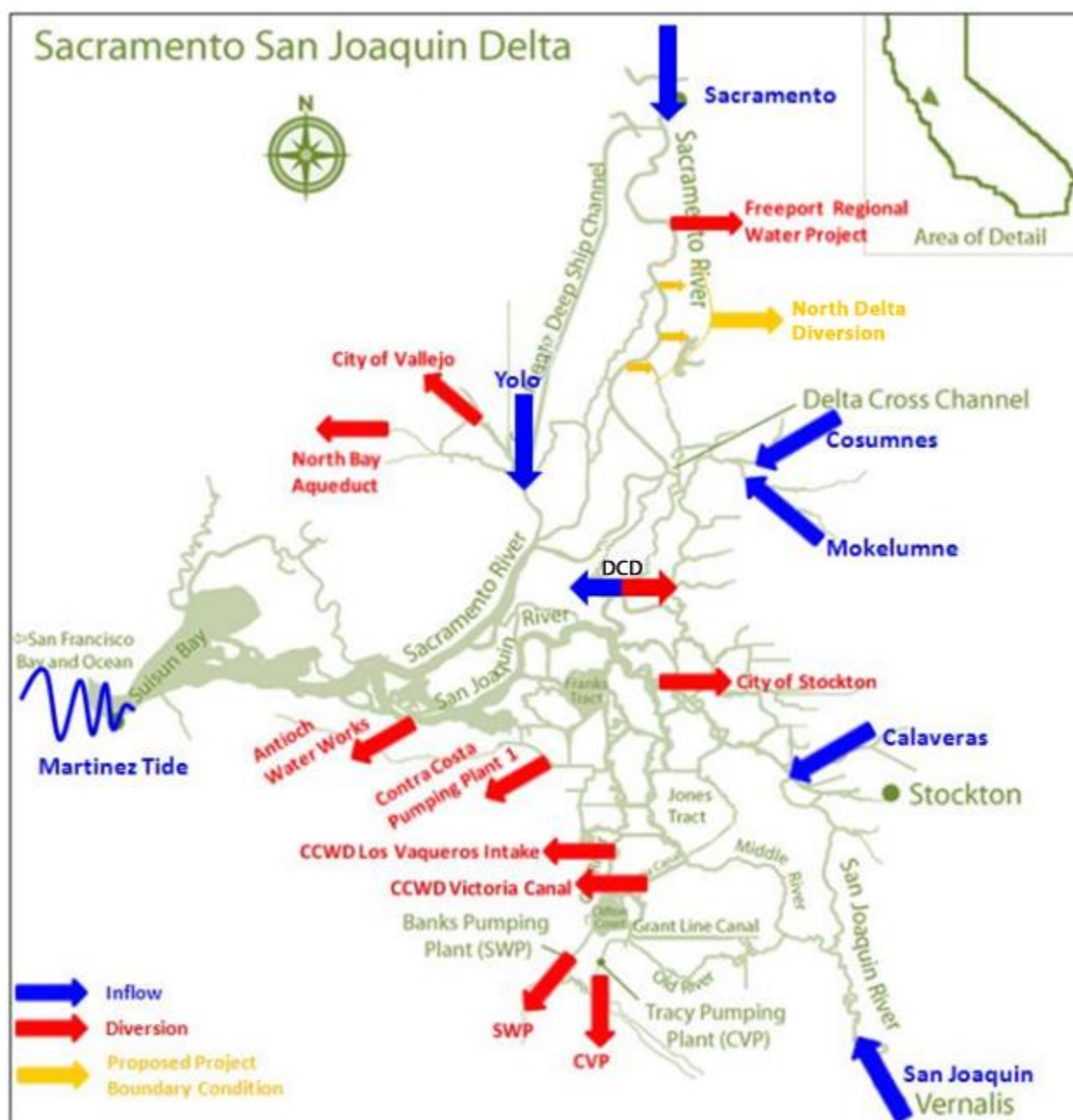
Input data requirements for Delta water temperature modeling and the methods used to derive some of these data are described in the document *DSM2 Water Temperature Model Input Extension*

(California Department of Water Resources 2021d). The method for development of boundary effluent data is based on information provided in Attachment 4, *DSM2 Temperature Modeling* (ICF 2016) that made use of the effluent inflow data from the wastewater treatment plants for the years 2000 through 2005. A few changes were made to these data including the use of simulated effluent data from CalSim 3.

A significant change from the earlier work described in BDCP and WaterFix studies is in the development of meteorological input data and water temperature boundary data. Meteorological boundary conditions for DSM2 include dry-bulb temperature, wet-bulb temperature, atmospheric pressure, wind speed, and cloud cover. These data are needed for DSM2 to simulate Delta-wide water temperature for the years 1922 through 2015. The meteorological processor MetSim was modified to develop the meteorological variables based on research datasets with long records. ANNs were developed to generate water temperature at the Sacramento River and San Joaquin River as inflow boundaries and at Martinez as the tidal boundary. The details, including comparison of MetSim and ANN results with field data, are provided in the document *DSM2 Water Temperature Model Input Extension* (California Department of Water Resources 2021d). These methods can be adapted to generate input data for DSM2 water temperature modeling under different climate scenarios.

C.4.6 DSM2 Input Requirements

DSM2 requires input assumptions relating to the physical description of the system (e.g., Delta channel, marsh, and island configuration); descriptions of flow control structures such as gates, initial estimates for stage, flow, and EC throughout the Delta; and time-varying input for all boundary river flows, diversions, and exports, tidal boundary conditions, gate operations, and constituent concentrations at each inflow. Figure 5A-C.1 illustrates the hydrodynamic and water quality boundary conditions required in DSM2. For long-term planning simulations, output from CalSim 3 generally provides the necessary input for the river flows, municipal diversions, and exports.



Note: A text description of this figure is provided in Chapter 39, *Description of Figures*.

Figure 5A-C.1. Hydrodynamic and Water Quality Boundary Conditions in DSM2

Assumptions relating to Delta configuration and gate operations are directly input into the hydrodynamic models. Adjusted astronomical tide (Ateljevich 2001a) normalized for sea level rise (Ateljevich and Yu 2007) is assigned at the Martinez boundary. Constituent concentrations are specified at the inflow boundaries, which are either estimated from historical information or CalSim 3 results. EC boundary condition for the San Joaquin River at the Vernalis location is derived from the CalSim 3 results. Martinez EC boundary condition is derived based on the simulated net Delta outflow from CalSim 3 and using a modified G-model (Ateljevich 2001b). For other northern boundary freshwater inflows, constant low EC values are assumed based on historical salinity data.

The major hydrodynamic boundary conditions are listed in Table 5A-C.1, and the locations at which constituent concentrations are specified for the water quality model are listed in Table 5A-C.2.

Table 5A-C.1. DSM2-HYDRO Boundary Conditions

Boundary Condition	Location/Control Structure	Typical Temporal Resolution
Tide	Martinez	15 minute
Delta Inflows	Sacramento River at Freeport	1 day
	San Joaquin River at Vernalis	1 day
	Eastside streams (Mokelumne and Cosumnes Rivers)	1 month
	Calaveras River	1 month
	Yolo Bypass	1 month
Delta Exports/Diversions	Banks Pumping Plant (SWP)	1 month
	Jones Pumping Plant (CVP)	1 month
	Contra Costa Water District Diversions at Rock Slough, Old River at Highway 4 and Victoria Canal	1 month
	North Bay Aqueduct	1 month
	City of Vallejo	1 month
	Antioch Water Works	1 month
	Freeport Regional Water Project	1 month
	City of Stockton	1 month
	Isolated Facility Diversion	1 month
Delta Channel Depletion	Diversion	1 month
	Seepage	1 month
	Drainage	1 month
Gate Operations	Delta Cross Channel	Irregular Timeseries
	South Delta Temporary Barriers	Dynamically operated on 15 minute
	Montezuma Salinity Control Gate	1 month

Table 5A-C.2. DSM2-QUAL Boundary Conditions Typically used in a Salinity Simulation

Boundary Condition	Location/Control Structure ^a	Typical Temporal Resolution
Ocean Salinity	Martinez	15 minute
Delta Inflows	Sacramento River at Freeport	Constant
	San Joaquin River at Vernalis	1 day
	Streams Mokelumne and Cosumnes	Constant
	Calaveras River	Constant
	Yolo Bypass	Constant
Delta Channel Depletion	Drainage	1 month (pattern repeated each year)

^a For other water quality constituents, concentrations are required at the same locations.

For DSM2 temperature simulations additional source flows are included to account for the effluent discharges from the wastewater treatment plants located in the Delta. Temperature modeling also requires meteorological inputs.

C.4.7 Model Calibration

DSM2 calibrations are typically performed when there are sufficient changes to the model grid due to changes in the physical system or when there are sufficient improvements in the availability of bathymetry and/or observed hydrodynamics and water quality data to justify a calibration. DSM2 hydrodynamics and EC were initially calibrated in 1997 (California Department of Water Resources 1997). DSM2 was recalibrated by multiple agencies in 2000, and by CH2M Hill in 2009 (CH2M Hill 2009). The CH2M Hill recalibration extended the upstream Sacramento River boundary by 40,000 feet, added a reservoir to represent the flooding of Liberty Island, and moved nodes to the locations of proposed north Delta intakes as agreed upon in the January 29th, 2010, BDCP Steering Committee meeting. DWR performed a ‘mini’ calibration in 2012 (California Department of Water Resources 2012).

In the 2009 CH2M Hill calibration (CH2M Hill 2009), monitoring data up to 2008 were used. Since then, new flow, stage, and salinity measurements have become available. These new data collectively provide a better depiction of the current hydrodynamic and water quality conditions in the Delta. Also, the DCD model has been extended to the Suisun Marsh for the purpose of the proposed operation of the Suisun Marsh Salinity Control Gates (SMSCG) (California Department of Water Resources 2021a).

The DWR Calibration Memo (California Department of Water Resources 2021a) compares calibration results for DSM2 v8.2.0 vs DSM2 v8.1.2, using several calibration metrics. The flow, stage, and EC simulations from the calibrated DSM2 v8.2.0 were mostly similar to those of the previously calibrated DSM2 v8.1.2 but in better agreement with observed data in most cases. Particularly, DSM2 v8.2.0 led to a tighter fit with the observed EC data during the validation period at most key locations (California Department of Water Resources 2021a).

C.4.8 Delta Channel Depletion Model (DCD)

Most recently, the Delta Evapotranspiration of Applied Water (DETAW) v2.0 (Liang and Suits 2017) and the DCD model v1.0 (Liang and Suits 2018) were developed to better estimate daily Delta evapotranspiration (ET) and channel depletion, respectively. These two models, when combined (termed DETAW-DCD), were calibrated concurrent with DSM2 in order to improve simulated historical patterns in salinity intrusion.

In 2020, CalSim 3 and SCHISM were tested using DETAW v2.0- and DCD v1.0-simulated channel depletions as model inputs. The results indicate that linking the models can improve the overall performance. But a seamless linkage requires streamlining the data transfer between the models, the original reason for updating DETAW v2.0 and DCD v1.0. In addition, the development platform of DETAW-DCD was upgraded from Python 2.0+ to Python 3.0, and the Python reader for the Hydrologic Engineering Center Data Storage System (PyHecdss) was adopted as the data processing tool to read and write timeseries, thus reducing DETAW-DCD’s run time by more than 80%.

Concurrent with these efforts, the modeling strategy for the Delta Conveyance Project requires DSM2, SCHISM, and CalSim 3 to use the same Delta channel depletions. In order to best represent

Delta conditions under the Delta Conveyance Project, DETAW v2.1 and DCD v1.1 have been modified to align with CalSim 3 and SCHISM; however, because the recalibration of DETAW-DCD-SMCD-DSM2 (SMCD, includes additional estimates for the channel depletions for the Suisun Marsh area) indicated the leaching assumption in DCD v1.0 had to be adjusted, DETAW v2.2-DCD v1.2 was updated. The new version ensures that DSM2, CalSim 3, and SCHISM receive consistent Delta channel depletion estimates.

C.4.9 Model Limitations

DSM2 is a one-dimensional model with inherent limitations in simulating hydrodynamic and transport processes in a complex estuarine environment such as the Delta. DSM2 assumes that velocity in a channel can be adequately represented by a single average velocity over the channel cross-section, meaning that variations both across the width of the channel and vertically through the water column are negligible. DSM2 does not have the ability to model short-circuiting of flow through a reach, where a majority of the flow in a cross-section is confined to a small portion of the cross-section. DSM2 does not conserve momentum at the channel junctions and does not model the secondary currents in a channel. DSM2 also does not explicitly account for dispersion due to flow accelerating through channel bends. It cannot model the vertical salinity stratification in the channels.

DSM2 has inherent limitations in simulating the hydrodynamics related to the open water areas. For open waterbodies, DSM2 assumes uniform and instantaneous mixing over the entire open water area. Thus, it does not account for any salinity gradients that may exist within the open waterbodies. Significant uncertainty exists in flow and EC input data related to in-Delta agriculture, which leads to uncertainty in the simulated EC values. Caution needs to be exercised using model output in areas in the Delta where the in-Delta agriculture has a substantial effect on water quality. Currently DSM2-QUAL allows for a single meteorological region for the entire model domain in water temperature modeling. This can cause some loss in accuracy (1–2 degree Celsius, approximately) in the simulation of water temperature in some DSM2 regions during the time spans when the meteorological conditions, especially wind velocities, vary significantly across those regions. However, modifications were made during the model calibration process to account for the regional variability and minimize any such loss in accuracy (Resources Management Associates 2011, 2015a; California Department of Water Resources 2021b).

C.5 DSM2 Modeling Assumptions

C.5.1 River Flows

For all DSM2 simulations, the river flows at the DSM2 boundaries are based on the monthly flow timeseries from CalSim 3.

C.5.2 Tidal Boundary

For all 2020 studies, the tidal boundary condition at Martinez is based on an adjusted astronomical tide normalized for sea level rise (Ateljevich and Yu 2007). For all the future 2040 studies, Martinez tide estimates for 2020 were adjusted by 1.8 feet (55 centimeters) to represent sea level rise (see Section C.6.2, *Incorporating Sea Level Rise Effects in DSM2 Planning Simulations*).

C.5.3 Water Quality

C.5.3.1 Martinez Electrical Conductivity

For all studies representing the 2020 level of development, the Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001). For the 2040 studies, Martinez EC is modified to account for the salinity changes related to the sea level rise using the regression equation derived based on the three-dimensional (SCHISM) modeling of the Bay-Delta under the future conditions with 1.8 feet sea level rise at year 2040 (see Section C.6.2, *Incorporating Sea Level Rise Effects in DSM2 Planning Simulations*).

C.5.3.2 Vernalis Electrical Conductivity

For all DSM2 simulations, the Vernalis EC boundary condition is based on the monthly San Joaquin River EC timeseries provided by CalSim 3.

C.5.4 Facilities

C.5.4.1 Delta Cross Channel Gates

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the gates are open is based on the monthly timeseries from CalSim 3.

C.5.4.2 South Delta Temporary Barriers

The three agricultural temporary barriers located on Old River, Middle River, and Grant Line Canal are included in the model. The temporary fish barrier located at the Head of Old River is not included in any of the scenarios modeled.

C.5.4.3 Clifton Court Forebay Gates

Clifton Court Forebay gates are operated based on the Priority 3 operation, where the gate operations are synchronized with the incoming tide to minimize the impacts to low water levels in nearby channels.

C.5.5 Operations Criteria

C.5.5.1 Montezuma Salinity Control Gate Structure

The radial gates in the Montezuma Slough Salinity Control Gate Structure are assumed to be tidally operating based on a monthly schedule as provided by CalSim 3 to minimize the sea water intrusion in the Suisun Marsh area.

C.5.5.2 North Delta Intakes

DSM2 nodes 336, 337, and 338 are used as the representation of the three possible north Delta intakes A, B, C. Operation of the individual intakes are handled through the use of operating rules

1 within DSM2. More information about the operation of the proposed Delta Conveyance Project
2 intakes is included in Section C.6.4, *North Delta Intakes Operation*.

3 **C.6 Application of DSM2 to Evaluate Delta** 4 **Conveyance Project**

5 Several long-term planning analyses have used DSM2 to evaluate Delta hydrodynamics and water
6 quality. For the Delta Conveyance Project, DSM2 was run for a 94-year period from water year 1922
7 to water year 2015, on a 15-minute timestep. The inputs needed for DSM2, inflows, exports, and
8 Delta Cross Channel gate operations, were provided by the 94-year CalSim 3 simulations. The tidal
9 boundary condition at Martinez was provided by an adjusted astronomical tide (Ateljevich and Yu
10 2007).

11 Monthly Delta channel depletions (i.e., diversions, seepage, and drainage) were estimated using
12 DWR's DCD model. CalSim 3 provides monthly inflows and exports in the Delta. Monthly flows for
13 the Sacramento and San Joaquin River inflows are disaggregated to a daily timestep for use in DSM2
14 by applying rational histosplines. The splines allow a smooth transition between the months. The
15 smoothing reduces sharp transitions at the start of the month, but still results in constant flows for
16 most of the month. Other inflows, exports and diversions were assumed to be constant over the
17 month. Delta Cross Channel gate operation input in DSM2 is based on CalSim 3 output. For each
18 month, DSM2 assumes the gates are open for the number of the days open simulated in CalSim 3,
19 starting from the beginning of the month. Similarly, Montezuma Slough Salinity Control Gate
20 Structure operations are directly read from CalSim 3 output. When operated, the opening and
21 closing times for Montezuma Slough Salinity Gate Structure is determined dynamically by DSM2
22 based on specific operating rules described in terms of stage differential and river velocity in the
23 area.

24 For salinity, EC at Martinez is estimated using the G-model on a 15-minute timestep, based on the
25 Delta outflow simulated in CalSim 3 and the pure astronomical tide at Martinez (Ateljevich 2001a).
26 The monthly averaged EC for the San Joaquin River at Vernalis estimated in CalSim 3 for the 94-year
27 period is used in DSM2. For other river flows, which have low salinity, constant values are assumed.
28 For the Sacramento River and Yolo Bypass boundary inflows, a constant EC of 175 microsiemens per
29 centimeter ($\mu\text{mhos}/\text{cm}$) was used. For the eastside streams, a constant EC of 150 $\mu\text{mhos}/\text{cm}$ was
30 used. Monthly average timeseries of the EC values associated with Delta agricultural drainage and
31 return flows was estimated for three regions in the Delta based on observed data identifying the
32 seasonal trend. These values are repeated for each year of the simulation.

33 **C.6.1 Changes to the DSM2 Grid**

34 DSM2 nodes 336, 337 and 338 were used to represent the location of the three Delta Conveyance
35 Project intakes (representing intakes 2, 3 and 5) as appropriate. Node 336 was relocated to
36 geographically coincide with the updated location of intake 2. As a result, the length of the
37 connecting DSM2 channels 415 and 416 were modified to reflect this change, however, the
38 combined total length of the DSM2 channels 415 and 416 remained the same. The cross-sections
39 defined for these channels were also modified in order to be consistent with the changes in the
40 channel lengths.

Four new restoration areas were added to the DSM2 grid. These include Yolo Flyway, Tule Red, Decker Island, and Lindsey Slough. The first three restoration areas mentioned are represented as open bodies of water similar to all other reservoirs. Results from the 2009 through 2010 historical simulation using SCHISM (with the hypothetical inclusion of the new restoration areas) were used to assist in the selection of reasonable values for the reservoir flow coefficients for the new restoration areas. The magnitude of the DSM2 reservoir flow coefficients were adjusted to give the best overall comparison of the flow exchange in/out of the new restoration areas between the two models.

A separate sensitivity test was conducted to determine whether the addition of the new restoration areas affect the flow salinity relationship at key locations in the Delta. Two sets of DSM2 runs were conducted (with and without the restoration areas) based on the 2000 through 2015 historical flows. The sensitivity test showed only a very small change in salinity predictions at key locations in the Delta (maximum difference in daily average EC of 92 $\mu\text{mhos/cm}$ at Collinsville, 105 $\mu\text{mhos/cm}$ at Emmaton, 17 $\mu\text{mhos/cm}$ at Rio Vista, 31 $\mu\text{mhos/cm}$ at Jersey Point, and 7 $\mu\text{mhos/cm}$ at Old River at Rock Slough in the entire 15 years of simulation). The actual changes in salinity were typically well below these values. The sensitivity test confirmed that no new recalibration is needed because of the addition of the new restoration areas.

C.6.2 Incorporating Sea Level Rise Effects in DSM2 Planning Simulations

A sea level rise of 55 centimeters (1.8 feet) at the Golden Gate Bridge was assumed at year 2040 for the analysis of future conditions under project alternatives. The hydrodynamics and salinity changes in the Delta due to sea level rise were determined from the SCHISM three-dimensional Bay-Delta model simulations based on 2009 through 2010 historical hydrology. SCHISM results for changes of stage at Martinez were dominated by a scalar shift of about 1.8 feet. SCHISM results also indicated that there would be a very small phase shift (2 to 3 minutes) with the assumed sea level rise, with the tides arriving slightly earlier due to faster propagation in deeper water. Given that the magnitude of the phase shift is very small relative to the DSM2 timestep, it was assumed that 1.8 feet sea level rise would lead to 1.8 feet incremental change at Martinez with no phase shift. A regression equation was developed to estimate the incremental change in EC at Martinez due to the assumed sea level rise as shown below:

$$\text{Change in EC at Martinez (for 1.8 ft sea level rise)} = -0.0297 * \text{filtered_ec (for no sea level rise)} - 89.91 * \text{tidal_energy} + 2494.$$

where the filter used is the cosine lanczos squared filter and the tidal energy measure is defined as the cosine lanczos of the residual tide squared (tide minus filtered tide squared).

DSM2 model results were corroborated for the assumed sea level rise using SCHISM results. DSM2 results indicated a stronger salinity response mostly along the San Joaquin River. In order to obtain a better corroboration between the two models, changes were introduced in the dispersion coefficients in some DSM2 channels. These changes were mostly along the San Joaquin River, to ensure that the incremental changes in salinity at key locations in the Delta due to the assumed 1.8 feet of sea level rise predicted by the two models are similar. The updated DSM2 model along with the modifications to the boundary conditions for stage and EC at Martinez were used for analyzing the impacts of the project alternatives for 2040 future conditions.

C.6.3 Artificial Neural Networks (ANN) Training

ANNs are used to model the flow-salinity relationship in CalSim 3. Embedded in CalSim 3, the ANNs emulate the DSM2 Delta salinity for CalSim 3 simulated flows. ANNs need to be retrained when Delta flow and salinity conditions change drastically (e.g., sea level rise). For the Delta Conveyance Project, two different sets of ANNs were trained.

1. Base — 2020 hydrology without sea level rise
2. Sea Level Rise — 2040 hydrology with 1.8 feet sea level rise

The newly developed and improved ANNs, when used in CalSim 3, provide more accurate insights on salinity levels in the Delta. A detailed description of the ANN training procedure and the full circle analysis is provided in Seneviratne and Wu (2007). ANN retraining process involved the following steps, starting with the appropriate DSM2 model: historical calibrated version for base and corroborated version of the DSM2 model for 1.8 feet sea level rise effect.

- Development of three CalSim 3 scenarios to provide a broad range of Delta boundary conditions for the DSM2 modeling scenarios:
 1. Without project's north Delta diversion and with Suisun Marsh Salinity Control Gate (SMSCG) operating throughout the year.
 2. Without project's north Delta diversion and with no SMSCG operations in the summer.
 3. With 6,000 cubic feet per second (cfs) project's north Delta diversion with SMSCG operating throughout the year.
- Using the grid configuration and the correlations from the corroboration process, three 93-year (water years 1923–2015) DSM2 planning runs are simulated based on the boundary conditions from the identified CalSim 3 scenarios to create a training dataset for each new ANN.
- ANNs are trained using inputs below, along with the EC results from DSM2.
 1. Northern flow (Sacramento River, Yolo Bypass, Mokelumne River, Cosumnes River, and Calaveras River inflows).
 2. San Joaquin River flow.
 3. Exports (Banks, Jones, and Contra Costa Pumping Plants).
 4. Delta Cross Channel gate operation.
 5. Net Delta channel depletion.
 6. Tidal energy (daily maximum-daily minimum of astronomical tide).
 7. SMSCG operation.
- The training dataset is divided into two parts: one part is used for training the ANNs, and the other part is for validating.
- Once the ANNs are trained, a full circle analysis is performed to assess the performance of the ANNs.

1 There are some differences in the way CalSim 3 ANNs were trained compared with earlier versions.
2 The ANNs used in CalSim II were trained using a shorter period of time (water years 1974–1991).
3 This shorter period includes two historically dry periods (1975–1977 and 1986–1992). However, it
4 was observed that these ANNs were not performing well from 1928 through 1934, another
5 important dry period in planning. In addition, the old ANNs (developed for CalSim II) were not
6 performing well in the new CalSim 3 model. Therefore, there was a need to develop new and better
7 performing ANNs for CalSim 3 (Jayasundara et al. 2019).

8 In addition to the above changes, in the Delta Conveyance Project ANNs, the Vernalis inflow salinity
9 was replaced by SMSCG operation. Three studies and a longer training period (1940–2015)
10 provided a larger range of data for better training, which provides more robust ANNs for larger
11 range of hydrologic and salinity conditions.

12 **C.6.4 North Delta Intakes Operation**

13 The diversion operation at the north Delta intakes is dynamically simulated in DSM2 such that the
14 daily amounts specified by CalSim 3 are diverted while subjecting each intake to the sweeping
15 velocity and the ramping criteria. A maximum of 3,000 cfs (or 1,500 cfs) is withdrawn at each intake
16 while meeting a velocity requirement of 0.4 feet per second downstream of each intake. The intakes
17 are operated as long as the daily diversion volume specified by CalSim 3 is not diverted. Once the
18 specified volume is diverted for the day, the diversions at the intakes are shut off until the following
19 day. The remaining volume for the day will be diverted such that operation of the upstream intake is
20 prioritized over the downstream one. Intake diversions are ramped over a 90-minute period to
21 allow smooth transitions when they are turned on or off. In the situation where the specified volume
22 is not diverted by the end of the day (due to not meeting the velocity criteria), the “unmet” diversion
23 volume is carried forward to the following day, and this process continues until the amount of north
24 Delta diversion specified by CalSim 3 is met in DSM2. In general, the amount of north Delta diversion
25 specified by CalSim 3 is met in DSM2 within the month, however, there could be some daily
26 fluctuations caused by specific tidal conditions.

27 An operating rule is added in DSM2 to generally operate the north Delta intakes during daytime
28 hours beginning at 6:00 a.m. to the extent possible (except during the months of July–September)
29 and to achieve a steady pumping rate during this time with ramping up and ramping down assumed
30 to occur over a 1.5-hour period. This modified operation is only possible when the amount of north
31 Delta diversion specified by CalSim 3 is somewhat less than half the total combined capacity of the
32 intakes. For modeling purposes, the start of pumping each day depends on the daily diversion
33 volume from CalSim 3 (QND) and the total capacity of the north Delta diversion. Outside of the
34 summer months, the start of pumping is 6:00 a.m. for QND less than 50% of the total north Delta
35 diversion capacity. The start of pumping is 3:00 a.m. for QND less than 67% of total capacity (62%
36 for 4,500 cfs north Delta diversion). For QND greater than 67% of total capacity (62% for the 4,500
37 cfs north Delta diversion), the start of pumping is 12:00 a.m. During the summer months (July–
38 September) pumping always starts at 12:00 a.m.

39 For modeling purposes, the target diversion rate at each intake outside of the summer months
40 depends on the daily diversion volume from CalSim 3 and the total capacity of the intake(s). When
41 QND is below 40% of the total physical capacity of the north Delta intake(s), the target diversion
42 rate is $2.5 \times \text{QND}$ distributed between the different north Delta intakes. When QND is above 40% of
43 the physical capacity of the intake(s), the target diversion rate is equal to the physical capacity of the

intake(s). The target diversion rate for the summer months (July–September) is always 1.5*QND, distributed between the different north Delta intakes.

C.6.5 Application of DSM2-PTM to Evaluate the Delta Conveyance Project

DSM2-PTM simulations have been used to characterize the potential entrainment effects of various species of fish during different parts of their life cycles in the Delta. To assist in evaluating the potential entrainments of fish under the Delta Conveyance Project, two sets of simulations were conducted based on the assumption that the particles are either neutrally buoyant or surface oriented.

C.6.5.1 DSM2-PTM for Evaluating Neutrally Buoyant Particles

DSM2-PTM Period Selection

DSM2-PTM runs were conducted from January to June in each year from 1923 to 2015, leading to a total of 558 release periods for this application.

DSM2-PTM Simulation

Neutrally buoyant particles were released at the 39 locations shown in Figure 5A-C.2. These locations are also listed in Table 5A-C.3. DSM2-PTM simulations were performed in a batch mode for each of the 558 insertion periods. This brought the total DSM2-PTM simulations performed for 93 years, to 21,762 under this application. 4,000 neutrally buoyant passive particles were released over a 24.75-hour period, starting on the first day of the selected month for each DSM2-PTM simulation. Particle entrainment at the Delta agricultural locations and at the north Delta intakes was prevented in these simulations.

Each DSM2-PTM simulation was run for a 92-day period from the date of release, and the fate of the released particles was tracked continuously over the 92 days. The particle flux was tracked at the key exit locations—south Delta exports (CVP Jones Pumping Plant, SWP Clifton Court Forebay), north Delta intakes, North Bay Aqueduct, past Martinez, and particles remaining in the Delta channels, and at several internal tracking locations as shown in Figure 5A-C.2. The timeseries output was post-processed to determine the percent of particles ending up at the above locations at the end of 30, 45, 60 and 90 days after release and used in the neutrally buoyant particle evaluation.

C.6.5.2 DSM2-PTM for Evaluating Surface Oriented Particles

DSM2-PTM Period Selection

Surface-oriented particles were inserted during the months January through March in each of the 93 years, leading to a total of 279 release periods for this application.

DSM2-PTM Simulation

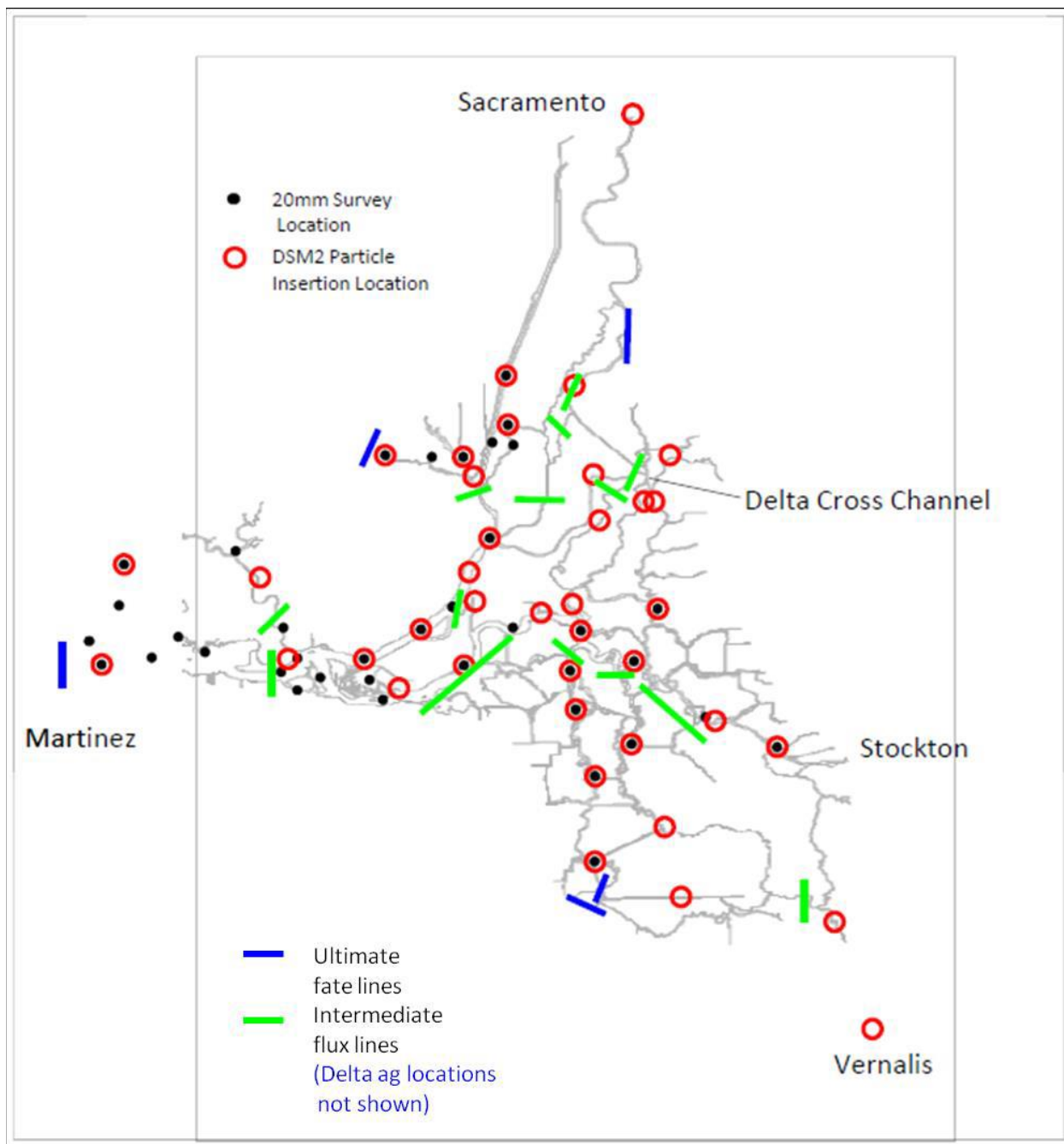
Surface-oriented and neutrally buoyant particles were released at the same 39 insertion locations shown in Figure 5A-C.2. DSM2-PTM simulations were performed in a batch mode for each of the 279 insertion periods. This brought the total DSM2-PTM simulations performed for 93 years, to 10,881

1 under this application. Four thousand surface-oriented passive particles were released over a 24.75-
2 hour period, starting on the first day of the selected month for each DSM2-PTM simulation. Particle
3 entrainment at the Delta agricultural locations and at the north Delta intakes was prevented in these
4 simulations.

5 Particles released were restricted to the upper 10% of the water column during the entire
6 simulation period. Each DSM2-PTM simulation was run for a 92-day period, from the date of release,
7 and the fate of the released particles was tracked continuously over the 92 days. The particle flux
8 was tracked at the key exit locations—south Delta exports (CVP Jones Pumping Plant, SWP Clifton
9 Court Forebay), north Delta intakes, North Bay Aqueduct, past Martinez and particles remaining in
10 the Delta channels, and at several internal tracking locations, as shown on Figure 5A-C.2. The
11 timeseries output was post-processed to determine the percent of particles ending up at the above
12 locations at the end of 30, 45, 60 and 90 days after release and used in the surface-oriented particle
13 evaluation.

14 **C.6.5.3 DSM2-PTM Limitations**

15 DSM2-PTM results are most often used to understand the potential movement of eggs and larval fish
16 with flow changes. DSM2-PTM approximates movement of neutrally buoyant particles or particles
17 with position restrictions based on the hydrodynamics. DSM2-PTM requires input of channel
18 velocity fields from DSM2-HYDRO, which leads to the translation of the limitations inherent to
19 DSM2-HYDRO to DSM2-PTM. The partitioning of the particles at a junction in the DSM2-PTM is
20 simplistic and is based on the flow split into different branches at a junction. Information related to
21 higher order hydraulics such as acceleration around the bend and secondary currents are not
22 simulated in the DSM2-PTM, despite its use of an approximate three-dimensional velocity field. Use
23 of DSM2-PTM results to analyze certain species and life stages with significant active behavior
24 responses should be used with caution. While some uncertainty exists in the DSM2-PTM results, the
25 model is a reasonable tool to compare the movement and fate of particles between various
26 scenarios, if results are interpreted within the context of these limitations.



Note: A text description of this figure is provided in Chapter 39, *Description of Figures*.

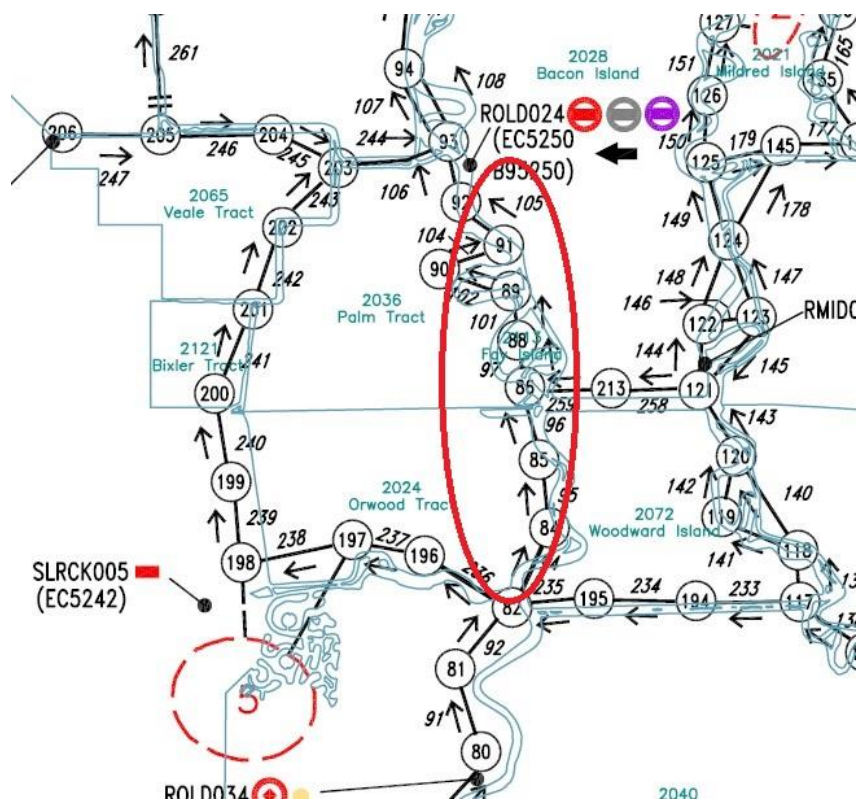
Figure 5A-C.2. Particle Release and Tracking Locations

Table 5A-C.3. List of Particle Release Locations

Location	DSM2 Node
San Joaquin River at Vernalis	1
San Joaquin River at Mossdale	7
San Joaquin River downstream of Rough and Ready Island	21
San Joaquin River at Buckley Cove	25
San Joaquin River near Medford Island	34
San Joaquin River at Potato Slough	39
San Joaquin River at Twitchell Island	41
Old River near Victoria Canal	75
Old River at Railroad Cut	86
Old River near Quimby Island	99
Middle River at Victoria Canal	113
Middle River upstream of Mildred Island	145
Grant Line Canal	174
Frank's Tract East	232
Threemile Slough	240
Little Potato Slough	249
Mokelumne River downstream of Cosumnes confluence	258
South Fork Mokelumne	261
Mokelumne River downstream of Georgiana confluence	272
North Fork Mokelumne	281
Georgiana Slough	291
Miner Slough	307
Sacramento Deep Water Ship Channel	314
Cache Slough at Shag Slough	321
Cache Slough at Liberty Island	323
Lindsey slough at Barker Slough	324
Sacramento River at Sacramento	330
Sacramento River at Sutter Slough	339
Sacramento River at Ryde	344
Sacramento River near Cache Slough confluence	350
Sacramento River at Rio Vista	351
Sacramento River downstream of Decker Island	353
Sacramento River at Sherman Lake	354
Sacramento River at Port Chicago	359
Montezuma Slough at Head	418
Montezuma Slough at Suisun Slough	428
San Joaquin River downstream of Dutch Slough	461
Sacramento River at Pittsburg	465
San Joaquin River near Jersey Point	469

C.6.6 Residence Time Analysis for Cyanobacterial Harmful Algal Blooms

One of the factors that affect cyanobacterial harmful algal blooms is residence time. DSM2-QUAL was used to analyze changes in residence time in certain locations in the Delta. Figure 5A-C.3 shows the DSM2 representation of a portion of the Delta being analyzed for changes in residence time. DSM2 needs an initial concentration of the constituent to start the simulation. For this analysis, a concentration of 100 is assigned to all DSM2 channels within the zone defined, while for all other DSM2 channels outside the zone an initial concentration of zero is assigned. Once the simulation starts, the constituent starts moving outside the zone shown through the processes of advection and dispersion. Model output is requested at the middle of each of the DSM2 channels within the zone. For each channel within the zone, residence time for a given channel is defined as the length of time it takes for 90% of the constituent to leave through either end of channels. To determine the residence time for each channel as defined, the elapsed time is determined for the concentration of the constituent at the middle of channel to reach a value of 10. The residence time for the entire zone is defined as the average of the length of residence time for the individual DSM2 channels within the defined zone.



Note: A text description of this figure is provided in Chapter 39, *Description of Figures*.

Figure 5A-C.3. DSM2 Schematics Used to Determine the Residence Time for a Defined Zone within the Delta

Residence times vary greatly depending on the Delta inflows, exports, and the specific location within the Delta. The residence time analysis performed for the Delta Conveyance Project mainly

1 focused on the months of June through November. A total of 558 individual DSM2-Qual runs were
2 performed (93 years x 6 months) for different zones within the Delta known for cyanobacterial
3 harmful algal blooms formation. The residence time analysis was performed for the Delta
4 Conveyance Project existing conditions and all project alternatives for each of the time periods
5 simulated. Results were compared and further analyzed.

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