Appendix A2. DeltaSOS: Delta Standards and Operations Simulation Model

C-061255

Appendix A2. DeltaSOS: Delta Standards and Operations Simulation Model

SUMMARY

This appendix describes the application of the Delta Standards and Operations Simulation (DeltaSOS) model developed for evaluating compliance of Delta water management operations with likely Delta standards. The discussion summarizes the sources of the initial Delta water budget terms required for DeltaSOS simulations and describes DeltaSOS input matrices of flow values associated with Delta standards for water quality and fish protection. The set of input matrices offers DeltaSOS users a choice of Delta standards against which to test likely future Delta operations. The Delta standards are specified as monthly values for each of five selected water-year types for each of the following:

- *Sacramento River flow at Freeport,*
- *diversions from the Sacramento River at Hood,*
- *Delta Cross Channel (DCC) and Georgiana Slough operations,*
- *Sacramento River flow at Rio Vista,*
- *San Joaquin River flow at Vernalis,*
- *operation of a barrier at the head of Old River,*
- *QWEST flow,*
- *operation of the Suisun Marsh salinity control gate,*
- *Delta outflow,*
- *1995 Bay-Delta Water Quality Control Plan (WQCP) outflow standards for estuarine habitat,*
- *Delta export pumping at the State Water Project (SWP) Banks Pumping Plant and the Central Valley Project (CVP) Tracy Pumping Plant, and*
- *operation of an in-Delta storage facility.*

This appendix describes the relationships between these variables and Delta water quality requirements, and describes DeltaSOS input matrix values for WQCP standards.

INTRODUCTION

Use of DeltaSOS, a simulation and analysis tool, is necessary to reliably describe the effects of several types of existing and proposed Delta standards on likely future operations of the Delta. Environmental assessment of an in-Delta storage project, such as the proposed Delta Wetlands (DW) project, depends on reliable descriptions of these likely future Delta conditions. The DeltaSOS monthly model provides a general analysis tool for evaluating a wide range of possible future Delta standards and likely future operations that will comply with these standards.

DeltaSOS is built on these general concepts:

- Applicable Delta standards for water quality and fish protection are specified as monthly flow values at 12 locations for each of five selected water-year types (wet, above normal, below normal, dry, and critically dry).
- An initial monthly Delta water budget for 1922-1991 is specified, consisting of terms for Sacramento and San Joaquin River inflows, Yolo Bypass and eastside stream inflows, Delta channel depletion (including North Bay Aqueduct exports), combined CVP and SWP exports, Contra Costa Water District (CCWD) diversions, and initial Delta outflow at Collinsville.
- Incremental changes in Delta operations required to meet each of the specified Delta standards are calculated and compared with the initial specified Delta water budget for each month of simulation. Revised Delta water budget terms that satisfy the specified standards are reported.

This appendix briefly describes the DeltaSOS spreadsheet model to allow interested parties to review simulation results obtained for water management operations that correspond to specified Delta standards and facilities.

POSSIBLE HYDROLOGIC INPUTS

DeltaSOS does not simulate upstream storage reservoirs but provides a description of Delta conditions and operations corresponding to a wide range of possible Delta standards.

DeltaSOS requires an initial monthly water budget of the Delta for water years 1922-1991 to calculate monthly conditions in the Delta. Initial monthly Delta inflows and exports can be estimated from three general sources: historical records (California Department of Water Resources' [DWR's] DAYFLOW data set), simulation results from a monthly SWP or CVP operations planning model (DWRSIM, PROSIM, or SANJASM), or results from a previous Delta simulation by the DeltaSOS model. Results from the SWP or CVP operations planning model can be combined with DeltaSOS results to provide a complete description of water supply and Delta conditions corresponding to selected Delta standards. An iterative process might be used to resolve differences between the planning model results and specific in-Delta requirements identified with DeltaSOS. The monthly water budget terms used in DeltaSOS are described in Appendix A1, "Delta Monthly Water Budgets for Operations Modeling of the Delta Wetlands Project", and are summarized below.

Historical Flows

The historical monthly Delta water budget is provided by DWR in the DAYFLOW data set, available beginning with water year 1930. DAYFLOW is an accounting of historical measured Delta inflows and exports and estimates of Delta consumptive use and outflow. JSA has used DWR estimates of unimpaired flows for 1922-1929 to extend the historical record of Delta inflows to encompass 70 years. Because the historical record includes effects of changing water use patterns and water resource facilities, adjustments could be made to historical upstream diversion estimates and storage patterns to reflect present facilities and operations.

Simulation Results from Operations Planning Models

Results from a monthly operations planning model, such as DWRSIM, PROSIM, or SANJASM, constitute the second possible source of values for an initial monthly Delta water budget. The DAYFLOW and unimpaired flow data do not reflect Delta operations (e.g., Delta exports and releases of flows from upstream facilities) that would occur with present-day facilities and demand for exports; therefore, monthly operations planning models are used to estimate Delta operations under the hydrologic conditions represented by the historical record. Results from these models provide an estimate of likely Delta conditions under a particular set of assumed facilities, operations rules, water demands, and applicable Delta standards. Monthly inputs are used in DeltaSOS for Sacramento River, San Joaquin River, eastside stream, and Yolo Bypass inflows; CCWD diversions; CVP and SWP exports (combined); Delta channel depletion; Delta outflow; and estimated "carriage water" requirements.

Iterative DeltaSOS Results

A modified monthly Delta water budget produced by DeltaSOS to satisfy a set of proposed Delta standards may be used as the initial conditions for investigating the incremental effects of slightly different Delta standards. The DeltaSOS model includes an option to reset the initial monthly Delta water budget terms to the most recent revised values of the terms calculated to satisfy the previously specified set of Delta standards. This option is used to update the initial water budget terms for Sacramento and San Joaquin River inflows, Delta exports, and Delta outflow. The calculated Delta conditions will reflect these changed input values.

Classification of Water-Year Type

DeltaSOS allows the classification of water-year type for the Sacramento and San Joaquin River basins to be selected and specified as part of the monthly inputs. Selection of the year-type classification scheme is important because Delta standards can differ substantially for each water-year type. The year-type classification specified in Water Right Decision 1485 (D-1485) includes a "subnormal snowmelt" year type that replaces wet, above-normal, and below-normal types when the snowpack is below normal. Required D-1485 Delta outflows for May-July are substantially modified under this year-type classification. The 1995 WQCP uses a slightly different year-type classification, called the 40-30-30 scheme. The selected year type is specified as an input.

DeltaSOS allows the San Joaquin River year type to vary independently of the Sacramento River year type, as specified in the 1995 WQCP. The Vernalis inflow requirements and Old River barrier operations in DeltaSOS depend on San Joaquin River water-year type.

Under most year-type classification schemes, the water-year type cannot be accurately determined until approximately halfway into a new water year (i.e., March or April). DeltaSOS establishes a new year type in February of each year to properly match relatively large spring outflow requirements with the contemporary year type. DeltaSOS simulates October-January flows according to the previous year-type standards.

The 1995 WQCP outflow requirements depend on the previous month's runoff, rather than the annual year-type classification. These monthly runoff values are provided as inputs to DeltaSOS, as discussed below under "Delta Outflow".

DELTA STANDARDS SIMULATED IN DELTASOS

Delta standards consist of numerical criteria or limits that are specified in narrative decisions of the California State Water Resources Control Board (SWRCB), Endangered Species Act biological opinions, and agreements between and other documents from various regulatory or water management agencies. SWRCB established its currently applicable Delta standards in the 1995 WQCP. SWRCB listed these standards according to the resource use they are protecting at certain locations and specified values for selected parameters (minimum flow, pumping limit, salinity, electrical conductivity [EC], or chloride) during certain periods of the year (dates or days per year) for particular year types. Additional Delta requirements that must also be satisfied are contained in SWRCB water right decisions and have been introduced in the Coordinated Operations Agreement (COA) of DWR and the U.S. Bureau of Reclamation (Reclamation), recent actions related to the Endangered Species Act, and other legislative mandates (CVP Improvement Act).

DeltaSOS uses input matrices of monthly Delta standards specifying required monthly flows (minimum or maximum) at a location for each month for each year type. Translating the wide variety of possible Delta standards into a matrix of required flows can be difficult and requires interpretation of hydrologic and water quality factors. Assumptions about important parameters and relationships, such as flow-salinity relationships, are sometimes necessary. Specifying average monthly flow requirements at appropriate Delta locations for the full set of applicable standards provides an objective basis for systematically analyzing likely future Delta conditions. DeltaSOS can thus describe flow conditions that satisfy the specified set of Delta standards at an averaged monthly time scale appropriate for planning studies.

The following sections define the input matrices used in DeltaSOS to specify possible standards or requirements at the 12 Delta locations shown in Figure A2-1. Delta salinity standards are not directly simulated in DeltaSOS and must be protected indirectly using specified minimum monthly flow requirements (see "Carriage Water Calculations" below). Table A2-1 provides an example of the DeltaSOS control matrices. The matrices shown in Table A2-1 are samples of matrices that may be used, and the values may not match actual Delta standards required by the 1995 WQCP and other current regulations.

Sacramento River Flows at Freeport

The input matrix for minimum Sacramento River flows at Freeport can be used to specify requirements for pulse flows to assist migrating fish or transport eggs and larvae from the Sacramento River through the Delta to Suisun Bay. Pulse flows that may be required for less than a month must be averaged with requirements for the remainder of the month to establish monthly values of the DeltaSOS matrix. The 1995 WQCP does not contain Freeport minimum flow requirements.

Diversions from the Sacramento River at Hood

Facilities do not currently exist at Hood to allow diversion of exports from the Sacramento River. Hood diversions therefore are not included in simulations of DW project operations for evaluating potential environmental impacts. DeltaSOS includes a switch, however, to allow simulation of possible diversions at Hood into an isolated facility to transfer water directly to the CVP and SWP pumps or to divert water into the Mokelumne River channels. If this option is used, three matrices of input standards are needed to specify operational controls for the Hood diversions and the transfer facility.

Hood diversions as simulated in DeltaSOS would be limited by two different control matrices. A maximum diversion rate limiting the diversions at Hood can be specified for each month of each water-year type. A second control matrix specifies the allowable fraction of Sacramento River flow that could be diverted at Hood. In combination, these two control matrices can simulate a wide range of operational limits for possible Hood diversions. A third matrix in DeltaSOS can be used to specify required releases from the transfer facility to provide inflows to sloughs that connect with the Mokelumne River or the San Joaquin River or to these rivers themselves.

DeltaSOS does not allow Hood diversions to exceed the specified maximum diversion rate or the maximum specified fraction of Sacramento River inflow. Hood diversions are also limited indirectly in DeltaSOS by the need to satisfy requirements for Delta outflow and Rio Vista flows. Thus, five separate standards in DeltaSOS can be used to limit simulated Hood diversions.

Delta Cross Channel and Georgiana Slough Operations

Operations of the DCC gates are controlled on a daily basis and may depend on either the Sacramento River inflow or Delta outflow at Chipps Island. A flood control standard operating procedure closes the DCC to protect DCC structure and the Mokelumne River channel levees whenever Sacramento River inflow (below Hood) is greater than 25,000 cubic feet per second (cfs). The 1995 WQCP contains provisions to close the DCC 50% of the time during November-January and requires complete DCC closure from February 1 to May 20. The DCC is closed 4 days each week from May 21 to June 15.

Approximating the DCC daily operation requirements with a monthly average closure criterion introduces some inaccuracy for months that have average flows near the DCC closure criterion. If the monthly flows are either very low or very high compared with the criterion, however, the closure condition specified as a monthly average flow is a good approximation of the average of the daily closure conditions. Simulating the periods with partial DCC closure is not possible in DeltaSOS.

DeltaSOS requires two flow-standard matrices to simulate the DCC closure standards because they depend on flows at two different Delta locations. The first matrix specifies the maximum monthly Sacramento River flow below Hood for the DCC to remain open. The flood control standard is simulated at 25,000 cfs. Mandatory closure of the DCC for a month is specified in DeltaSOS with a value of 0 cfs in the input matrix.

The second DCC flow matrix specifies the maximum Delta outflow for the DCC to remain open (i.e., at higher outflows, the DCC will be closed). For example, D-1485 standards required the DCC to be closed if Delta outflow was greater than 12,000 cfs in the months of January-April. Delta outflow in the initial Delta water budget is used to determine DCC closure based on this standard. If the initial Delta outflow is below the outflow standard (such that the DCC remains open) but exports are reduced to comply with specified standards (e.g., pumping limits), DeltaSOS may allow the revised Delta outflow to increase above the specified Delta outflow for DCC closure. In this case, DeltaSOS will not satisfy the DCC closure standard for Delta outflow. The 1995 WQCP does not contain a DCC closure criterion for Delta outflow.

Another flow matrix specifies the maximum monthly Sacramento River flow below Hood for simulated Georgiana Slough gates to remain open. These potential gates have not been constructed. A matrix value of 100,000 cfs will simulate Georgiana Slough maintained in an open configuration because Sacramento River channel capacity in the vicinity of DCC and Georgiana Slough is less than 100,000 cfs.

Sacramento River Flows at Rio Vista

The 1995 WQCP specifies minimum flows at Rio Vista to protect migrating salmon. Sacramento River flows at Rio Vista are equivalent to flows at Freeport, minus any Hood diversions, minus the DCC and Georgiana Slough flows, minus an assumed fraction (25%) of Delta channel depletions that occur between Freeport and Rio Vista, plus any Yolo Bypass inflows. Rio Vista is upstream of the Threemile Slough connection to the lower San Joaquin River.

Sutter and Steamboat Slough diversions from the Sacramento River below Hood rejoin the Sacramento River at Rio Vista. The diversions are calculated in DeltaSOS, but no gates or tidal controls for Sutter or Steamboat Sloughs are simulated in DeltaSOS.

QWEST Flows

QWEST is a variable calculated to be equivalent to the net flow moving from near the mouth of the Mokelumne River and Old River (Franks Tract) toward Antioch in the San Joaquin River, False River, and Dutch Slough channels. Requirements for QWEST minimum flows are a new feature of Delta standards, first introduced in SWRCB's proposed Water Right Decision 1630 (D-1630). Subsequently, QWEST limits were specified as protection measures for fish in 1993 and 1994 biological opinions under the federal Endangered Species Act for both winter-run salmon and Delta smelt. Minimum QWEST flows are specified to minimize the net upstream movement of passive larval and juvenile fish life stages from the Antioch region (western Delta) into the central Delta where they would become vulnerable to potential entrainment losses at the export pumps and agricultural diversions, as well as other potentially adverse environmental conditions (e.g., mortality, straying, and limited food resources). There are no QWEST limits, however, in the 1995 WQCP.

The U.S. Geological Survey (USGS) has recently installed an ultrasonic velocity meter (UVM) to measure San Joaquin River tidal flow at Jersey Point, downstream of the junction with Threemile Slough and downstream of the False River flow from Franks Tract (Figure A2-1). A similar UVM is being installed by USGS in Threemile Slough. The USGS measurements at Jersey Point and Threemile Slough can be used to calculate QWEST values as estimated in DAYFLOW. DAYFLOW estimates of QWEST flows do not include the contribution of Sacramento River flow from Threemile Slough. Flows measured by USGS at Jersey Point will be slightly less than San Joaquin River flows at Antioch because (according to the RMA Delta model) approximately 5% of net San Joaquin River flow moves through Dutch Slough between Franks Tract and Big Break, thus entering the San Joaquin River downstream of Jersey Point (Figure A2-1).

In DeltaSOS, the user can apply QWEST standards either with or without Threemile Slough flows included in the QWEST calculation. Prior calculations of QWEST values have been based on DAYFLOW estimates, with Threemile Slough flows excluded. Including Threemile Slough flows in the QWEST calculations would allow regulation of DeltaSOS-simulated San Joaquin River flows in the vicinity of Antioch using the values specified in the QWEST standard.

In the DeltaSOS standards input matrix, the QWEST variable is given a value of -15,000 cfs in months with no QWEST flow limits. This input value thus represents a minimum possible QWEST flow with full export pumping even when there are no inflows to the central Delta.

San Joaquin River Flows at Vernalis

Minimum required San Joaquin River flows at Vernalis can be indirectly estimated from maximum allowable values for salinity (EC or total dissolved solids

[TDS]) as generally specified in Condition 5 of SWRCB D-1422, which governs the water rights for New Melones Reservoir and from an assumed EC-flow relationship to approximate flows equivalent to the Vernalis salinity standards. For example, the D-1422 TDS standard of 500 parts per million (ppm) is equivalent to an EC value of about 833 μS/cm (0.833 mS/cm), assuming the generally observed EC/TDS ratio of 1.67, which requires a flow of approximately 1,000 cfs at Vernalis. DWR uses a slightly different flow-EC relationship, which requires 1,500 cfs to satisfy the 500-mg/l TDS standard. The 1995 WQCP requires maximum Vernalis EC of 0.7 mS/cm in the irrigation season (April-August) and of 1.0 mS/cm during the remainder of the year. The Vernalis flows equivalent to these EC values can be estimated from an assumed EC-flow relationship.

The 1995 WQCP includes fish transport flows for the San Joaquin River during February-June. These flows depend on San Joaquin River year type and increase by a specified increment whenever Delta outflow is greater than 11,400 cfs (when the X2 position is downstream of Chipps Island, as described below under "WQCP Outflow Standards for Estuarine Habitat"). A 30-day pulse-flow period is also specified in April-May. DeltaSOS calculates the San Joaquin River pulse flow and base inflow during April and May from the average monthly input flows.

Head of Old River Barrier

DeltaSOS estimates diversion flows from the San Joaquin River into Old River based on results of the Resource Management Associates (RMA) Delta hydrodynamic model. Flow into Old River is potentially blocked by a barrier at the head of Old River. Temporary barriers have been placed in fall to reduce diversions to Old River and thus to increase flows in the San Joaquin River past Stockton. Increased flows in the San Joaquin River may increase dissolved oxygen concentrations in fall and improve conditions for salmon migration in spring.

DeltaSOS requires a control matrix that specifies the maximum monthly San Joaquin River flow at Vernalis for the barrier at the head of Old River to remain closed. DeltaSOS will simulate opening of the barrier for flood control purposes if San Joaquin River flow exceeds the specified threshold. At a threshold value of 10,000 cfs, DeltaSOS will simulate closure of the barrier unless the San Joaquin River flow is greater than 10,000 cfs at Vernalis. A value of 0 cfs will simulate opening of the barrier during the month for any San Joaquin River flow. Note that this has an effect that is opposite that of the DCC closure matrix.

Delta Outflow

Chipps Island, just below the confluence of the Sacramento and San Joaquin Rivers near Pittsburg, is the traditional location for specification of minimum Delta outflow requirements. Prior to the recent introduction of requirements for flushing flows, QWEST limits, and Suisun Marsh salinity standards, all Delta salinity and flow requirements could be approximately combined into minimum Delta outflow requirements at Chipps Island. DWR has used a computer subroutine called Minimum Delta Outflow (MDO) to estimate the monthly Delta outflow requirements for use as minimum flow constraints in DWRSIM modeling of SWP and CVP operations. (MDO is now incorporated within DWRSIM.)

For DeltaSOS inputs of standards, various Delta outflow and salinity requirements can be approximated as a single matrix of monthly flows, using the specified salinities and salinity-outflow relationships such as those assumed by DWR in the MDO program. In cases in which different salinity standards apply at different Delta locations (i.e., Chipps Island, Emmaton, or Jersey Point), the flows required to maintain the specified salinities are compared and the largest necessary flow (i.e., controlling standard) is used as the minimum outflow requirement. When standards apply for only part of a month or when cumulative standards apply (e.g., 150 mg/l chloride at Rock Slough for a certain number of days for each water-year type), the monthly flow value is estimated as the average of the daily controlling values.

The matrix of minimum Delta outflows at Chipps Island can be derived from a combination of specified flows for fish transport, EC standards to protect Suisun Marsh, and EC standards at Emmaton and Jersey Point to protect agricultural uses. Each EC standard at each location must be interpreted as an outflow standard based on an assumed EC-outflow relationship. For example, the Emmaton EC standard of 0.45 mS/cm has been interpreted to be an outflow requirement of about 7,600 cfs.

One of the Suisun Marsh EC standards in D-1485 requires a flow of 12,000 cfs for 2 out of 4 months (January-April) in above-normal and below-normal years. This type of Delta standard cannot be specified as fixed monthly flow requirements in DeltaSOS. An additional matrix (OUTQ) is used to represent this D-1485 Suisun Marsh EC standard in DeltaSOS.

OUTQ specifies the required number of months within the selected control period that must have an outflow greater than the specified flow for each year type. The OUTQ matrix includes three specified outflow values. Because the 1995 WQCP monthly outflow requirements depend on the previous month's runoff, the OUTQ matrix is not used and all OUTQ matrix values are set at 0.

1995 WQCP Outflow Standards for Estuarine Habitat

The 1995 WQCP includes additional Delta outflow requirements for the February-June control period to limit salinity in the estuarine habitat of Suisun Bay. The 1995 WQCP standards require that the specified salinity standard (which is assumed to be equivalent to a certain specified Delta outflow) be met for a certain number of days each month during the February-June control period. The proposed standards have been formulated in terms of the number of days that the mean daily salinity gradient value of 2 parts per thousand (ppt) TDS (3 mS/cm EC), designated X2, must be downstream of three control locations: the confluence of the Sacramento and San Joaquin Rivers near Collinsville, Chipps Island, and Roe Island. Furthermore, the outflow requirements are adjusted based on actual hydrologic conditions during the previous month.

DeltaSOS uses the assumed steady-state Delta outflows that would maintain the X2 position for a specified number of days at each of these locations (WQCP, Table 3, Footnote 11) to estimate the required monthly outflow and equivalent required X2 position. The X2 position can be maintained at Collinsville (81 km) with an outflow of 7,100 cfs; at Chipps Island (74 km) with 11,400 cfs; and at Roe Island (64 km) with 29,200 cfs. The number of days for which X2 is maintained at each location depends on the previous month's runoff (the sum of the unimpaired runoff of eight specified rivers, published as DWR's Eight-River Index). The 1995 WQCP states that the X2 position must be maintained at Roe Island only if the previous month's position (14-day average EC at Roe Island on the last day of the month) was downstream of Roe Island. This is simulated in DeltaSOS with a specified trigger X2 position slightly upstream of Roe Island (66.3 km used). If the previous month's X2 was downstream of the trigger position, higher flows are required than if the previous month's X2 position was upstream of this trigger position. These two sets of outflow requirements are specified in tables that identify the required outflow for each month as a function of the previous month's runoff (Table A2-2). The 1995 WQCP outflow requirements for January also depend on previous month's runoff.

The X2 position is assumed to depend on the previous month's X2 position and the current month's Delta outflow as follows (Kimmerer and Monismith 1992):

$$\text{X2 (km)} = 122.2 + 0.3278 \cdot \text{X2 (previous month)} - 17.65 \cdot \log(\text{outflow [cfs]})$$

The following is therefore the steady-state equation for X2 as a function of outflow:

$$\text{X2 (km)} = 181.8 - 26.26 \cdot \log(\text{outflow [cfs]})$$

The required X2 position is estimated from the steady-state equation using the monthly outflow obtained from the look-up tables. The steady-state Delta outflow is adjusted using the previous month's X2 position as follows:

$$\text{Required outflow} = \text{steady-state outflow} \cdot (1 - 0.044 \cdot [\text{required X2} - \text{previous X2}])$$

According to this equation, each kilometer of difference between the previous month's X2 position and the required X2 position is equivalent to about a 4% change in required outflow. DeltaSOS assumes that this adjustment in required outflow is made for the upstream previous month's X2 (increased outflow needed), as well as downstream previous month's X2 (reduced outflow needed).

The 1995 WQCP provides a relaxation of these X2 position standards in May and June of years with runoff of less than 8.1 million acre-feet (MAF). DeltaSOS applies this relaxation in below-normal (7.8 MAF) and drier year types.

DeltaSOS also includes a switch that allows the specified Delta outflow to be applied either at Chipps Island or at Collinsville, upstream of Montezuma Slough. If the outflow standard is applied at Collinsville, the effects of Montezuma Slough diversions on satisfying the required Delta outflow standards are eliminated. If the Delta outflow standards are simulated at Collinsville, however, possible effects of the Montezuma Slough diversions on flow and salinity at Chipps Island should be carefully considered. Because the Suisun Marsh salinity control gate has only been operated since 1989, net diversion flow into Montezuma Slough has not been accounted for in DAYFLOW and may not yet be represented in MDO and DWRSIM results.

An additional method of specifying required Delta outflow is possible with DeltaSOS. The monthly DWRSIM results for minimum Delta outflow (including all possible requirements) can be obtained and specified in the DeltaSOS input column for "carriage water" (see discussion below). If this option is used, the required Delta outflow matrix, as well as the OUTQ matrix, should be reset to zeros, and the carriage water switch should be set at 1.0. This option will make the total outflow requirements identical to those calculated by DWRSIM but will not allow changes in the required outflow objectives to be simulated. This was the option used for simulating the DW project alternatives; outflow requirements were identical to those simulated with DWRSIM.

Delta Export Pumping at Banks and Tracy Pumping Plants

DeltaSOS represents combined CVP (Tracy Pumping Plant) and SWP (Banks Pumping Plant) Delta export pumping limits in another Delta standard matrix. The CVP Tracy export pumping capacity is 4,600 cfs, but the Delta-Mendota Canal (DMC) capacity is limited to 4,200 cfs in December-March without deliveries for irrigation. For evaluation of 1995 WQCP standards, SWP export capacity is assumed by DWR to be 6,680 cfs. The combined CVP and SWP export pumping capacity is therefore 11,280 cfs for April-November and 10,880 cfs for December-March.

DWR currently operates the four new pumps at the SWP Banks Pumping Plant within the general provisions of U.S. Army Corps of Engineers (Corps) regulations under Section 10 of the Rivers and Harbors Act of 1899. Corps public notice 5820A (amended October 13, 1981) includes a provision to allow pumping of 33% of the total San Joaquin River daily inflow, if the inflow exceeds 1,000 cfs during the period of December 15 to March 15, up to the SWP export capacity of 10,300 cfs. Increased water elevations in the southern Delta during periods of high San Joaquin River inflow are apparently the basis for allowing increased SWP exports.

The net effect of daily San Joaquin River inflows and daily Clifton Court Forebay gate capacity (as currently operated) on increased monthly average export pumping is somewhat uncertain. Actual pumping rates during periods of high San Joaquin River inflow in 1993 led DWR to increase the estimated monthly simulated maximum to 8,500 cfs.

In DeltaSOS, the San Joaquin River inflow provision is simulated by allowing a specified fraction of monthly San Joaquin River inflow, if greater than a specified minimum (1,000 cfs), to be exported in addition to the specified export pumping limits. In these months, DeltaSOS simulates the total allowable pumping as the specified pumping limit plus the specified allowable export of the San Joaquin River flow, up to the maximum capacity given in the last column of the export pumping matrix. The January-February capacity with 8,500 cfs of SWP pumping is 12,700 cfs. The December and March capacity is 11,700 cfs.

Full capacity for combined CVP and SWP export pumping could be simulated with matrix values of 14,500 cfs (December-March) and 14,900 cfs (balance of year). DeltaSOS does not allocate the Delta pumping between the CVP and SWP projects and therefore does not require rules to satisfy COA provisions. CCWD diversions are specified as inputs and are not adjusted in DeltaSOS; CCWD diversions are considered separately from CVP exports at the Tracy Pumping Plant.

The DeltaSOS export pumping limits apply solely to allowable direct diversions from the southern Delta. Such direct southern Delta diversions would be in addition to the exports of the Hood diversions (if simulated) less any required releases of Hood diversions back to the Delta (if simulated). The specified pumping limits control direct exports, and net Hood diversions (if simulated) can augment total export, as constrained by the physical pumping limits specified in the monthly pumping matrix.

In addition to these permitted Delta export pumping capacities, the 1995 WQCP sets monthly export pumping limits for the CVP and SWP pumping plants as a specified fraction of Delta inflow. These export pumping limit fractions are specified in another DeltaSOS input matrix. The February fraction of 0.35 is increased to 0.45 if the January runoff value is less than 1 MAF. These "percent of inflow" criteria are an additional constraint on pumping; often Delta outflow requirements or permitted pumping capacity will limit exports to less than the allowable percent of inflow. A sixth column is used to specify the allowable export fraction for discharges made from the in-Delta storage facilities for export.

The WQCP places additional limits on pumping during a 30-day April-May pulse-flow period. During this period, the maximum export pumping is limited to the San Joaquin River inflow. In DeltaSOS simulations, it is assumed that the pulse flow is split equally between April and May. The pulse flow, as specified in the Vernalis flow input matrix, controls pumping during half of April and May. Pumping during the other half of April and May is limited to 35% of Delta inflow. DeltaSOS splits the monthly San Joaquin River inflow into the pulse flow and base flow for estimating allowable exports and available water for diversions to in-Delta storage.

Operation of the Suisun Marsh Salinity Control Gate

The Suisun Marsh salinity control gate was constructed to maintain more suitable salinity in Suisun Marsh by allowing diversion of Sacramento River flow into the marsh on ebb tide and blocking movement of water from the marsh to the Sacramento River during flood tide. This tidal gate operation scheme produces a net flow into Montezuma Slough from the Sacramento River at Collinsville. In the DeltaSOS input standards matrix, the user specifies whether the gate is operating (1 = operating) each month of each year type.

DeltaSOS estimates net flow through Montezuma Slough as a function of total Delta outflow at Collinsville, based on results from the RMA Delta hydrodynamic model. The RMA Delta model indicates that approximately 2% of total Delta outflow at Collinsville enters Suisun Marsh through Montezuma Slough when the gates are open (i.e., not operating) throughout the tidal cycle. The RMA hydrodynamic model results indicate that when the Suisun Marsh salinity control gate is operated, a net flow of about 2,200 cfs plus 0.5% of total Delta outflow enter Suisun Marsh through Montezuma Slough. This net Montezuma Slough flow can be a significant portion of total Delta outflow at relatively low outflow values.

The Delta salinity effects of the diversion of Delta outflow into Montezuma Slough have not been estimated. With regard to salinity control at Chipps Island, DWR estimates that the effective diversion of outflow through Montezuma Slough may only be 15% of the actual diversion, because most of the diversion flow returns as outflow into Suisun Bay (Russell pers. comm.).

DeltaSOS allows an effective Montezuma Slough diversion fraction to be specified by the user. DeltaSOS also provides a switch to allow Montezuma Slough diversions to be reduced if an outflow deficit is calculated, thus preventing diversions of Delta outflow to Montezuma Slough from causing a potential Delta outflow deficit.

In-Delta Storage Facility

DeltaSOS simulates the possible operations of in-Delta water storage facilities that would be operated to divert excess Delta inflows to temporary or seasonal storage in the Delta, and to then discharge the stored water for Delta outflow or for export during periods with available CVP or SWP pumping capacity.

DeltaSOS requires five input matrices to simulate possible operations of an in-Delta storage facility. The first matrix specifies the maximum end-of-month storage volume (in units of thousands of acre-feet [TAF]). This matrix can be used to specify seasonal as well as year-round storage volumes for each water-year type.

A second input matrix specifies the monthly assumed evaporation losses from the storage facility (TAF units). The matrix specifies the assumed monthly reductions in Delta channel depletion that result from conversion of Delta islands from agricultural production to a water storage facility. Anticipated adjustments in Delta water use patterns, such as addition of seasonal wetland flooding, are also specified in this column.

A third input matrix is used to specify the maximum average monthly diversion rate (cfs units) when storage capacity and available Delta inflow exist. (Water allowable for export under the 1995 WQCP is the lesser of the amount specified by the export limits [under the "percent of inflow" criterion] and the amount remaining after outflow requirements have been satisfied. Available inflow [inflow available for diversion] is any portion of allowable export that cannot be pumped with the permitted CVP and SWP pumping rate.) DeltaSOS uses a separate monthly column of parameters to specify the fraction of calculated available Delta inflow that can be diverted to the simulated in-Delta storage facility, with a specified minimum excess Delta inflow that acts as a buffer for Delta storage operations.

The fourth input matrix for in-Delta storage facility operations specifies the maximum monthly discharge rate. Discharge from Delta storage could be used for increasing Delta outflow or for increasing Delta export pumping. DeltaSOS calculates discharge from storage for Delta export according to the specified DeltaSOS parameters.

The fifth input matrix for in-Delta storage facility operations specifies any required discharge for Delta outflow. If storage is available, this specified release is required before DeltaSOS allows any export of the water from the in-Delta storage facility.

CALCULATED EFFECTS OF DELTA STANDARDS ON DELTA OPERATIONS

DeltaSOS tests each input matrix against calculated Delta channel flows for each month of the simulation period. If a specified standard is not satisfied, some action within the Delta would be required to meet the specified standard. DeltaSOS identifies several options for satisfying the specified standards if they are not met. DeltaSOS then calculates the incremental effects of each specified standard on Delta conditions.

The following sections describe the possible options in DeltaSOS for satisfying Delta standards and calculating the resulting incremental effects for each standard. Each output column in DeltaSOS is described. Table A2-3 provides a summary description of each DeltaSOS input and output variable.

Freeport Inflows

Freeport minimum flows are used to specify required flows to assist the migration of salmon and the transport of striped bass eggs and larvae. The only realistic way to provide these flows, when they do not occur naturally from storm runoff, is to increase upstream reservoir releases. DeltaSOS calculates the increase in the initial Sacramento River inflow that would be needed to provide the specified Freeport flows. The flow requirement, the incremental flow needed to satisfy the requirement, and the resulting Sacramento flow are reported in DeltaSOS output columns.

DeltaSOS itself does not simulate upstream reservoir storage and releases and does not adjust subsequent Delta inflows. Therefore, the increased inflows calculated by DeltaSOS are, in a sense, "imaginary water". As long as the required additional inflows are relatively small, however, additional inflows to satisfy flushing-flow requirements can likely be provided by modified upstream reservoir storage operations.

If DeltaSOS uses a planning model simulation that already includes these specified Sacramento flows in its initial Delta water budget, further adjustment in the Sacramento River inflow values will not be needed. If such a planning model simulation is not available, DeltaSOS provides a tool for estimating the magnitude of various potential flushing-flow requirements at Freeport.

Hood Diversions and Transfer Facility Operation

In DeltaSOS simulations, potential diversions from the Sacramento River at Hood can be limited by four operational constraints. Because diversions at Hood would reduce Sacramento River flow downstream, diversions from the Sacramento River into Sutter and Steamboat Sloughs, diversions into the DCC and Georgiana Slough, and Rio Vista flows would be reduced. Hood diversions, Sacramento River flow below the Hood diversions, and releases of Hood diversions back to the Delta are reported in DeltaSOS output columns.

Sacramento River Diversions to Steamboat and Sutter Sloughs, the DCC, and Georgiana Slough

Once DeltaSOS determines the DCC and Georgiana Slough gate status according to the gate control input matrices, DeltaSOS calculates Steamboat and Sutter Slough diversions, DCC flow, and DCC plus Georgiana Slough flow to the central Delta. The Steamboat and Sutter Slough, DCC, and Georgiana Slough channel flow calculations in DeltaSOS are based on results from the RMA Delta hydrodynamic model that show the division of flow from the Sacramento River to these side channels. The flow splits used in DeltaSOS are similar but not identical to the linear estimates used in DAYFLOW for the DCC and Georgiana Slough.

Rio Vista Minimum Flows

DeltaSOS calculates the Sacramento River flow at Rio Vista as the Sacramento River flow not diverted at Hood (if simulated) and not diverted into the DCC and Georgiana Slough, plus inflow from the Yolo Bypass. Diversions into Sutter and Steamboat Sloughs reenter the Sacramento River at Rio Vista. If the Rio Vista flow standard is not satisfied and the DCC is not already closed, DeltaSOS reduces the estimated DCC flow to increase the flow remaining in the Sacramento River. Because of the hydraulic relationship between DCC and Georgiana Slough flows, however, the DCC reduction must be greater than the required Rio Vista increase. Because Georgiana Slough diverts about 25% of Sacramento River flow, approximately 25% of the DCC diversion reduction will be diverted into Georgiana Slough. Calculated DCC reductions are reported in an output column along with the Rio Vista flows.

If a flow deficit remains at Rio Vista with the DCC closed, DeltaSOS does not further increase Sacramento River inflows. The Rio Vista flow deficit is reported as a separate column in the simulation results and could be used to adjust the Sacramento River inflow. The effects of operation of a potential Georgiana Slough gate can be simulated by changing the input matrix for the simulated Georgiana Slough gate. If the Rio Vista flow deficits are large, however, use of an initial water budget based on another planning model simulation may be required to better satisfy the specified Rio Vista flow standards.

Vernalis Inflows

Additional inflow that may be needed to satisfy the D-1422 TDS standard of 500 mg/l, additional EC standards, or flushing-flow requirements will have to be released from upstream reservoirs. The Vernalis flow requirement, the incremental increase in the initial San Joaquin River inflow needed to satisfy the requirement, and the resulting Vernalis flow are reported in DeltaSOS output columns.

Because DeltaSOS cannot simulate changes in upstream reservoir storage and cannot adjust subsequent San Joaquin River inflows, DeltaSOS is required to simulate "imaginary water". Use of an initial Delta water budget for DeltaSOS based on a planning model simulation that already includes these specified Vernalis flows will avoid further adjustment in the San Joaquin River inflow values.

QWEST Flows

DeltaSOS estimates initial QWEST flow after the adjusted DCC and Georgiana Slough flows have been calculated. QWEST as estimated in DAYFLOW is equal to the sum of the flows in the San Joaquin River, the eastside streams, the DCC, and Georgiana Slough; minus the SWP and CVP exports and CCWD diversions; and minus about 65% of the estimated Delta channel depletions. If DeltaSOS simulates Hood diversions, those diversions may also change QWEST values by reducing DCC and Georgiana Slough diversions, reducing direct exports, and releasing water to southern Delta channels. The initial QWEST flow and the QWEST requirement are reported in DeltaSOS output columns.

If DeltaSOS estimates the QWEST flow to exceed the minimum monthly QWEST standard, no adjustments are required. If the QWEST estimate is less than the QWEST standard, however, DeltaSOS calculates the export pumping reduction required to satisfy the QWEST minimum flow for each month and reports these reductions in an output column. A combination of DCC closure requirements and relatively high QWEST limits could result in large export pumping reductions.

Delta Outflow

DeltaSOS calculates the total Delta outflow at Collinsville, recognizing export reductions resulting from specified QWEST standards. The net effective diversion through the Suisun Marsh salinity control gate into Montezuma Slough is estimated from the total Delta outflow at Collinsville. Remaining Delta outflow at Chipps Island is calculated as the difference. DeltaSOS then compares the outflow past Collinsville or Chipps Island with the applicable minimum outflow standard. The minimum required outflow consists of a combination of the monthly standard matrix, calculations using the OUTQ matrix, and the X2-position standards for estuarine habitat. The initial Collinsville and Chipps Island outflow, along with the required Delta outflow, are reported as DeltaSOS output columns.

When calculated outflow is less than the required minimum value, DeltaSOS provides two options for satisfying the outflow deficits. The first option consists of modifying the operation of the Suisun Marsh salinity control gate to increase Delta outflow if the specified outflow standard is to be met at Chipps Island. The second option is to reduce exports to a specified minimum value to provide greater Delta outflow. Both the revised Montezuma Slough flow and reductions in export pumping for outflow are reported in DeltaSOS output columns.

Outflow deficits may remain, especially if the specified outflow requirements differ greatly from those used in the initial water budget for DeltaSOS (e.g., from planning model results). The outflow deficit may also be reduced by export pumping limits. Any remaining outflow deficits are reported in a DeltaSOS output column.

DeltaSOS cannot determine the ability of upstream reservoirs to supply the additional releases needed to satisfy remaining calculated outflow deficits. DeltaSOS can, however, evaluate the incremental requirements of various outflow standards.

Export Pumping Adjustments

DeltaSOS calculates the CVP and SWP export pumping limits as the combination of fixed pumping limits, allowable increases in SWP pumping of San Joaquin River inflow, and "percent of inflow" criteria. The 1995 WQCP restrictions during the April-May San Joaquin River pulse-flow period are also calculated in DeltaSOS. If Hood diversions are simulated, the total export limits are considered to apply to direct export pumping from the southern Delta. The full specified export pumping capacity is assumed to be available for total exports, the combination of direct pumping and Hood diversions. The "percent of inflow" export limits and the export reductions needed to satisfy the combined pumping limits are reported in DeltaSOS output columns.

DeltaSOS includes an option to increase initial export pumping rates if available water can be exported within the specified pumping limits. The possibility of increased export pumping is based on assumptions that annual export demands are likely to be greater than amounts of water available for export in the future, and that south-of-Delta facilities needed to store exported water are likely to become available.

DeltaSOS simulation of maximum possible Delta exports is based on the assumption that all available water within the specified export pumping limits will be exported as long as QWEST and Delta outflow standards remain satisfied. DeltaSOS reports the additional export of available water as positive values in the monthly net export change column of DeltaSOS output. These simulated maximum possible exports may not be realistic during wet years if available south-of-Delta storage is full and full deliveries of water are being made. The direct export and total export (including Hood diversions) are reported in output columns. The revised QWEST flow and Delta outflow are reported as DeltaSOS columns.

Simulating the export of all available water eliminates the possibility of a new in-Delta storage facility diverting water that could have been pumped by the CVP or SWP pumps, which have senior water rights. DeltaSOS simulates the maximum possible export pumping within the specified standards and choices for reducing outflow deficits prior to allowing diversions to or discharges from an in-Delta storage facility for export.

The planning models may simulate increased required Delta outflow with assumed carriage water requirements needed to satisfy export salinity standards. Carriage water estimates may limit the increased allowable export pumping. The following section explains the DWR carriage water calculations.

Carriage Water Calculations

Carriage water is a concept traditionally used to represent additional Delta outflow required to maintain acceptable chloride concentrations in export water as Delta exports are increased. With relatively low San Joaquin and eastside stream inflow, Sacramento River inflow must be increased to supply increased exports and maintain the required Delta outflow.

Flow is transported along three pathways from the Sacramento River to supply increased export pumping. Some of the Sacramento flow is diverted into the DCC and Georgiana Slough. For example, the following is DWR's DAYFLOW equation with the DCC represented as open:

$$\text{DCC and Georgiana Slough flow (cfs)} = 2{,}090 + 0.293 \cdot \text{Freeport flow (cfs)}$$

The remaining Sacramento River flow at Rio Vista is therefore:

$$\text{Rio Vista flow (cfs)} = 0.707 \cdot \text{Freeport flow (cfs)} - 2{,}090$$

Similar equations are used by DWR when the DCC is closed; less water is diverted from the Sacramento River when the DCC is closed:

$$\text{Georgiana Slough flow (cfs)} = 829 + 0.133 \cdot \text{Freeport flow (cfs)}$$

and

$$\text{Rio Vista flow (cfs)} = 0.867 \cdot \text{Freeport flow (cfs)} - 829$$

Increased export pumping that is not supplied from the DCC and Georgiana Slough must enter the central Delta from the Sacramento River through Threemile Slough or from the lower San Joaquin River channel as reversed flow from Antioch. This required flow is referred to as reverse QWEST flow needed to supply the exports.

DWR carriage water calculations are based on the assumption that 80% of the required reverse QWEST flow comes from Antioch while 20% comes through Threemile Slough (DWR 1987). The RMA Delta hydrodynamic model results indicate, however, that Threemile Slough flow is more accurately described by the following equation:

$$\text{Threemile Slough flow (cfs)} = 0.23 \cdot \text{Rio Vista flow} - 0.31 \cdot \text{QWEST}$$

The assumed hydraulic behavior of Threemile Slough flow is an important aspect of DWR's carriage water calculations. The UVM recently installed by USGS in Threemile Slough will soon provide a continuous record of tidal flows, so that net flow can be estimated directly. In the meantime, available results from the RMA Delta model are considered reliable because they are based on measured channel geometry and friction coefficients that have generally accepted values. Similar results are obtained from the Fischer Delta Model (Denton pers. comm.).

DWR estimates that carriage water may be required whenever QWEST is negative. As exports are increased, a larger fraction of exports must be supplied from the vicinity of Antioch or Emmaton, with the possibility that the salinity of exports will be higher than that of Sacramento River diversions to the DCC and Georgiana Slough. The RMA model results indicate that Threemile Slough flow may, however, supply the entire reversed QWEST flow without any reversed flow between Antioch and Jersey Point.

The relationship between monthly average CCWD chloride concentration measurements and effective Delta outflow is well described with a negative exponential equation (Denton 1993). The effective outflow is a relatively simple way to include the effects of antecedent (previous) outflow conditions, similar to the G-model described by CCWD (1994). This month's effective outflow can be estimated as a function of this month's outflow and last month's effective outflow:

$$\text{Effective outflow (cfs)} = \text{EO (previous month)} + (\text{outflow [cfs]} - \text{EO})\,(1 - \exp[-\text{EO}/15{,}000])$$

The monthly CCWD intake chloride data can be summarized as follows:

$$\text{CCWD intake Cl}^- \text{ (mg/l)} = 1{,}667 \cdot \exp(-.0005 \cdot \text{EO}) + 15$$

The observed CCWD chloride data, as summarized by this equation, indicate that the effective Delta outflow must be maintained at about 4,000 cfs throughout the year to satisfy the 250-mg/l chloride standard, with a variable number of months of 5,000-cfs outflow required to satisfy the 150 mg/l chloride requirements in the 1995 WQCP. These estimates are much lower than the "carriage water" requirements currently calculated by DWRSIM, and do not increase with pumping or with negative QWEST flows. DeltaSOS can assume any specified fraction of DWR-estimated carriage water requirements, which are included as DeltaSOS inputs.

Available Flow for In-Delta Diversions

Once the adjustments in direct exports have been calculated, DeltaSOS calculates the available water for possible diversion to an in-Delta storage facility. Available water is calculated as the allowable export determined using the "percent of Delta inflow" criterion that is not needed to satisfy outflow requirements or QWEST standards and that cannot be pumped at the SWP and CVP pumping plants because of pumping rate limits. The available water for diversion is calculated as the minimum of excess Delta outflow, excess QWEST flow, and excess allowable export according to the "percent of inflow" and San Joaquin River pulse-flow restrictions. The available water for diversion is reported as a DeltaSOS output column.

In-Delta Storage Facility Operation

DeltaSOS calculates the operation of an in-Delta storage facility according to the control input matrices described above. The possible diversions to increase storage are limited by the available flow for diversion, the remaining in-Delta storage capacity, and the specified maximum diversion rate.

The possible discharges for export pumping are limited by the available in-Delta storage, the specified discharge flow capacity, the aqueduct conveyance capacity that can be specified in the DeltaSOS inputs, and the selected options for calculating allowable export of in-Delta storage discharges.

The possible discharges for Delta outflow are simulated according to the specified input matrix controlling releases for outflow, and the selected options for calculating allowable export of the in-Delta storage discharges, which may require additional releases for outflow.

DeltaSOS reports end-of-month storage (TAF), diversions, discharges for export, and discharges for outflow in output columns. Final total export, QWEST flow, and Delta outflow are reported as output columns. The DeltaSOS flow estimates for Threemile Slough, Antioch, and head of Old River diversions from the San Joaquin River and the combined Old River and Middle River flows are also given as output columns. The final output columns of DeltaSOS provide calculations of the X2 position (km) and estimated Delta export chloride concentration (mg/l).

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Table A2–1. DeltaSOS User–Defined Standards for the 1995 WQCP

Minimum required Sacramento River flow at Freeport (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Sacramento River trigger for the Delta Cross Channel (cfs) (closed if Sac flow below Hood>value)

	Wet	Above Normal	Below Normal	Dry	Critical	
Oct	25,000	25,000	25,000	25,000	25,000	
Nov	0	0	0	0	0	Half–time
Dec	0	0	0	0	0	Half–time
Jan	0	0	0	0	0	Half–time
Feb	0	0	0	0	0	
Mar	0	0	0	0	0	
Apr	0	0	0	0	0	
May	0	0	0	0	0	
Jun	25,000	25,000	25,000	25,000	25,000	
Jul	25,000	25,000	25,000	25,000	25,000	
Aug	25,000	25,000	25,000	25,000	25,000	
Sep	25,000	25,000	25,000	25,000	25,000	

Minimum Rio Vista flow (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	4,000	4,000	4,000	4,000	3,000
Nov	4,500	4,500	4,500	4,500	3,500
Dec	4,500	4,500	4,500	4,500	3,500
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	3,000	3,000	3,000	3,000	3,000

Minimum QWEST flow (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Nov	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Dec	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Jan	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Feb	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Mar	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Apr	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
May	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Jun	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Jul	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Aug	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)
Sep	(15,000)	(15,000)	(15,000)	(15,000)	(15,000)

Table A2–1. Continued

Minimum San Joaquin River flow at Vernalis (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical	
	7,330	5,730	4,620	4,020	3,110	Pulse–flow requirements
Oct	1,500	1,500	1,500	1,500	1,000	
Nov	900	900	900	900	900	
Dec	900	900	900	900	900	
Jan	900	900	900	900	900	
Feb	2,130	2,130	1,420	1,420	900	
Mar	2,130	2,130	1,420	1,420	900	
Apr	2,130	2,130	1,420	1,542	900	
May	2,130	2,130	1,420	1,420	900	
Jun	2,130	2,130	1,420	1,420	900	
Jul	900	900	900	900	900	
Aug	900	900	900	900	900	
Sep	900	900	900	900	900	
	1,290	1,290	860	860	430	Additional flow if X2<Chipps

Maximum percentage of San Joaquin River flow available for SWP export (%)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	17	17	17	17	17
Jan	33	33	33	33	33
Feb	33	33	33	33	33
Mar	17	17	17	17	17
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

San Joaquin River trigger for Old River gates (cfs) (open if SJR flow at Vernalis>value)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	10,000	10,000	10,000	10,000	10,000
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	10,000	10,000	10,000	10,000	10,000
May	10,000	10,000	10,000	10,000	10,000
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Minimum Delta outflow (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	4,000	4,000	4,000	4,000	3,000
Nov	4,500	4,500	4,500	4,500	3,500
Dec	4,500	4,500	4,500	4,500	3,500
Jan	4,500	4,500	4,500	4,500	4,500
Feb	7,100	7,100	7,100	7,100	7,100
Mar	7,100	7,100	7,100	7,100	7,100
Apr	7,580	7,580	7,580	7,580	7,100
May	7,580	7,580	7,580	7,580	4,000
Jun	7,580	7,580	6,845	6,120	4,000
Jul	8,000	8,000	6,500	5,000	4,000
Aug	4,000	4,000	4,000	3,500	3,500
Sep	3,000	3,000	3,000	3,000	3,000

Table A2–1. Continued

Maximum Delta export (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical	DW Exemption	Assumed Capacity
Oct	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Nov	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Dec	10,880	10,880	10,880	10,880	10,880	10,880	11,700
Jan	10,880	10,880	10,880	10,880	10,880	10,880	12,700
Feb	10,880	10,880	10,880	10,880	10,880	10,880	12,700
Mar	10,880	10,880	10,880	10,880	10,880	10,880	11,700
Apr	11,280	11,280	11,280	11,280	11,280	11,280	11,280
May	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Jun	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Jul	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Aug	11,280	11,280	11,280	11,280	11,280	11,280	11,280
Sep	11,280	11,280	11,280	11,280	11,280	11,280	11,280

Maximum percentage of inflow available for export (%)

	Wet	Above Normal	Below Normal	Dry	Critical	DW
Oct	65	65	65	65	65	65
Nov	65	65	65	65	65	65
Dec	65	65	65	65	65	65
Jan	65	65	65	65	65	65
Feb	35	35	35	35	35	35
Mar	35	35	35	35	35	35
Apr	35	35	35	35	35	35
May	35	35	35	35	35	35
Jun	35	35	35	35	35	35
Jul	65	65	65	65	65	65
Aug	65	65	65	65	65	65
Sep	65	65	65	65	65	65

Status of Suisun Marsh salinity control gates (0 = open, 1 = operating)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	1	1	1	1	1
Nov	1	1	1	1	1
Dec	1	1	1	1	1
Jan	1	1	1	1	1
Feb	1	1	1	1	1
Mar	1	1	1	1	1
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Maximum capacity of in–Delta storage facility (TAF)

	Wet	Above Normal	Below Normal	Dry	Critical	2–Island Evaporation	4–Island Evaporation
Oct	238	238	238	238	238	3.3	6.5
Nov	238	238	238	238	238	1.5	3.0
Dec	238	238	238	238	238	0.8	1.6
Jan	238	238	238	238	238	0.9	1.8
Feb	238	238	238	238	238	1.7	3.4
Mar	238	238	238	238	238	3.0	6.0
Apr	238	238	238	238	238	4.5	9.0
May	238	238	238	238	238	6.1	12.2
Jun	238	238	238	238	238	7.0	14.0
Jul	238	238	238	238	238	8.0	16.0
Aug	238	238	238	238	238	7.1	14.2
Sep	238	238	238	238	238	5.2	10.4

Table A2-1. Continued

Evaporation from in-Delta storage facility (TAF)

	Wet	Above Normal	Below Normal	Dry	Critical	Net CU Reductions	2-Island Net CU	4-Island Net CU
Oct	3.3	3.3	3.3	3.3	3.3	0.0	-0.6	2.5
Nov	1.5	1.5	1.5	1.5	1.5	0.0	-0.7	1.8
Dec	0.8	0.8	0.8	0.8	0.8	0.0	-1.3	0.9
Jan	0.9	0.9	0.9	0.9	0.9	0.0	0.9	1.1
Feb	1.7	1.7	1.7	1.7	1.7	0.0	1.3	2.3
Mar	3.0	3.0	3.0	3.0	3.0	0.0	4.5	3.4
Apr	4.5	4.5	4.5	4.5	4.5	0.0	3.0	4.4
May	6.1	6.1	6.1	6.1	6.1	0.0	3.7	6.2
Jun	7.0	7.0	7.0	7.0	7.0	0.0	4.1	7.8
Jul	8.0	8.0	8.0	8.0	8.0	0.0	4.8	9.2
Aug	7.1	7.1	7.1	7.1	7.1	0.0	3.7	7.1
Sep	5.2	5.2	5.2	5.2	5.2	0.0	1.5	4.1

Maximum diversion to in-Delta storage facility (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical	Required Delta Outflow	Required QWEST Flow
Oct	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Nov	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Dec	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Jan	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Feb	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Mar	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Apr	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
May	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Jun	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Jul	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Aug	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Sep	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)

Maximum discharge from in-Delta storage facility (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical	Required Delta Outflow	Required QWEST Flow
Oct	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Nov	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Dec	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Jan	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Feb	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Mar	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Apr	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
May	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Jun	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Jul	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Aug	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)
Sep	4,000	4,000	4,000	4,000	4,000	3,000	(15,000)

Discharge to outflow from in-Delta storage facility (cfs)

	Wet	Above Normal	Below Normal	Dry	Critical
Oct	0	0	0	0	0
Nov	0	0	0	0	0
Dec	0	0	0	0	0
Jan	0	0	0	0	0
Feb	0	0	0	0	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	0	0	0	0
Jun	0	0	0	0	0
Jul	0	0	0	0	0
Aug	0	0	0	0	0
Sep	0	0	0	0	0

Table A2-2. Delta Outflow Requirements under the 1995 WQCP Estuarine Salinity Standards

A. Previous Month's X2 Upstream of Roe Island Trigger Position

Monthly 8-River Index[a] (TAF)	Outflow (cfs)					
	Jan	Feb	Mar	Apr	May	Jun
0	4,500	7,100	7,100	7,100	7,100	7,100
250	4,500	7,100	7,100	7,100	7,100	7,100
500	4,500	11,400	7,100	7,100	7,100	7,100
750	4,500	11,400	7,100	7,100	7,100	7,100
1,000	6,000	11,400	8,765	7,387	7,100	7,100
1,250	6,000	11,400	11,400	7,960	7,100	7,100
1,500	6,000	11,400	11,400	8,963	7,100	7,100
1,750	6,000	11,400	11,400	9,967	7,100	7,100
2,000	6,000	11,400	11,400	10,683	7,239	7,100
2,250	6,000	11,400	11,400	10,970	7,516	7,100
2,500	6,000	11,400	11,400	11,257	8,626	7,243
2,750	6,000	11,400	11,400	11,257	9,874	7,387
3,000	6,000	11,400	11,400	11,400	10,845	7,673
3,250	6,000	11,400	11,400	11,400	11,123	8,247
3,500	6,000	11,400	11,400	11,400	11,261	8,963
3,750	6,000	11,400	11,400	11,400	11,400	9,680
4,000	6,000	11,400	11,400	11,400	11,400	10,397
4,250	6,000	11,400	11,400	11,400	11,400	10,683
4,500	6,000	11,400	11,400	11,400	11,400	10,970
4,750	6,000	11,400	11,400	11,400	11,400	11,113
5,000	6,000	11,400	11,400	11,400	11,400	11,257
5,250	6,000	11,400	11,400	11,400	11,400	11,257
5,500	6,000	11,400	11,400	11,400	11,400	11,400
5,750	6,000	11,400	11,400	11,400	11,400	11,400
6,000	6,000	11,400	11,400	11,400	11,400	11,400
6,250	6,000	11,400	11,400	11,400	11,400	11,400
6,500	6,000	11,400	11,400	11,400	11,400	11,400
6,750	6,000	11,400	11,400	11,400	11,400	11,400
7,000	6,000	11,400	11,400	11,400	11,400	11,400
7,250	6,000	11,400	11,400	11,400	11,400	11,400
7,500	6,000	11,400	11,400	11,400	11,400	11,400
7,750	6,000	11,400	11,400	11,400	11,400	11,400
8,000	6,000	11,400	11,400	11,400	11,400	11,400
8,250	6,000	11,400	11,400	11,400	11,400	11,400
8,500	6,000	11,400	11,400	11,400	11,400	11,400
8,750	6,000	11,400	11,400	11,400	11,400	11,400
9,000	6,000	11,400	11,400	11,400	11,400	11,400
9,250	6,000	11,400	11,400	11,400	11,400	11,400
9,500	6,000	11,400	11,400	11,400	11,400	11,400
9,750	6,000	11,400	11,400	11,400	11,400	11,400
10,000	6,000	11,400	11,400	11,400	11,400	11,400

B. Previous Month's X2 Downstream of Roe Island Trigger Position

Monthly 8-River Index[a] (TAF)	Outflow (cfs)					
	Jan	Feb	Mar	Apr	May	Jun
0	4,500	7,100	7,100	7,100	7,100	7,100
250	4,500	7,889	7,100	7,100	7,100	7,100
500	4,500	10,257	7,813	7,100	7,100	7,100
750	4,500	13,414	8,526	7,100	7,100	7,100
1,000	6,000	19,029	11,061	7,387	7,100	7,100
1,250	6,000	20,936	14,845	8,553	7,100	7,100
1,500	6,000	22,843	16,568	9,557	7,100	7,100
1,750	6,000	24,114	18,290	11,153	7,100	7,100
2,000	6,000	24,750	20,013	13,057	7,239	7,100
2,250	6,000	25,386	21,161	13,937	8,090	7,100
2,500	6,000	26,021	22,310	16,003	9,200	7,243
2,750	6,000	26,657	23,458	17,190	11,023	7,387
3,000	6,000	27,293	24,606	18,520	13,142	7,673
3,250	6,000	27,293	25,181	19,707	14,568	8,247
3,500	6,000	27,293	25,755	20,893	16,429	8,963
3,750	6,000	27,929	26,329	22,080	18,290	9,680
4,000	6,000	27,929	26,903	23,267	20,013	10,397
4,250	6,000	27,929	26,903	23,860	21,735	11,277
4,500	6,000	27,929	27,477	25,047	23,458	12,157
4,750	6,000	28,564	27,477	25,640	24,606	12,893
5,000	6,000	28,564	27,477	26,233	25,755	13,630
5,250	6,000	28,564	28,052	26,233	26,329	14,817
5,500	6,000	28,564	28,052	26,827	27,477	16,740
5,750	6,000	28,564	28,052	27,420	27,477	19,113
6,000	6,000	28,564	28,052	27,420	28,052	20,893
6,250	6,000	28,564	28,626	27,420	28,052	22,673
6,500	6,000	28,564	28,626	28,013	28,626	24,453
6,750	6,000	28,564	28,626	28,013	28,626	25,640
7,000	6,000	28,564	28,626	28,013	28,626	26,827
7,250	6,000	28,564	28,626	28,013	28,626	27,420
7,500	6,000	28,564	28,626	28,607	28,626	28,013
7,750	6,000	28,564	28,626	28,607	29,200	28,013
8,000	6,000	28,564	28,626	28,607	29,200	28,607
8,250	6,000	29,200	28,626	28,607	29,200	28,607
8,500	6,000	29,200	28,626	28,607	29,200	28,607
8,750	6,000	29,200	28,626	28,607	29,200	29,200
9,000	6,000	29,200	28,626	28,607	29,200	29,200
9,250	6,000	29,200	28,626	28,607	29,200	29,200
9,500	6,000	29,200	29,200	28,607	29,200	29,200
9,750	6,000	29,200	29,200	29,200	29,200	29,200
10,000	6,000	29,200	29,200	29,200	29,200	29,200

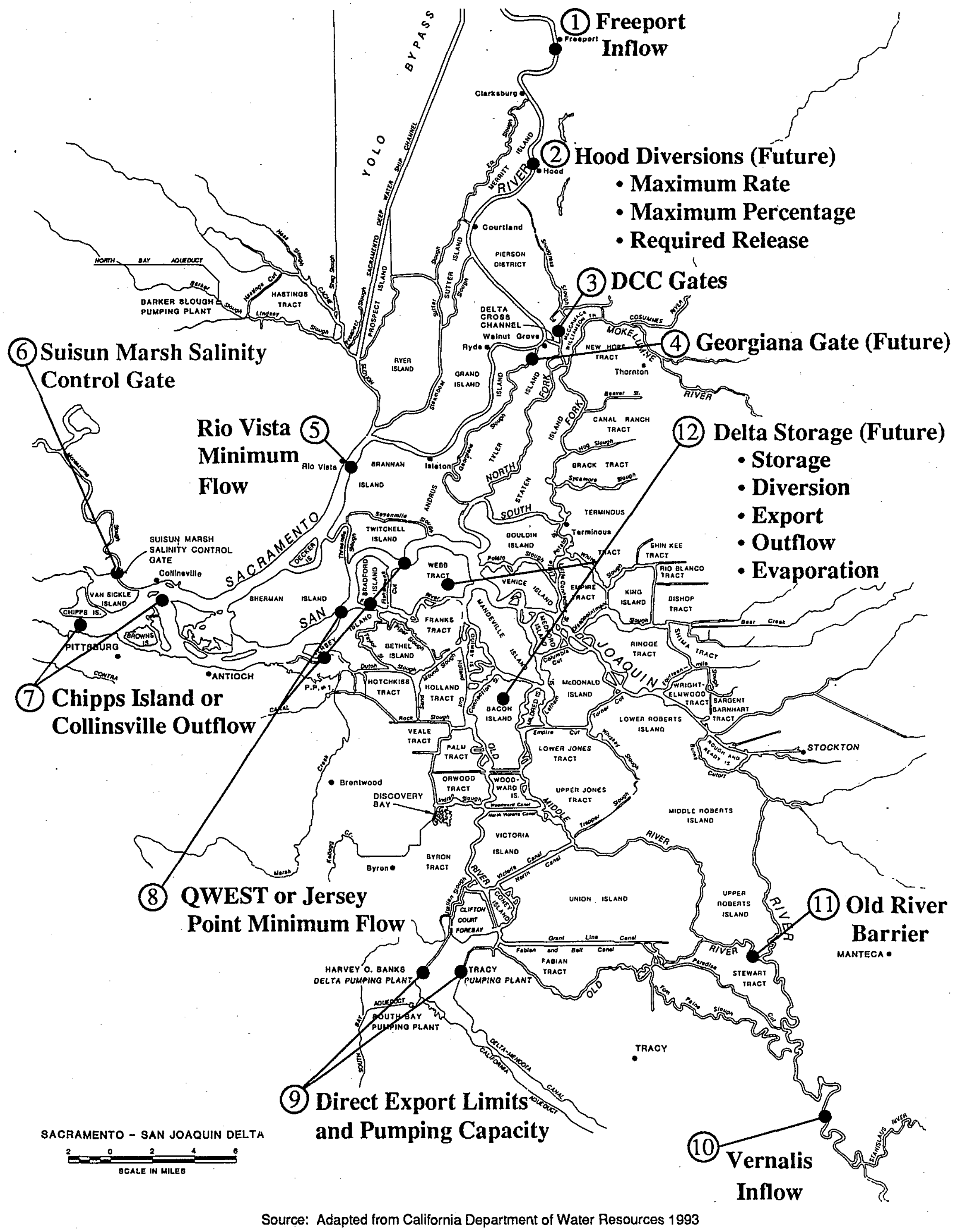
[a] Previous month's runoff volume from DWR's 8-River Index.

Column Label	Description
Fixed Inputs	
Sacramento Valley Four-River Index (TAF) for previous month	Sum of unimpaired flows for Sacramento River at Bend Bridge and the Feather, Yuba, and American Rivers
San Joaquin Valley Four-River Index (TAF) for previous month	Sum of unimpaired flows for San Joaquin River at Friant Dam and the Merced, Tuolumne, and Stanislaus Rivers
Central Valley Eight-River Index (TAF) for previous month	Sum of Sacramento Valley Four-River Index and San Joaquin Valley Four-River Index
Natural Delta (unimpaired) outflow estimate (cfs)	DWR's estimate of unimpaired Delta outflow with no upstream storage or diversions
Initial Delta Water Budget Inputs	
Sacramento River Basin year type	Hydrologic classification for the water year; classified as wet (1), above normal (2), below normal (3), dry (4), or critical (5) based on annual Sacramento Valley unimpaired runoff for Sacramento River at Bend Bridge and the Feather, Yuba, and American Rivers
Subnormal snowmelt	A "1" denotes water year with subnormal snowmelt (D-1485 year-type classification)
San Joaquin River Basin year type	Hydrologic classification for the water year; classified as wet (1), above normal (2), below normal (3), dry (4), or critical (5) based on annual San Joaquin Valley unimpaired runoff for the San Joaquin River at Friant Dam and the Merced, Tuolumne, and Stanislaus Rivers
SWP Banks and CVP Tracy Pumping Plants (cfs)	Sum of Delta exports from SWP Banks and CVP Tracy Pumping Plants
Sacramento River inflow (cfs)	Sacramento River flow at Freeport
Yolo Bypass inflow (cfs)	Yolo Bypass flow to the Delta
CCWD intake (cfs)	CCWD diversions from the Delta
Eastside inflow (cfs)	Sum of flows from the Mokelumne, Calaveras, and Cosumnes Rivers and miscellaneous streams to the Delta
San Joaquin River inflow (cfs)	San Joaquin River at Vernalis
Delta channel depletion (cfs)	Estimated evapotranspiration losses minus rainfall gains for Delta
Delta outflow (cfs)	Total Delta outflow at confluence of Sacramento and San Joaquin Rivers
Carriage water or required Delta outflow (cfs)	Initial estimate of Delta outflow requirements in addition to those specified in Delta outflow standards
Aqueduct wheeling capacity (cfs)	Initial estimate of total available (unused) export aqueduct capacity

Column Label	Description
DeltaSOS Outputs	
DCC Status	A "1" denotes that the DCC gates are simulated to be open
Required SAC flow	Freeport minimum flow required to assist migration of salmon and the transport of striped bass eggs and larvae
Added SAC flow	Additional Sacramento River flow required to meet specified Freeport standards
New SAC flow	The sum of input Sacramento River flow and any additional flow required to meet Freeport standards
Required SJR flow	Vernalis flow required to satisfy salinity standard or flushing-flow requirements
Added SJR flow	Additional San Joaquin River flow required to meet specified Vernalis standards
New SJR flow	The sum of the input San Joaquin River flow and any additional flow required to meet Vernalis standards
Hood Diversion	Diversion from the Sacramento River at Hood specified by Hood diversion control matrices and also limited by Rio Vista and Delta outflow standards
SAC below Hood Flow	Sacramento River flow below the Hood diversion
Hood Releases	Required releases from the Hood diversion to the Mokelumne and San Joaquin River channels
Steam & Sutter Flow	Sacramento River diversion to Steamboat and Sutter Sloughs
DCC Rio Vista Reduction	Reduction of DCC flow (DCC gates partially closed) to increase Sacramento River flow to meet Rio Vista standards
Revised DCC Flow	Calculated DCC flow after any required closure to meet Rio Vista standards
Revised Georgiana & DCC	Combined DCC and Georgiana Slough flow calculated after revisions are made to DCC gate operation
Revised Rio Vista Flow	Sacramento River flow at Rio Vista, including Yolo Bypass inflow
Rio Vista Deficit	Remaining deficit between Rio Vista flow and specified standards
QWEST w/Initial Export	Initial estimate of QWEST flow using calculated DCC & Georgiana flow and initial exports
Required QWEST Flow	QWEST flow required by specified standards
Reduced Export for QWEST	Required reduction of exports to meet specified QWEST standards
Initial Collinsville Outflow	Delta outflow at Collinsville adjusted for export reductions for QWEST standards
Initial Chipps Outflow	Delta outflow at Collinsville minus calculated Montezuma Slough diversion
Required Delta Outflow	Delta outflow required by specified standards

Column Label	Description
Montezuma Flow	Montezuma Slough flow, with reductions required to meet required Delta outflow
Reduced Export for Outflow	Required reduction of exports to meet specified QWEST standards
Export Pumping Limits	Maximum allowable export pumping limits, as controlled by fixed capacity limits and "percent of inflow" criteria, including San Joaquin River pulse-flow restrictions in the 1995 WQCP
Reduced Export for Limits	Required reduction of exports to meet specified export pumping limits
Outflow Deficit	Remaining deficient between Delta outflow and specified Delta outflow standards
Net Export Change	Net calculated change in exports to satisfy specified standards, including allowable increases to specified pumping capacity
Direct Export	Calculated exports diverted from south Delta channels
Total Export	Calculated total exports, including direct export diversions and Hood diversions
Revised QWEST Flow	Revised QWEST flow, including all export adjustments
Revised Delta Outflow	Revised Delta outflow, including all export adjustments
Available Flow	Possible DW diversions that would still meet QWEST and outflow standards within the "percent of inflow" criteria and San Joaquin River pulse-flow restrictions in the 1995 WQCP
Delta Storage (TAF)	End-of-month storage of in-Delta storage facility (e.g., the DW project reservoir islands)
Delta Storage Diversion	Calculated diversions to in-Delta storage facility
Delta Storage Export	Calculated discharges from in-Delta storage facility for export at Delta export pumps
Delta Storage Outflow	Calculated discharges from in-Delta storage facility for Delta outflow
Final Total Export	Calculated total exports, including discharges for export from in-Delta storage facility
Final QWEST Flow	Final QWEST flow, including in-Delta storage diversions and discharges for outflow
Final Delta Outflow	Final Delta outflow, including in-Delta storage diversions and discharges for outflow
3-Mile Slough Flow	Calculated Threemile Slough flow from Sacramento River to San Joaquin River
Antioch Flow	Calculated San Joaquin River flow at Antioch
Old River Diversion Flow	Calculated head of Old River diversion from San Joaquin River
Old River & Middle River Flow	Calculated flow in Old and Middle River channels, between San Joaquin River and export pumping plants
X2 Salinity Position	Estimate of the 2-ppt salinity position (km), relative to the Golden Gate Bridge

Column Label	Description
Export Chloride	Estimate of export chloride concentration (mg/l) obtained from DeltaSOS calculation of seawater intrusion



Source: Adapted from California Department of Water Resources 1993

Figure A2-1.
Locations Where Delta Standards Can Be Specified in the DeltaSOS Model

DELTA WETLANDS
PROJECT EIR/EIS
Prepared by: Jones & Stokes Associates