APPENDIX E

DSM2 Hydrodynamic Modeling Analyses for Site Selection and Performance

Progression of Hydrodynamic Model Deployment and Development

Model Deployment

Early in the analyses process, it was determined that complex delta smelt behavioral models would be required to, with reasonable accuracy, predict distribution, abundance and fate of delta smelt under OCAP and 2-Gates operational conditions. Because the development of such a model would be time-consuming and its success could not be accurately predicted, a decision was made to initially use the One-Dimensional (1D) DSM2 model formulation for hydrodynamic, water quality and particle tracking to determine the most favorable location of gates, their region of control and their benefits under OCAP-modified flow conditions. While this effort was taking place, the RMA team was directed to develop reasonably accurate behavioral model using a Two-Dimensional (2D) RMA formulation, as modified to characterize both the adult and larvae/juvenile dealt smelt behavior. When developed, the 2D behavioral models would be used to determine effects of the 2-Gates Project for environmental documentation purposes under OCAP-adjusted hydrodynamic conditions.

One-Dimensional DSM2 Analyses

<u>Screening of Gate Alternatives, Determination of Region of Control, and Formation of Physical and Hydraulic Barrier Against Delta Smelt Migration.</u>

The above studies used the most recent historic DSM2 simulation available from the Department of Water Resources (DWR) for analyses of 2-Gates and flow control measures. DSM2 analysis (1) evaluated hydrodynamics, fate and transport of neutrally buoyant particles for OCAP BO and 2-Gates scenarios in comparison with the historic conditions, and (2) provided technical analyses of alternatives that provide equal or better protection of delta smelt at reduced water cost compared to OCAP conditions. DSM2 simulates riverine systems, calculates stages, flows, velocities and particle transport; and simulates many mass transport processes, including salts, temperature and THM formation.

<u>One-Dimensional DSM2 Model Numerical Basis.</u>

The partial differential equations of mass and momentum in the DSM2 hydrodynamic model component (HYDRO) are based on an implicit finite difference scheme. As a one-dimensional formulation, the channel length is divided into discrete reaches and the partial differential equations are transformed into finite difference forms for the discrete reaches by integrating numerically in time and space. The resulting equations are then linearized over a single iteration in terms of incremental changes in unknown variables (flow rate and water level) using approximations from truncated series, representing a <u>function</u> as an <u>infinite sum</u> of terms calculated from the values of its <u>derivatives</u> at a single point. When the discretized equations are written for all computational cells at the current time and the next time lines, it forms a system of equations which are solved simultaneously using an implicit algorithm.

The DSM2 water quality numerical solution (QUAL) is based on a model in which advection-dispersion equation is solved numerically using a coordinate system where computational nodes move with the flow. Because of the stability and accuracy of this approach it was used for a network of channels with many branches and junctions. The current version of QUAL simulates about 11 constituents moving in as many as 30 branches connected at junctions. The HYDRO flow model provides the needed information to move the computational nodes with mean channel velocity in the moving coordinate system thus accounting indirectly for advection part of the transport process. The dispersion part, however, is computed directly based on input dispersion coefficient and change in concentration gradient (2nd partial derivative) computed during simulation.

The DSM2 particle tracking component (PTM) computes the location of an individual particle at any time step within a channel based on velocity, flow and water level information provided by HYDRO. The longitudinal movement is based on transverse and vertical velocity profiles computed from mean channel velocity provided by HYDRO. Mean channel velocity is multiplied by a factor which depends on particle's transverse location in the channel resulting in a transverse velocity profile resulting in slower moving particles closer to the shore. Mean channel velocity is also converted to vertical velocity profile using a logarithmic profile to account for slower particles closer to the channel bottom. The longitudinal movement is then the sum of transverse and vertical velocities multiplied by time step. Particles also move across the channel and in vertical direction along the depth due to mixing. A random factor and mixing coefficients and the length of time step is used to compute the movement of particle in transverse and vertical direction.

<u>Initial Site Screening Study using DSM2 Analyses.</u>
DSM2 PTM analyses of 34 individual and combined gate alternatives in the central and south Delta were the basis of determining the optimum locations and number of gates. Two-gates on the Old River near Bacon Island and on Connection Slough provided optimum protection to delta smelt, while reducing water export cuts under OCAP operations. DSM2 analyses determined that other individual or combined gate alternatives provided less favorable water supply and fish protective benefits, channel capacity and geotechnical conditions, including: (1) two-gates on Old River at Quimby Island; (2) three-gates at Connection Slough, Railroad Cut, and Old River below Woodward; (3) four-gates on Connection Slough, Woodward and Railroad Cuts, and Old River below Woodward; (4) selective weir removal on Paradise Cut; (5) a weir on the San Joaquin River downstream of the head of Old River; and (6) Clifton Court Forebay gate tidal re-operations.

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More than 140 PTM analyses using the DSM2 model, determined the 2-Gate Project to be very effective in controlling particle entrainment at the south Delta export facilities for a region largely bounded by the Old River, False River, Dutch Slough and Fisherman's Cut. Circulation patterns developed by one of the principle operations of the 2-Gate facilities (open on flood-tide and closed on ebb-tide) also promotes seaward movement of particles in Old River and away from the pumps. Further, operation of the 2-Gates is expected to improve water quality conditions in the south Delta.

<u>2-Gate and Qwest Studies to form Physical/Hydraulic Control using DSM2 Analyses.</u>
More than 320 PTM analyses determined that the 2-Gates Project operates compatibly with flow management measures on the San Joaquin River generated through OMR restriction during

critical periods. These operations maintained the general distribution of adult delta smelt north and west of the region of control of the gates, forming a physical/hydraulic barrier to upstream smelt migration. Operations of the 2-Gate Project are shown to be consistent with the protective actions proposed by the U.S. Fish and Wildlife Service's OCAP Biological Opinion.

Two-Dimensional RMA-2 Analyses

<u>Real-Time Operations under OCAP using Adult and Larvae/Juvenile Smelt Behavioral Models.</u>

Adult Delta Smelt. To date, all of the modeling for near-term solutions have modeled adult delta smelt as neutrally-buoyant particles. While reasonably accurate for the larval stage, researchers have observed behaviors associated with turbidity and light in the adult stage. Analyses have also shown patterns of salinity and turbidity habitat may correlate with smelt abundance. Scientists have postulated that the adult smelt may be "surfing" the tides as a means of staying within their desirable habitat range. Modeling has been developed to impart habitat seeking behavior on the particles in the RMA-2 model. Once the smelt behavior model reasonably reproduced salvage patterns at the export facilities, additional simulations were done with barriers in the Old River and Connection Slough.

Larvae/Juvenile Delta Smelt. To correlate observed and modeled distributions and abundance of larvae/juvenile delta smelt, the RMA-2 and RMA-PTRK models have evaluated the full larval and juvenile delta smelt period, roughly from March through June, for differing hydrologic years. For each period, hatching rates have been determined by "tuning" to match 20mm survey observations and, if possible, observed salvage. The hatching period and mortality rates used in the simulations have been specified based on published findings from credible researchers. Delta smelt density predictions were compared with 20mm survey observations and the predicted delta smelt salvage was compared with salvage observations at the Skinner Fish Facility and the Tracy Fish Facility. Entrainment at exports, exited (flushed from) Delta, and within Delta were estimated, to determine the fate of fish by region of the Delta.

<u>Two-Dimensional RMA Model Numerical Basis.</u>

Resource Management Associates (RMA) has developed and refined models of the Sacramento-San Joaquin Delta system (Delta model) utilizing the RMA finite element models for surface waters (see Appendix D). The RMA models are a generalized hydrodynamic model that is used to compute two-dimensional depth-averaged velocity and water surface elevation (RMA2) and another model (RMA11) is a generalized two-dimensional depth-averaged water quality model that computes a temporal and spatial description of water quality parameters. RMA11 uses stage and velocity results from RMA2. The Delta model extends from Martinez to the confluence of the American and Sacramento Rivers and to Vernalis on the San Joaquin River. Daily average flows in the model are applied for the Sacramento River, Yolo Bypass, San Joaquin River, Cosumnes River, Mokelumne River, and miscellaneous eastside flows which include Calaveras River and other minor flows. The model interpolates between the daily average flows at noon each day. Delta Islands Consumptive Use (DICU) values address channel depletions, infiltration, evaporation, and precipitation, as well as Delta island agricultural use. DICU values are applied on a monthly average basis and were derived from monthly DSM2 input values. Delta exports applied in the model include SWP, CVP, Contra Costa exports at Rock Slough and Old River intakes, and North Bay Aqueduct intake at Barker Slough. Dayflow and IEP database data are used to set daily average export flows for the CVP, North Bay Aqueduct and Contra Costa's exports.

2-Gate and OCAP Studies for OCAP BO Baseline and 2-Gates Conditions for Adult Delta Smelt using RMA Behavioral Analyses.

Particle simulations with habitat seeking behavior were performed for historic periods. Particles were initially seeded in regions of acceptable habitat at the start of the simulations. Adult delta smelt habitat has been characterized by salinity (EC) and turbidity. Options were added to the model to influence sensitivity to habitat gradients, chance of incorrect directional choices, and resistance to tidal flow velocity. Behavioral characteristics were adjusted to attempt to replicate take at water export facilities. Two-Gates Project operations were compatible with flow management measures of the U.S. Fish and Wildlife Service's OCAP Biological Opinion. Delta smelt distribution, entrainment and fate have been determined using modified operations scenarios for the OCAP BO baseline and OCAP + the 2-Gate Project conditions using the RMA Adult Behavioral Model from December through February for the 2000, 2002, 2004 and 2008 historic periods.

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These simulations used the RMA Bay-Delta Model and RMA-PTRK for passive particle tracking with post processing analysis of hatching and mortality. The hatching rates estimated for historic conditions were applied without modification to the various operations scenarios. Therefore, the effect of the revised operations on delta smelt hatching rate and distribution were reflected in the simulation results. The simulations focused on the effect of the operations on delta smelt distribution and fate after initial hatching. Simulations were conducted roughly from March through June for the 2000, 2002, 2004 and 2008 historic periods. Modified operations scenarios were simulated for revised export flows according to OCAP guidelines and OCAP + the 2-Gates Project to determine delta smelt distribution, entrainment and fate.

Hydrodynamic Analysis of 2-Gates Near-Field Effects

Near-field hydrodynamic analyses have been conducted to assess the effects from the construction and operation of the 2-Gates Project on flood stage in Old River and Connection Slough, and on navigation vessels from velocities and potential scour patterns in the vicinity of the gates. A One-Dimensional hydraulic model was developed to assess changes in flood stage of the gates. The One-Dimensional model was then utilized as the basis for developing localized, Two-Dimensional models representing the immediate vicinity of each gate barrier. Normal- and low-flow simulations were conducted using the One-Dimensional model to generate boundary conditions for the Two-Dimensional models. The higher resolution Two-Dimensional numerical models were developed for the immediate vicinity of each of the gate barriers to assess velocity distributions through and near the gates. These current magnitudes and patterns were used to assess the potential for scour and develop recommendations for the rock aprons and other rip-rap, if needed. Current velocities and patterns were also used to assess any potential effects on navigation.

Progression of DSM2 and RMA Model Deployment and Development

Introduction

Development of the 2-Gates Project has been supported by extensive computer simulation of hydrology, hydraulics, water quality and fish behavior. The following section provides a summary of the progression of the use of some of these models and the results derived from these computer simulations.

Model Deployment

Early in the 2-Gates Project analyses process, it was determined that complex delta smelt behavioral models would be required to, with reasonable accuracy, predict distribution, abundance and fate of delta smelt under OCAP and 2-Gates operational conditions. Because the development of such a model would be time-consuming and its success could not be accurately predicted, a decision was made to initially use the One-Dimensional (1D) DSM2 model formulation for hydrodynamic, water quality and particle tracking to determine the most favorable location of gates, their region of control and their benefits under OCAP-modified flow conditions. While this effort was taking place, the RMA team was directed to develop reasonably accurate behavioral model using a Two-Dimensional (2D) RMA formulation, as modified to characterize both the adult and larvae/juvenile dealt smelt behavior. When developed, the 2D behavioral models would be used to determine effects of the 2-Gates Project for environmental documentation purposes under OCAP-adjusted hydrodynamic conditions.

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To be provided by RMA.

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DSM2 Modeling Analysis for Limiting Entrainment

Introduction

As part of the interim remedy order of December 14, 2007, Judge Wanger imposed restrictions on reverse flows in the south Delta to ensure protection of the Delta Smelt from entrainment. This technical memorandum describes the hydrodynamic and particle entrainment analyses performed on two representative scenarios representing this order. In addition, this memorandum describes the modeling analyses of alternative approaches designed to achieve similar level of particle entrainment reduction at the south Delta pumps as the scenarios in the interim remedy order. Further, the memorandum summarizes the results from the water quality analyses performed on the scenarios and a proposed near-term alternative.

Objectives

The specific objectives of this analysis include:

(i) To evaluate hydrodynamics and fate and transport of neutrally buoyant particles of the Wanger scenarios in comparison with the historic conditions using the DSM2 model.

(ii) To provide technical analyses of potential near-term alternatives that provide similar level of reduction in the particle entrainment at the pumps as the Wanger scenarios.

Scenarios Considered

Methodology

Baseline Simulation

The most recent historic DSM2 simulation available from the Department of Water Resources (DWR) was used for the analyses described in the memorandum. The flow results from the three year (WY 2001 – WY 2003) historic DSM2 simulation were used to describe the baseline for the comparative analysis.

Interim Remedy Order (Wanger) Scenarios

The interim remedy order includes three main actions for Delta Smelt protection. In each of the three main actions, the decision requires the combined Old and Middle River (OMR) flow to be greater than a specified target. Action 1 requires that the 10-day running average OMR flow to be greater than -2,000 cfs for 10-days from the date of commencement of the action or until January 15. Action 2, which would commence immediately after Action 1 or on January 15, requires the 7-day running average OMR flow to be greater than -5000 cfs until February 20. Action 3 commences after the Action 2 and requires the 7-day running average OMR flow to be greater than a range of -750 cfs and -5000 cfs during the months of March through June for the protection of larval and juvenile Delta Smelt. Since, a range of OMR flows are possible for Action 3, two representative Wanger scenarios were simulated, namely Wanger 750 (with -750 cfs criteria) and Wanger 5000 (with -5000 cfs criteria), to evaluate the range of potential restrictions.

The exports specified in the baseline DSM2 simulations were curtailed by an amount equal to the 110 % of the difference between the baseline OMR flow and the OMR flow targets specified in the interim order (as summarized in the above paragraph). The curtailment was specified to be greater than the OMR curtailment (110% as opposed to 100%) since an export curtailment may not reflect an equal, and immediate, increase in OMR flows. This assumption is considered conservative, but does not account for operator behavior which would likely be even more conservative. The 110% was derived based on the MWDSC's OMR flow regression developed by Paul Hutton. Figure E-1 shows the total south Delta exports for the Baseline, Wanger 750 and Wanger 5000 scenarios. The winter and spring exports are significantly reduced under the Wanger scenarios. As shown in Table 1, the average annual exports for the Wanger scenarios decreased by 630 TAF for Wanger 5000 scenario and 1400 TAF for Wanger 750 scenario.

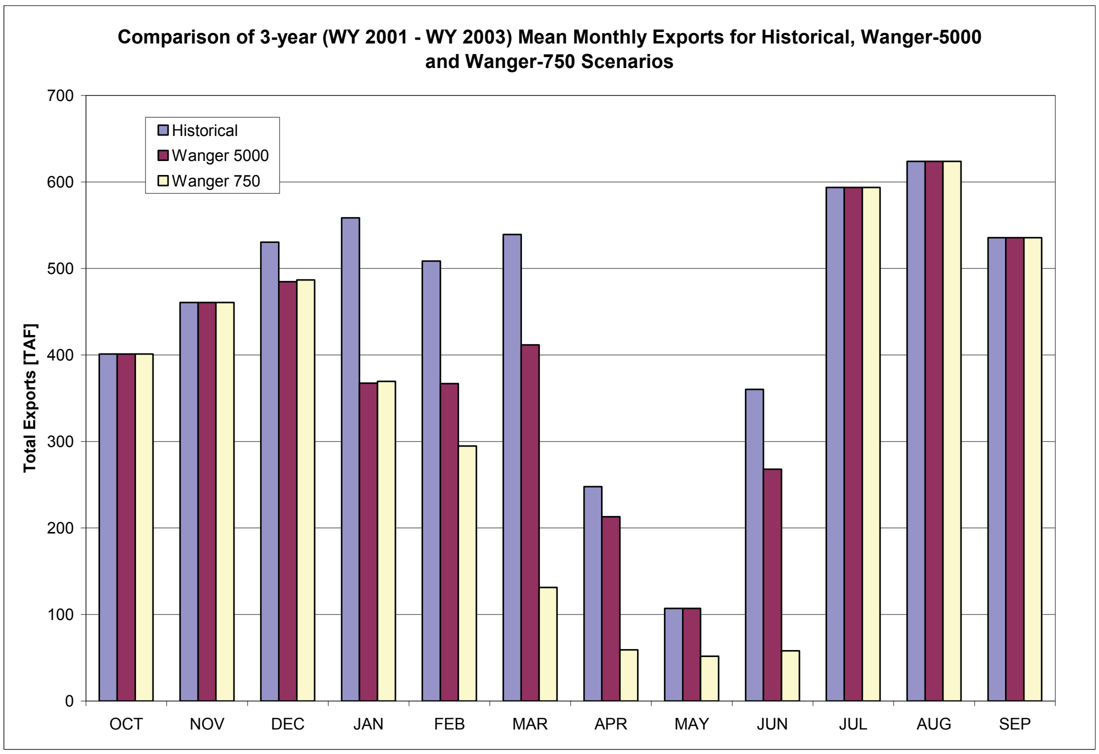

Figure E-1: Comparison of three year (WY 2001 – WY 2003) average monthly south Delta exports from Baseline, Wanger 750 and Wanger 5000 scenarios

In addition to the OMR flow targets, the interim order requires that the south Delta temporary agricultural barriers, if installed prior to June, have the flap gates tied open. Further, the decision requires that the Head of Old River Barrier installation be delayed until June 20. Thus the temporary barrier operations were modified in the Wanger scenarios as compared to the Baseline to reflect these actions. Figures E-2 and E-3 show the timeseries plots of improved simulated-OMR flows resulting from the two Wanger scenarios in comparison to the baseline on a daily and monthly scale. Figures E-4 and E-5 show the San Joaquin River at Jersey Point (QWEST) flow for the three scenarios on a monthly and daily scale. Figures E-2, E-3, E-4 and E-5 show the significantly improved positive Old and Middle River flows and the San Joaquin River flow. The improvement is during the winter and spring periods coinciding with the export curtailment. The difference between the two Wanger bookends is apparent during the "Action 3" period (March through June).

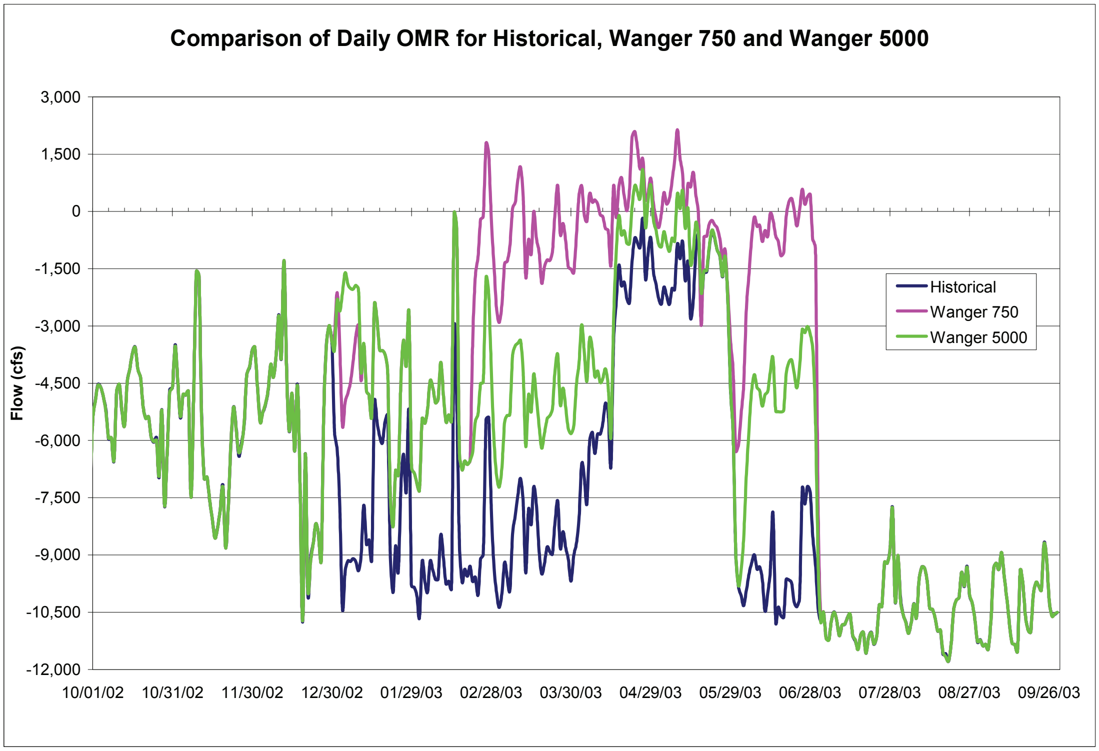

Figure E-2: Comparison of average daily combined Old and Middle River flow for WY 2003 from baseline, Wanger 750 and Wanger 5000 scenarios

The reduction in the particle entrainment at the pumps was quantified for the two Wanger scenarios. The particles were inserted at two locations: (1) Old River upstream of Quimby Island and (2) San Joaquin River downstream of Big Break. One thousand particles were inserted evenly over a 5-day period on March 2, 2003 and were tracked for 45 days from the insertion date. Since the difference between the two Wanger scenarios is expected only during the Action 3, March was selected for the PTM simulations. Further, March of 2003 was selected because a QWEST reversal occurred during this period and is believed to be representative of conditions that contribute to entrainment. Table 1 shows the summary of percent particle entrainment at the pumps for the two Wanger scenarios and the Baseline. The Wanger 750 scenario significantly reduces the particles entrained at the pumps for both insertion points as compared to the Baseline. Although, the Wanger 5000 scenario shows reduced entrainment for particles released in the San Joaquin River, the results show significant entrainment at the pumps for the particles released in the Old River upstream of Quimby Island. These results show that even when the exports are curtailed in Wanger 5000 scenario, the net flows are still significantly negative to pull the particles towards the pumps. This is shown in Figure E-1.

Table E-1: Summary of average annual exports and percent particle entrainment at export pumps for the Baseline and the two Wanger simulations

Option	Average Annual Exports (TAF)	% Particle Entrainment at Banks and Jones Pumping Plants	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Historic	5,467	30%	95%
Wanger (> -5000 cfs)	4,833	5%	88%
Wanger (> -750 cfs)	4,065	0%	9%

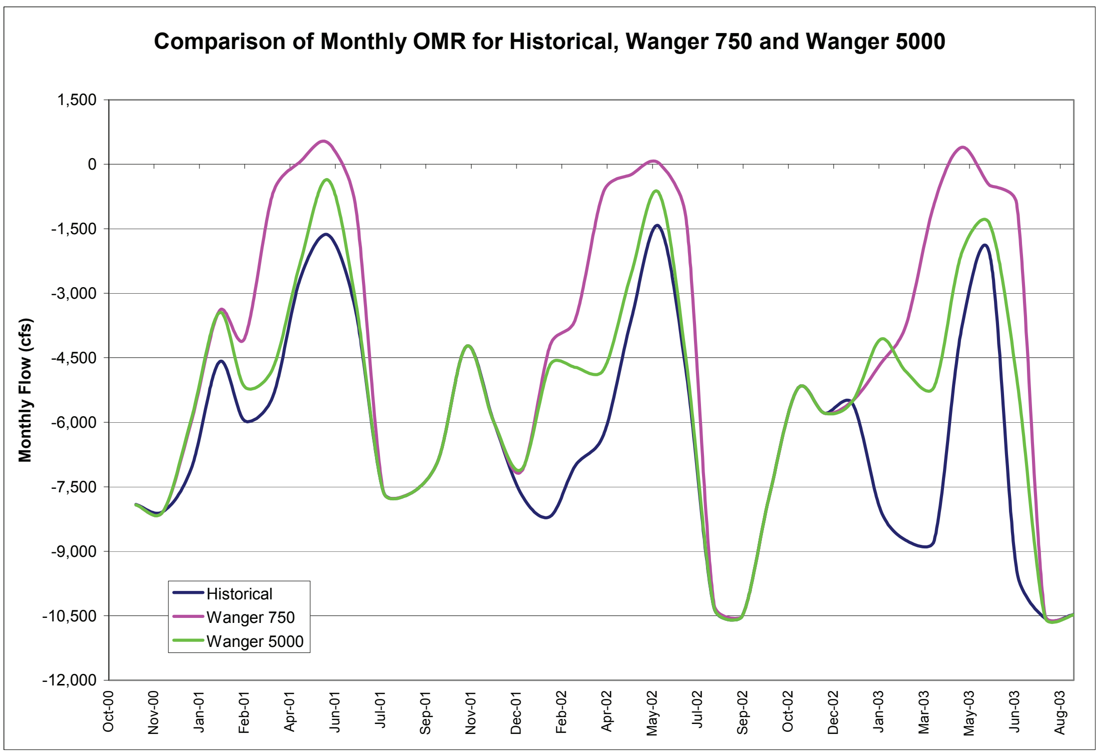

Figure E-3: Comparison of average monthly combined Okld and Middle River flow from baseline, Wanger 750 and Wanger 5000 scenarios

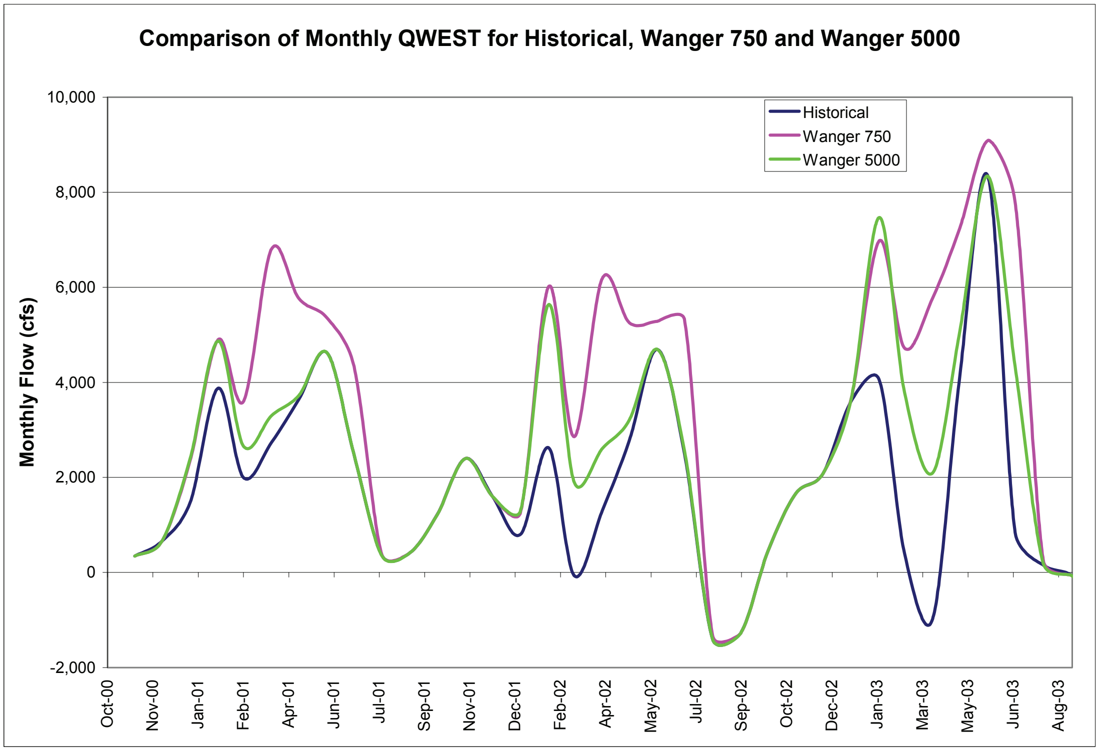

Figure E-4: Comparison of average monthly QWEST flow from baseline, Wanger 750 and Wanger 5000 scenarios

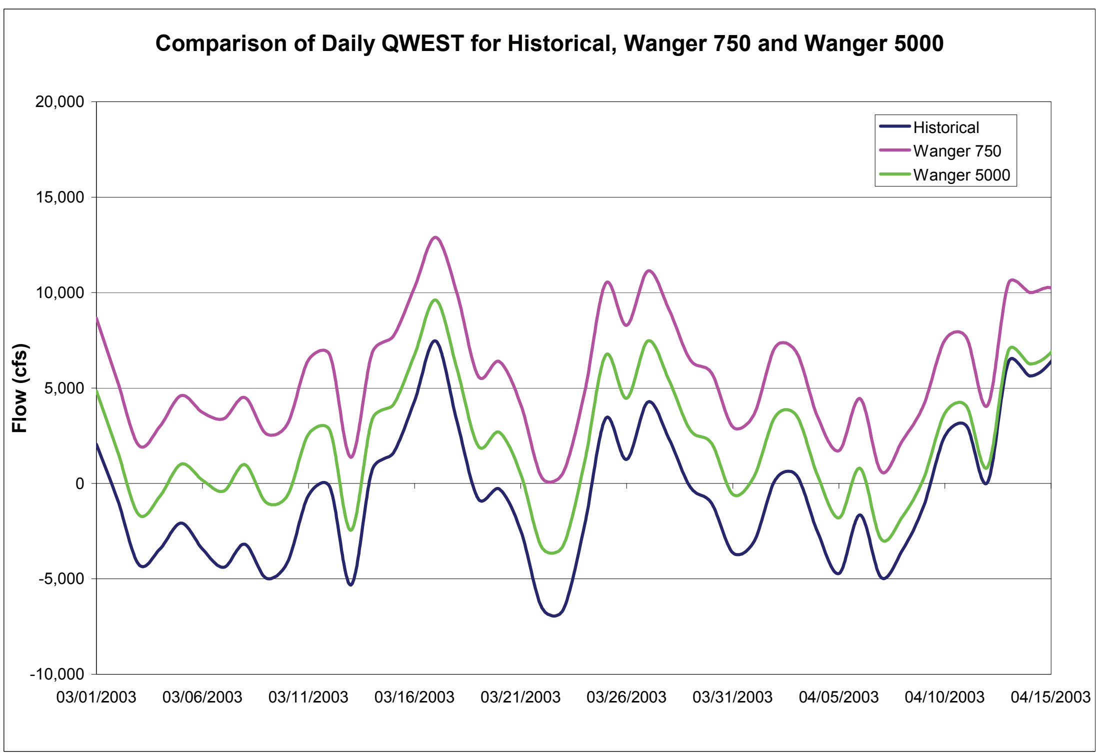

Figure E-5: Comparison of average daily QWEST flow from baseline, Wanger 750 and Wanger 5000 scenarios for March 1, 2003 to April 15, 2003

Near-term Alternatives

Near-term alternatives were developed during the course of this work by MWDSC and influenced by results of earlier analyses. The near-term alternatives were designed to provide comparable particle entrainment reductions as the Wanger scenarios, but at reduced water cost and operational impacts to the projects. Broadly, three options were identified: (1) **export curtailment** to achieve a target San Joaquin River at Jersey Point (QWEST) flow, (2) **operational changes** such as modifying the existing Delta Cross Channel (DCC) gate operations, and (3) **structural changes** such as adding new barriers in the Delta channels. In this analysis, in addition to testing the performance of the three options individually, various combinations of the three options were evaluated to identify promising alternatives to Wanger scenarios.

The metrics used to compare to the Wanger scenarios were: (1) the percent reduction in particle entrainment at the pumps compared to the Baseline (particle tracking was performed for same insertion period and locations used for the Wanger scenarios for comparability), and (2) export water cost compared to the Baseline

Export Curtailment Options

The concept guiding these options was to attempt to restrict the movement of fish located around the Sacramento – San Joaquin confluence (confluence) from moving upstream towards the pumps by maintaining positive QWEST flows. Several export curtailment options were analyzed. The exports from the baseline were curtailed to achieve QWEST target flows of 0 cfs, 500 cfs, 1,000 cfs, and 1,500 cfs.

For QWEST flow target of 0 cfs, the exports specified in the baseline were curtailed by an amount equal to the difference between the baseline QWEST flow and 0 cfs between December and June. For the remaining QWEST targets, the exports specified in the “QWEST > 0” scenario were curtailed by an amount equal to the difference between the QWEST resulting in the “QWEST>0” scenario and the QWEST target. Under this approach, it was assumed that a given export curtailment would result in an equal increase in the QWEST flow. This assumption may not entirely hold for many reasons such as tidal flows at target location, and distance between the export pumps and the target location.

Operational Change Options

Similar to the above option, the concept driving the operation change options was to restrict the fish located around the confluence from moving upstream towards pumps by increasing San Joaquin River flows. However, the mechanism used to achieve higher QWEST under this option was to modify the operation of the DCC gates. During December through May period, the DCC gates were opened during the day (1 hour after sunrise to 1 hour before sunset) and closed during the night when the Sacramento River flow at Freeport was below 25,000 cfs. The assumption was that the fish were actively moving during the night times and resting during the day. Greater opening of the DCC gates would provide more flow to the lower San Joaquin River and enhance QWEST flows.

Structural Change Options

The structural change options were developed under the concept that if the fish are present in the lower San Joaquin downstream of, or in the vicinity of, the mouth of Old River, then one or more physical barriers may be needed to protect against fish entrainement at the pumps. Several combinations of the barriers at different locations were considered in this analysis. The list of the combination of barriers/gates is shown below:

(i) *2-Gates* – Operable/inoperable Old River at Bacon Island Gate and inoperable Connection Slough Gate

(ii) *4-Gates* – Inoperable gates at Old River at Highway 4, Connection Slough, Rail Road Cut and Woodward Cut

(iii) *3-Gates* – Inoperable Gates at Old River between Woodward Cut and Indian Slough, Connection Slough and Rail Road Cut Gates.

In the combination (i) the Old River at Bacon Island gate was tested in both operable and inoperable mode. In the operable mode, the gate is operating tidally (i.e. the gate is open during the ebb tide and closed during the flood tide). In the inoperable mode, the gate is closed at all times. While testing these gate options, the assumption was that these gates would be installed during December through June of every year.

In addition to the above listed structural change options that were designed to protect the fish in the vicinity of the mouth of the Old River, two other structural changes were analyzed. These combinations were developed to limit entrainment of fish located in the vicinity of the confluence:

(iv) *Three Mile Slough Gate* – Operable gate in Three Mile Slough. The water quality operation developed by DWR was assumed in this option.

(v) *False River Barrier* – Inoperable barrier in the West False River.

Results

This section presents the results for the various near-term alternatives analyzed in this Task. The results are presented such that the incremental benefit is apparent to the reader. For this purpose, the results are grouped into stand-alone options, combinations of operational changes and export curtailment, combinations of structural changes and export curtailment, combinations of structural changes and operational changes, and finally, combinations of structural changes, operational changes and export curtailment.

For each group the results listed below are shown:

(i) average annual exports for the three year simulation period,

(ii) percentage of particles entrained at the export pumps for the baseline and the other near-term options,

(iii) monthly QWEST timeseries for the three year simulation period, and

(iv) daily QWEST for the PTM simulation period (March 1 – April 15, 2003).

Stand-alone Options

Table 2 shows the various stand-alone near-term options analyzed. Except for the export curtailment options [QWEST (>0 cfs) and QWEST (>500 cfs) scenarios] and the inoperable 4-Gate scenario, other runs listed in the table had the exports equal to the baseline. The 4-Gate scenario was found to have the highest average annual water cost (~ 1 MAF), which can be attributed to the reduction in the available conveyance capacity to physically export at Baseline levels without significant dredging. As expected for stand-alone export curtailment options, the water cost increases with increasing QWEST flow target.

Table E-2: Summary of average annual exports and percent particle entrainment at export pumps for the baseline and Stand-alone near-term options

Option	Average Annual Exports (TAF)	% Particle Entrainment at Banks and Jones Pumping Plants	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Historic	5,467	30%	95%
Qwest (>0 cfs)	5,191	14%	92%
Qwest (> 500 cfs)	5,040	8%	89%
DCC Re-Ops	5,467	14%	95%
2-Gate (Inoperable)	5,467	25%	27%
2-Gate (Operable)	5,467	26%	43%
4-Gate (Inoperable)	4,460	6%	11%
3-Gate (Inoperable)	5,467	24%	18%
False River Gate	5,467	26%	95%
3-Mile Slough Gate	5,467	2%	95%

Further, it was found that the structural change options [2-Gate, 3-Gate and 4-Gate scenarios] have the best chance of reducing the entrainment at the pumps for the Old River upstream of Quimby Island release as indicated in Table 2. The 2-Gate scenario reduces particle entrainment significantly even at the baseline exports for the particles inserted in the vicinity of mouth of Old River. It was also found that the inoperable scenario does better at reducing the entrainment as compared to the operable scenario. The operable scenario, which allows the flow across the Old River gate during the ebb-tide, promotes the Middle River water to flow into the Old River. This process leads more particles transported to the export pumps in the operable scenario.

For the release point on the San Joaquin downstream of Big Break, Three Mile Slough Gate shows the highest reduction in entrainment at the pumps. Other scenarios that boost the QWEST by export curtailments [QWEST (>500) and 4-Gate scenarios] or operational changes [DCC Re-ops scenario] also show reduction in the entrainment. The monthly and daily QWEST plots in Figures 6 and 7 support the above conclusion. These two figures show that the Three Mile Slough Gate scenario has the highest positive QWEST flow compared to the baseline followed by the DCC Re-Ops scenario and the other export curtailment scenarios. Another important observation is that the DCC Re-Ops scenario showed an equal reduction in entrainment as the “QWEST (> 0cfs)” scenario for the particle inserted on the San Joaquin River.

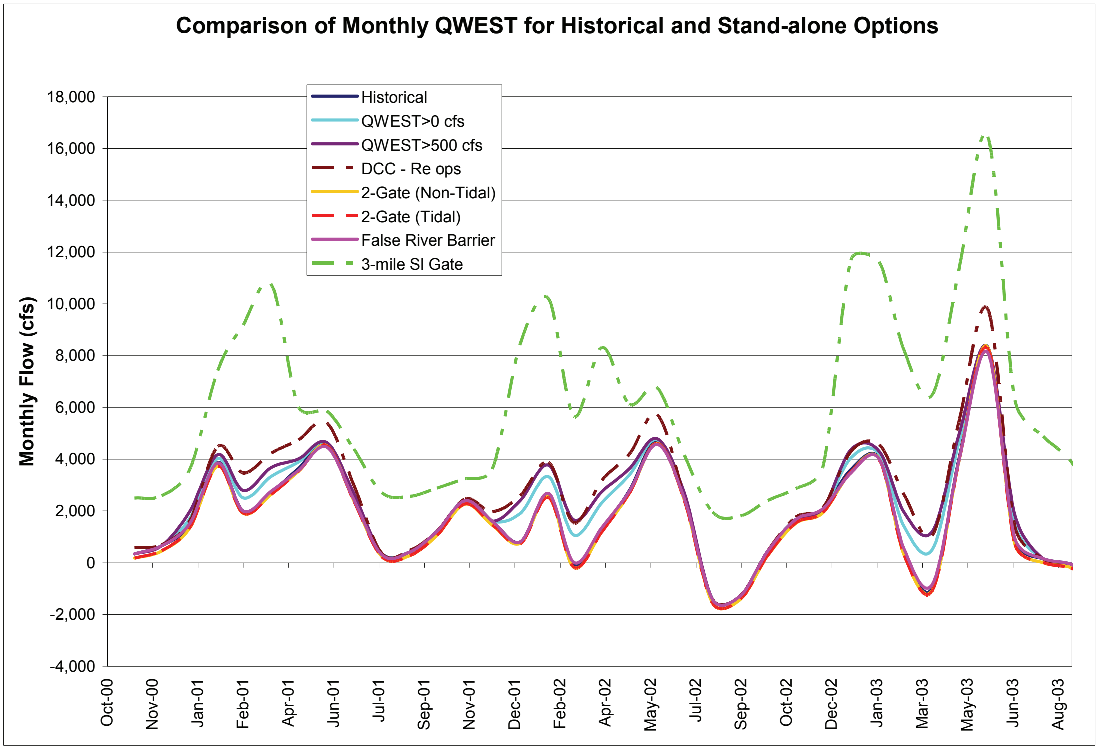

Figure E-6: Comparison of monthly QWEST flow from stand-alone near-term options and the baseline simulation

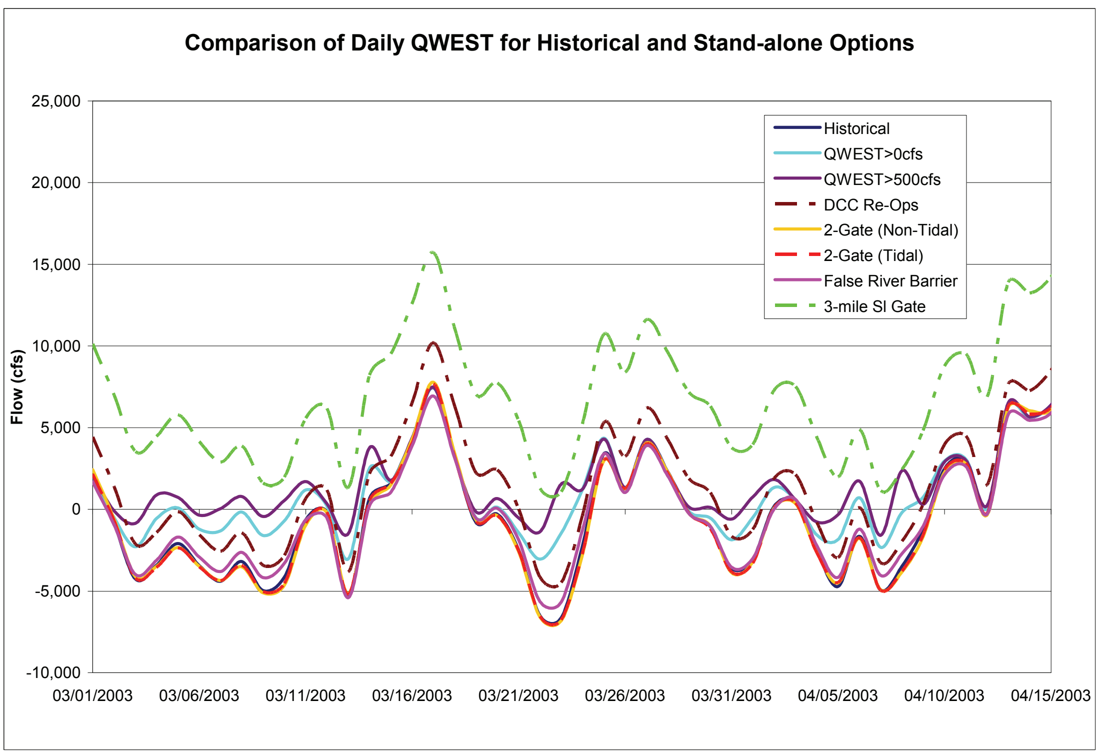

Figure E-7: Comparison of daily QWEST flow from stand-alone near-term options and the baseline simulation during March 1, 2003 to April 15, 2003

Combinations of Opertational Changes and Export Curtailments

Table 3 lists the scenarios involving various combinations of operational changes and export curtailments. In these scenarios, the operational change was first implemented and then the exports were curtailed by an amount equal to the difference between the QWEST flow resulting from the operational change and a target QWEST. The water cost associated with these scenarios increases with the increasing QWEST target. However, the incremental benefit in terms of reduction in the particle entrainment at the export pumps is not necessarily directly related to the reduction of exports (or increase in water cost). That is, approximately 350 TAF of export cuts were needed to reduce the entrainment of the particles released on the San Joaquin River from 14% to 4%. Figures 8 and 9 show the monthly and daily QWEST flows for the scenarios listed in the Table 3.

Table E-3: Summary of average annual exports and percent particle entrainment at export pumps for the baseline and combinations of operational changes and export curtailments

Option	Average Annual Exports (TAF)	% Particle Entrainment at Banks and Jones Pumping Plants	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Historic	5,467	30%	95%
DCC Re-Ops	5,467	14%	95%
DCC Re-Ops + Qwest (> 0 cfs)	5,321	9%	94%
DCC Re-Ops + Qwest (> 500 cfs)	5,218	7%	94%
DCC Re-Ops + Qwest (> 1000 cfs)	5,170	6%	91%
DCC Re-Ops + Qwest (> 1500 cfs)	5,113	4%	91%

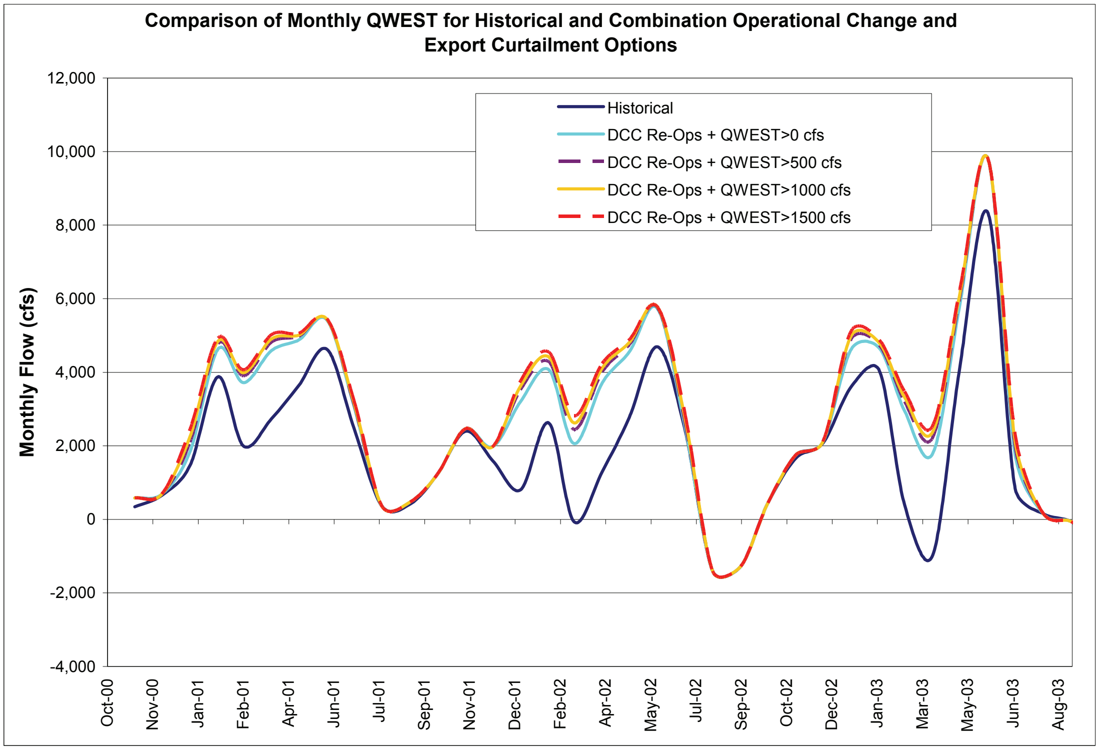

Figure E-8: Comparison of monthly QWEST flow from combinations of operational changes and export curtailments and the baseline simulation

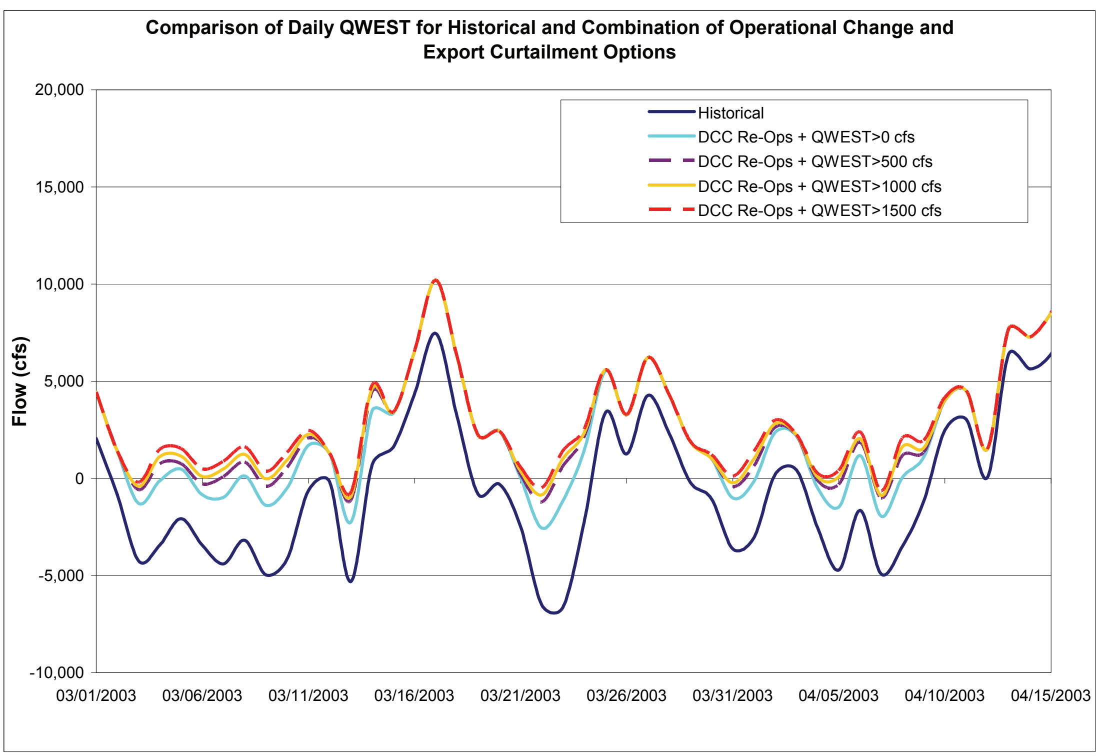

Figure E-9: Comparison of daily QWEST flow from combinations of operational changes and export curtailments and the baseline simulation during March 1, 2003 to April 15, 2003

Combinations of Structural Changes and Export Curtailments

Table 4 lists the scenarios involving various combinations of structural changes and export curtailments. As noted in section 4.1, the structural changes perform well in terms of reducing the entrainment of the particles inserted in the vicinity of mouth of Old River. The inoperable and operable 2-Gate options were carried forward and analyzed in combination with export curtailments. The exports were curtailed by an amount equal to the difference between the QWEST resulting in the 2-Gate scenario and specified QWEST target flow. Adding export curtailments on top of the structural changes has lower incremental reduction in the entrainment of particles released in the Old River compared to that for the particles released in the San Joaquin River. This is due to the increased QWEST resulting from the export curtailment. Figures 10 and 11 show the monthly and daily QWEST flows for the historical and the combinations listed in Table 4.

The inoperable 2-Gate scenario with export curtailments to meet QWEST > 0 cfs criteria resulted in a significant reduction in the particles entrained at the pumps for both Old River and San Joaquin River insertions. However, further increasing the export curtailments for QWEST>500 cfs, which increases water cost by ~160 TAF does not result in a large reductions in the entrainment.

Table E-4: Summary of average annual exports and percent particle entrainment at export pumps for the baseline and combinations of structural changes and export curtailments

Option	Average Annual Exports (TAF)	% Particle Entrainment at Banks and Jones Pumping Plants	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Historic	5,467	30%	95%
2-Gate (Inoperable)	5,467	25%	27%
2-Gate (Operable)	5,467	26%	43%
2-Gate (Inoperable) + Qwest (>0 cfs)	5,181	8%	17%
2-Gate (Operable) + Qwest (>0 cfs)	5,179	11%	31%
2-Gate (Inoperable) + Qwest (>500 cfs)	5,019	4%	14%
2-Gate (Operable) + Qwest (>500 cfs)	5,019	5%	21%

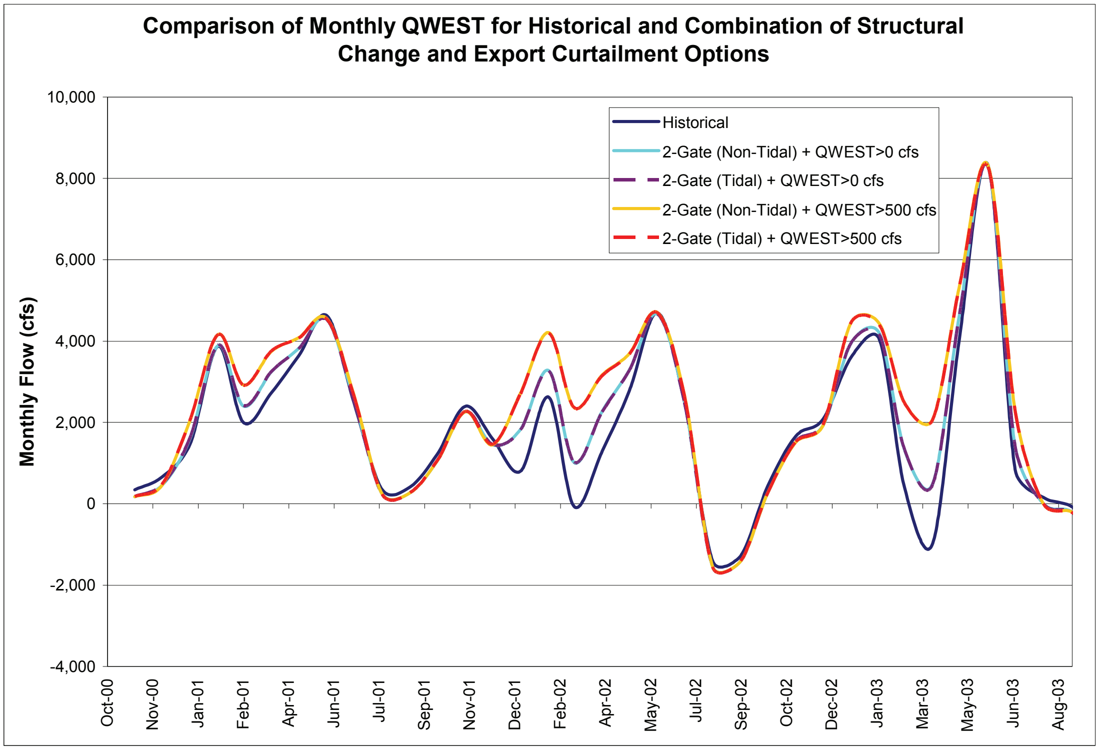

Figure E-10: Comparison of monthly QWEST flow from combinations of structural changes and export curtailments and the baseline simulation

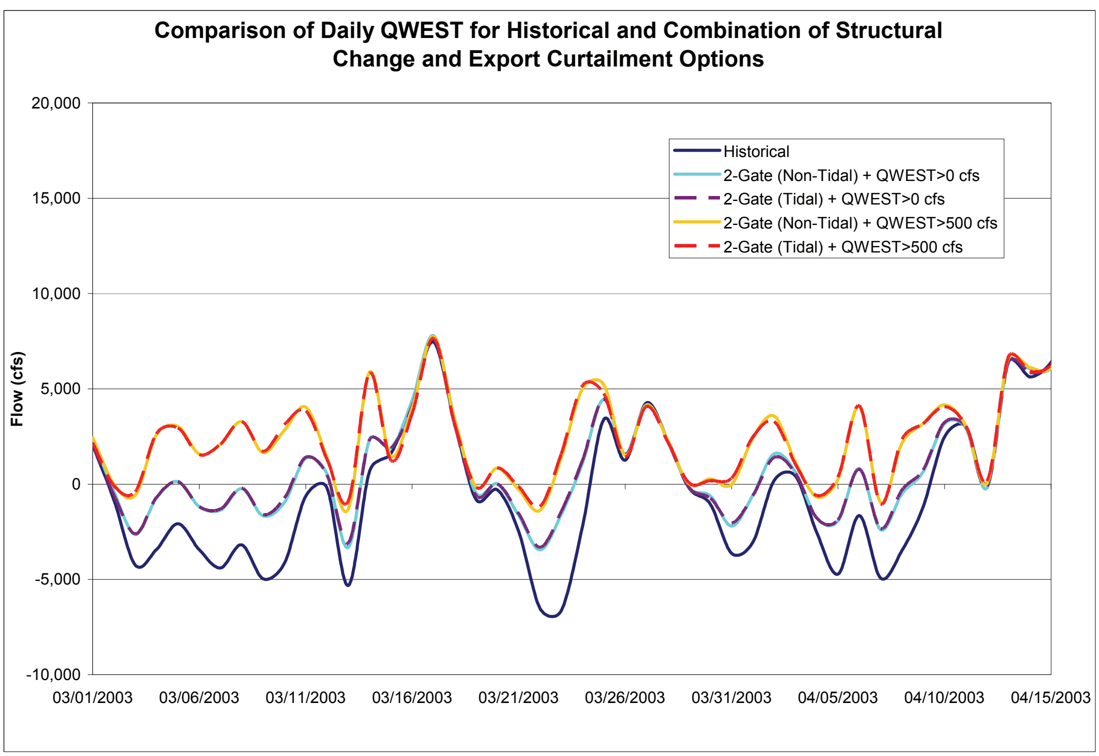

Figure E-11: Comparison of daily QWEST flow from combinations of structural changes and export curtailments and the baseline simulation during March 1, 2003 to April 15, 2003

Combinations of Structural Changes and Operational Changes

Table 5 lists the scenarios involving various combinations of structural and operational changes. Similar to the export curtailments, the operational change of DCC gates results in higher QWEST flows. Therefore, the benefit of adding operational changes on top of structural changes is mainly towards reducing the entrainment of particles inserted in the San Joaquin River. Figures 12 and 13 show the monthly and daily QWEST flows for the scenarios listed in Table 5. The 2-Gate scenario with DCC reoperation performs on par with the 2-Gate scenario with export curtailment for QWEST>0 cfs in terms of reducing the particle entrainment at the pumps for both the insertions keeping the exports equal to Baseline.

The QWEST flow resulting when the Three Mile Slough Gate scenario was combined with the DCC gate reoperation is shown in Figures 12 and 13. This combination reduces the entrainment of the particles inserted on the San Joaquin River by 98% compared to the Baseline at no water cost.

Table E-5: Summary of average annual exports and percent particle entrainment at export pumps for the baseline and combinations of structural changes and operational changes

Option	Average Annual Exports (TAF)	% Particle Entrainment at Banks and Jones Pumping Plants	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Historic	5,467	30%	95%
2-Gate (Inoperable)	5,467	25%	27%
2-Gate (Operable)	5,467	26%	43%
2-Gate (Inoperable) + DCC Re-Ops	5,467	9%	16%
2-Gate (Operable) + DCC Re-Ops	5,467	12%	25%
3-Mile Slough Gate + DCC Re-Ops	5,467	1%	95%

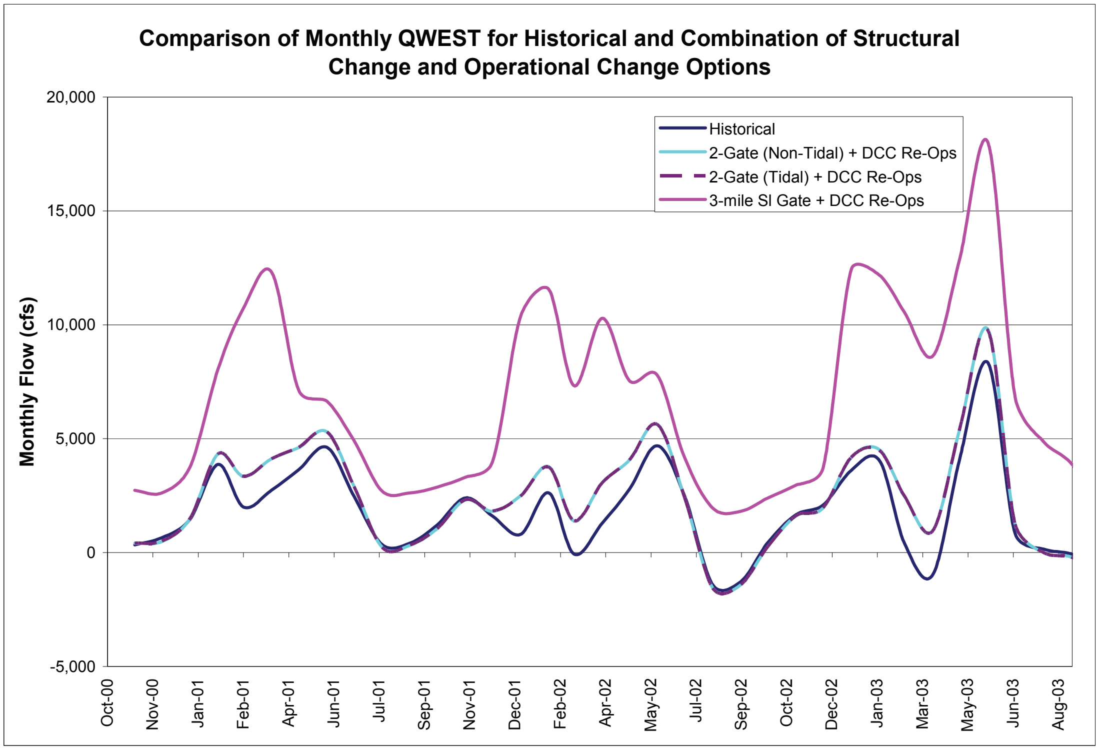

Figure E-12: Comparison of monthly QWEST flow from combinations of structural changes and operational changes and the baseline simulation

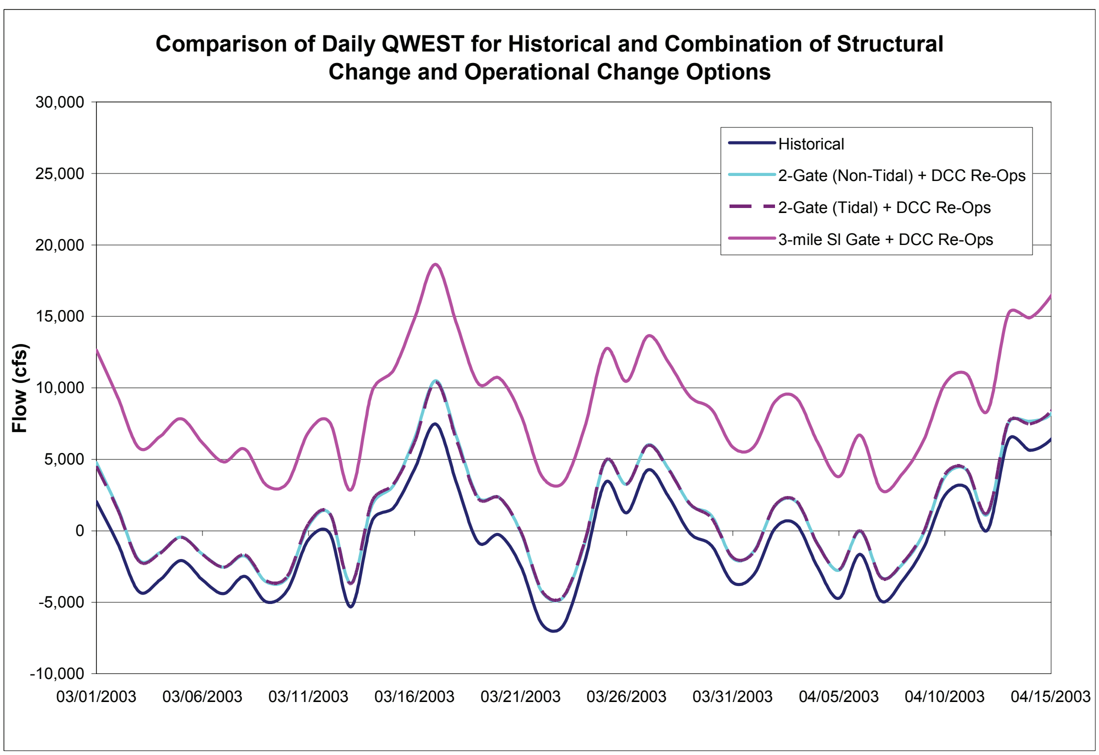

Figure E-13: Comparison of daily QWEST flow from combinations of structural changes and operational changes and the baseline simulation during March 1, 2003 to April 15, 2003

Combinations of Structural Changes, Operational Changes and Export Curtailments

Table 6 lists the scenarios involving various combinations of structural and operational changes and the export curtailments. From the analyses described in the above sections, the best scenarios in the structural, operational and export curtailment options were combined to develop a set of scenarios that can reduce the particle entrainment on par with the Wanger scenarios without the huge water cost.

Two sets of scenarios were formulated. The inoperable and operable 2-Gate scenario was combined with the DCC gate reoperations first. Based on the resulting QWEST, exports were curtailed to meet QWEST > 0 cfs criteria. Using the QWEST resulting from this simulation, exports were further curtailed to meet QWEST > 500 cfs criteria. The average annual exports and the particle tracking results for each of the four scenarios are listed in the Table 6. In addition, the exports and particle tracking results for the historic and the Wanger scenarios are shown for reference. Figures 14 and 15 show the improved QWEST compared to the baseline on a monthly and daily scale.

In summary, with about 150 TAF water cost, the 2-Gate with DCC reoperation and export curtailment to meet QWEST>0cfs criteria performed on par with the Wanger 5000 scenario for particles inserted in the San Joaquin River and significantly out-performed the Wanger 5000 scenario for particles inserted in the Old River. When compared to the lower Wanger scenario, Wanger 750, the above near-term combination performs on par for the Old River insertion and slightly worse for the San Joaquin insertion. However, if the exports are curtailed by approximately 100 TAF more, this near-term combination performs on par with even the Wanger 750 scenario, as shown in the inoperable 2-Gates with DCC reoperation and export curtailment to meet QWEST>500 cfs criteria.

Table E-6: Summary of average annual exports and percent particle entrainment at export pumps for the baseline and combinations of structural changes, operational changes and export curtailments

Option	Average Annual Exports (TAF)	% Particle Entrainment at Banks and Jones Pumping Plants	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Historic	5,467	30%	95%
Wanger (> -5000 cfs)	4,833	5%	88%
Wanger (> -750 cfs)	4,065	0%	9%
2-Gate (Inoperable) + DCC Re-Ops + Qwest (>0 cfs)	5,313	4%	11%
2-Gate (Operable) + DCC Re-Ops + Qwest (>0 cfs)	5,311	6%	21%
2-Gate (Inoperable) + DCC Re-Ops + Qwest (>500 cfs)	5,200	2%	8%
2-Gate (Operable) + DCC Re-Ops + Qwest (>500 cfs)	5,199	3%	19%

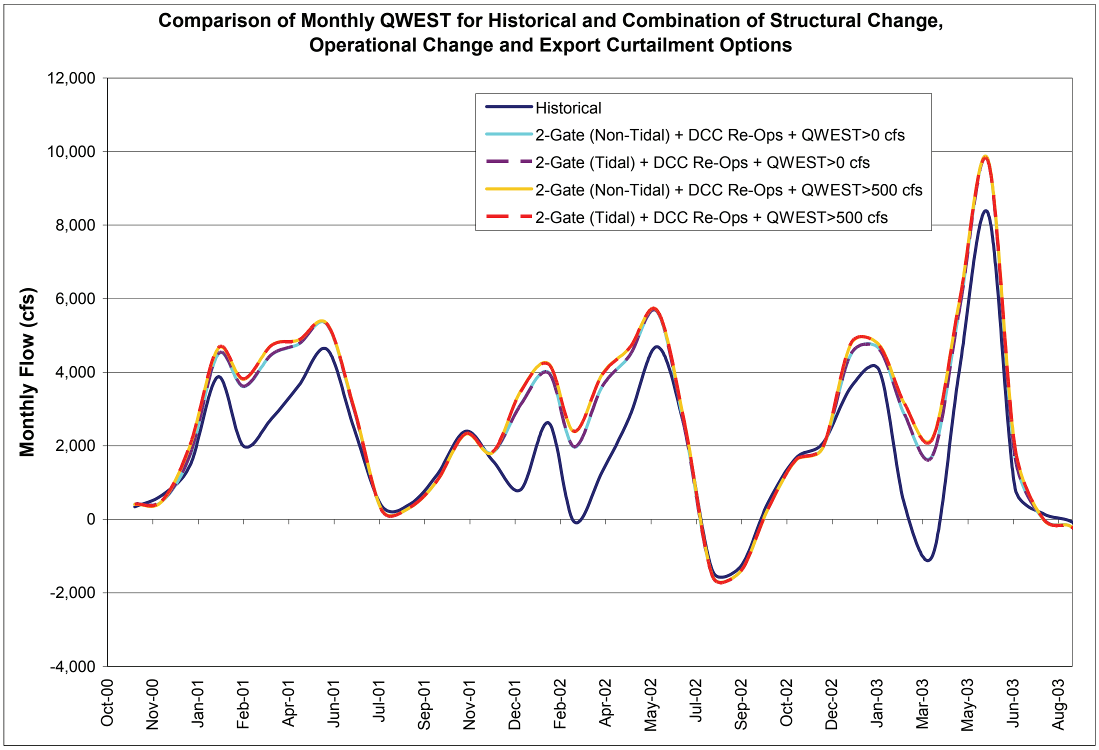

Figure E-14: Comparison of monthly QWEST flow from combinations of structural changes, operational changes and export curtailments and the baseline simulation

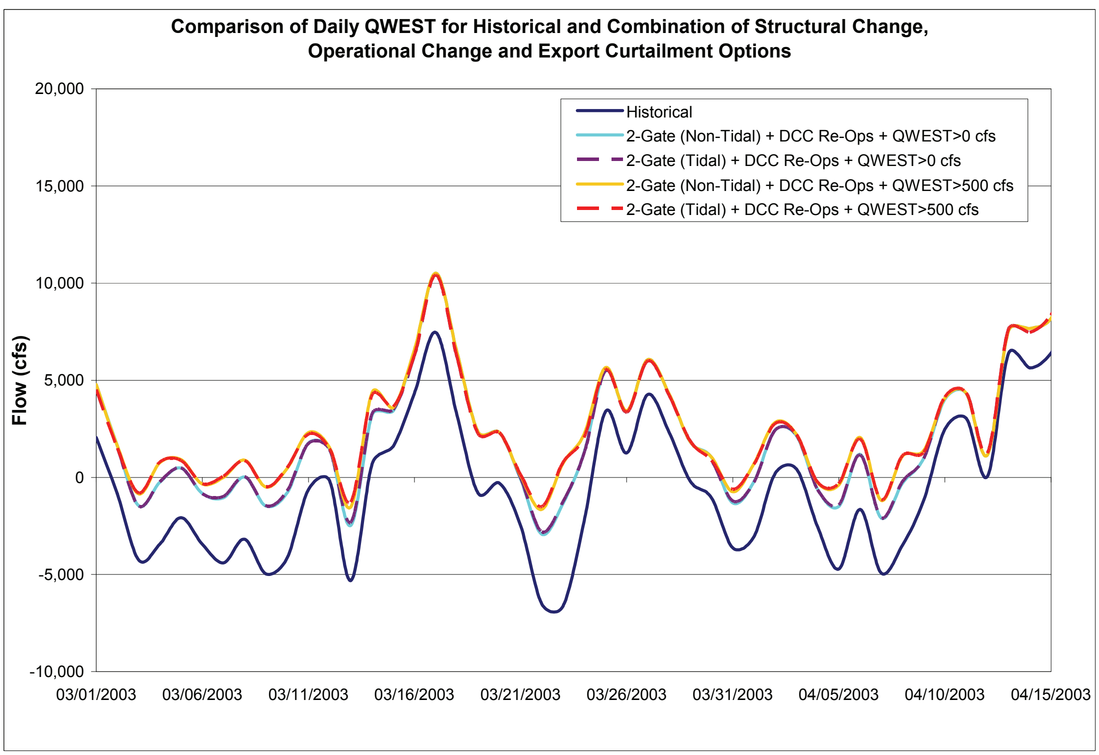

Figure E-15: Comparison of daily QWEST flow from combinations of structural changes, operational changes and export curtailments and the baseline simulation during March 1, 2003 to April 15, 2003

Limitations

An exhaustive amount of effort was put forth to develop such a wide range of scenarios as described in this memorandum. However, it is important to highlight some key limitations associated with these analyses and to provide some bounds on extrapolation of these results. First, particle tracking tracks neutrally buoyant particles, not fish. The PTM simulations should be viewed as providing the net transport of particles, but to the extent that the fish of concern can swim of its own volition this should be considered. Second, the analyses have been performed to estimate particle entrainment effects for two insertion locations and for one period in 2003. This was considered reasonable, and necessary, for performing analyses of a large array of scenarios. However, transport can vary considerably based on hydrologic conditions, tides, and operations, and the science describing occurrence and behavior of Delta smelt, in particular, is evolving. Finally, the DSM2 analyses assumed a static set of project operations where exports could be curtailed or gates could be operated to achieve the target criteria. In reality, the operational decisions would likely be based on forecasts of fish presence of hydrodynamic conditions and the time to see actual changes occurring in the Delta would be delayed. It is important to keep these limitations, and perhaps others, in mind as this information is used to help direct future analyses or lead to evaluation of alternatives.

Conclusions

Two representative Wanger bookend scenarios were formulated and the Delta hydrodynamics were analyzed using the DSM2 model for a three year period (WY 2001 – WY 2003). Particle tracking analyses were performed to assess the effectiveness of the Wanger scenarios in reducing the entrainment at the export pumps. The results were compared with the historical DSM2 simulation for the same period. Potential near-term alternatives to the Wanger scenarios that provide similar level of reduction in the particle entrainment at the pumps were developed using DSM2. In the process of developing the potential near-term alternatives, various combinations of structural changes, operational changes and export curtailments were analyzed.

Table 7 summarizes the results for all 26 different scenarios analyzed as part of this task. For each scenario, the table shows the average annual water cost in TAF compared to the baseline. It also includes the percent reduction of particle entrainment at the pumps compared to the baseline for both San Joaquin River downstream of Big Break and Old River upstream of Quimby Island, March 2003 insertions. Note that these values are presented as percent reduction from historical particle entrainment at the pumps, while elsewhere in this Appendix; values are presented as absolute percent entrainment at the export pumps. This table provides a good incremental summary of each option considered.

Table E-7: Summary of average annual water costs and percent reduction in the particle entrainment at export pumps compared to the baseline for all the scenarios analyzed as part of this task

Option	Average Annual Water Cost (TAF)	% Reduction from Historical	
		San Joaquin River downstream of Big Break Insertion	Old River upstream of Quimby Island Insertion
Wanger (> -5000 cfs)	630	82%	8%
Wanger (> -750 cfs)	1,400	100%	90%
Qwest (>0 cfs)	276	55%	4%
Qwest (> 500 cfs)	427	75%	6%
DCC Re-Ops	0	53%	0%
False River Gate	0	14%	0%
3-Mile Slough Gate	0	93%	1%
2-Gate (Inoperable)	0	17%	72%
2-Gate (Operable)	0	15%	55%
3-Gate (Inoperable)	0	20%	81%
4-Gate (Inoperable)	1,007	79%	88%
DCC Re-Ops + Qwest (> 0 cfs)	146	71%	2%
DCC Re-Ops + Qwest (> 500 cfs)	249	78%	2%
DCC Re-Ops + Qwest (> 1000 cfs)	297	81%	4%
DCC Re-Ops + Qwest (> 1500 cfs)	354	87%	4%
2-Gate (Inoperable) + Qwest (>0 cfs)	286	75%	82%
2-Gate (Operable) + Qwest (>0 cfs)	288	65%	67%
2-Gate (Inoperable) + Qwest (>500 cfs)	448	86%	85%
2-Gate (Operable) + Qwest (>500 cfs)	448	84%	78%
2-Gate (Inoperable) + DCC Re-Ops	0	72%	83%
2-Gate (Operable) + DCC Re-Ops	0	60%	74%
2-Gate (Inoperable) + DCC Re-Ops + Qwest (>0 cfs)	154	86%	89%
2-Gate (Operable) + DCC Re-Ops + Qwest (>0 cfs)	156	81%	78%
2-Gate (Inoperable) + DCC Re-Ops + Qwest (>500 cfs)	267	94%	92%
2-Gate (Operable) + DCC Re-Ops + Qwest (>500 cfs)	268	91%	80%
3-Mile Slough Gate + DCC Re-Ops	0	98%	0%

The following key conclusions can be drawn from this analysis:

- Representative Wanger scenarios showed that particle entrainment can be significantly reduced by limiting negative OMR flows, but the water costs will be large (ranging between 600 and 1400 TAF/YR).
- For the particles inserted in the Old River upstream of Quimby Island location, the Wanger 5000 bookend proved to be ineffective in reducing the particle entrainment.
- A structural change option such as the 2-Gate scenario may be preferred over a pure export curtailment option such as Wanger scenarios, to reduce the entrainment at pumps for particles released in the Old River at a significantly lower water cost.
- The DCC Gates re-operation scenario performs on par with the export curtailment scenarios in terms of reducing the entrainment of particles inserted in the San Joaquin River downstream of Big Break. Therefore, considering such an operational change before triggering export curtailments would lower water costs at similar levels of protection.
- The near-term scenario with two inoperable gates, DCC re-operation, and exports curtailed for QWEST>500 cfs performs on par with Wanger 750 scenario in terms of reduction in particle entrainment at a water cost of approximately 260 TAF as compared to the water costs of over 1.0 MAF/YR for the Wanger 750 scenario.
- Three Mile Slough Gate is the most effective scenario at controlling the QWEST flows, which resulted in the highest increase in QWEST flows compared to the baseline. A combination of Three Mile Slough Gate and a structural change such as 2-Gate scenario would be the most effective scenario in terms of reducting in the particle entrainment and also limiting water costs.
- Given the level of uncertainty in the science of fish movement and preferred habitats, and particle entrainment under a wide range of conditions, alternatives with the greatest amount of flexibility are probably preferred for future analyses.

Snapshot of 2-Gate Project Operations Modeling

Attached are essential outputs of comprehensive 2-Gate Project modeling, which give insights into conceptual operations planning. Essential outputs are derived from:

- 34 PTM analyses to determine the optimum locations/number of gates.[1]
- 140 PTM analyses to determine region of control of 2-Gates operations.[2]
- 320 PTM analyses at 20 mm smelt survey locations (Fig. 1) to determine operational effects of combined 2-Gates and Qwest operations.[3]

2-Gates and modest Qwest operations prevented (<3%) particle entrainment at the pumps in most model runs (Tables 1-6):

- 2-Gates and Qwest operations form physical/hydraulic barrier to smelt passage.
- 2-Gates effective in preventing entrainment of particles in region of control (Fig. 1).
- 2-Gates and Qwest @ San Andreas (> -1,000 cfs to 0 cfs)[4] forms physical/hydraulic barrier (Fig. 1) which is effective in preventing entrainment in most model runs.
- Gates can be left open or operated with additional Qwest flow depending on severity of forecasted condition.

[1] Release date: 2Mar03
[2] Release dates: 1Apr91, 1Mar 01, 2Mar03, 27Mar03, 1Feb05
[3] Release dates: 9Jun99, 12Jun02, 15May02, 30May02, 21May03, 1May04, 16Dec03, 30Dec04

Figure 1. 20 mm Smelt Survey, Particle Release Points and Region of Control

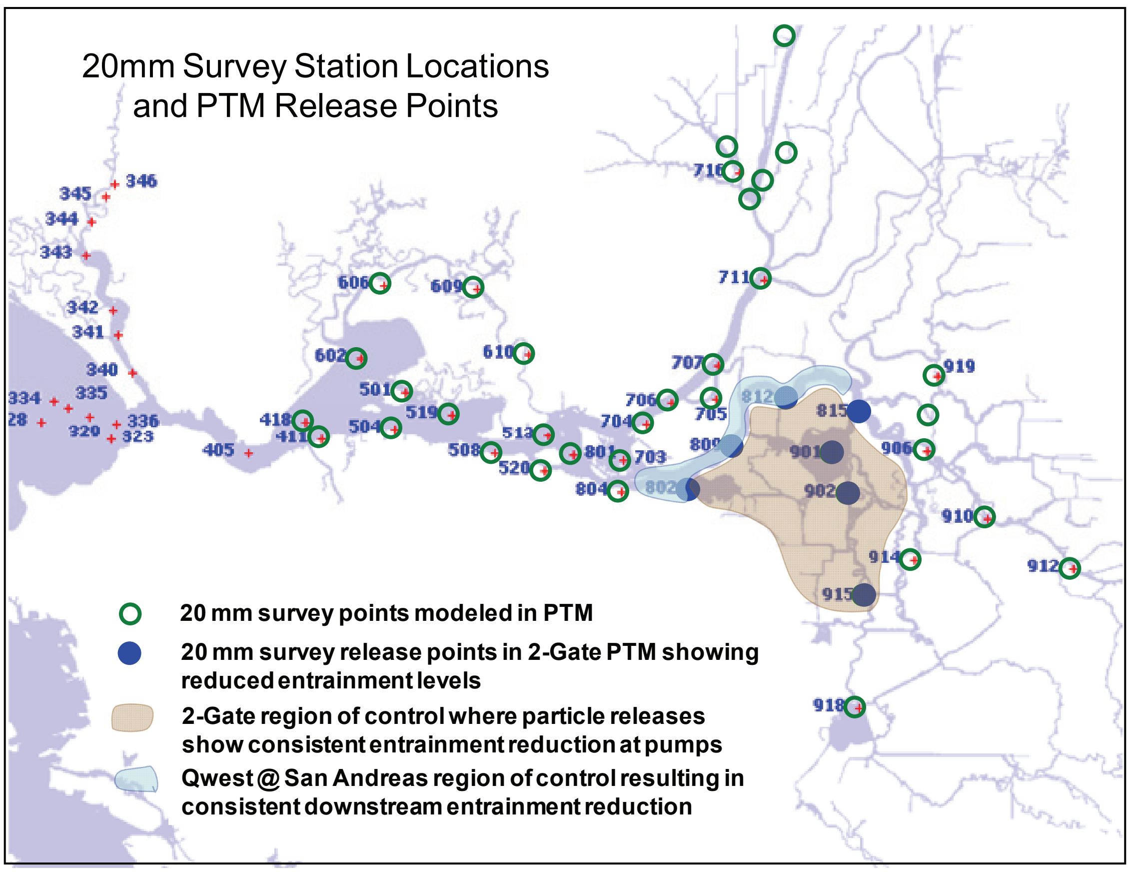

Table 1. Entrainment Results for Release Point #802

Survey Location /Release Point	% Entrainment from Release Location #802	
	Feb-Jun	Dec-Feb

	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic	0	3	0	1	1	0	17	1
Historic + 2-Gates	0	1	0	0	0	0	17	0
Historic + 2-Gates + Qwest > -1,000 cfs	0	1	0	0	0	0	4 [5]	0
Historic + 2-Gates + Qwest > 0 cfs	0	0	0	0	0	0	2 [5]	0

[5] 0% entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 2. Entrainment Results for Release Point #809

Survey Location /Release Point	% Entrainment from Release Location #809							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic	2	5	0	2	2	1	29	3
Historic + 2-Gates	0	2	0	1	1	0	25	1
Historic + 2-Gates + Qwest > -1,000 cfs	1	1	0	1	0	0	9 [5]	0
Historic + 2-Gates + Qwest > 0 cfs	1	0	0	0	0	0	6 [5]	0

[5] 0% entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 3. Entrainment Results for Release Point #812

Survey Location /Release Point	% Entrainment from Release Location #812							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic	5	14	0	8	14	1	59	17
Historic + 2-Gates	5	17	1	7	13	2	68	16
Historic + 2-Gates + Qwest > -1,000 cfs	2	7	0	3	9	1	38 [5]	12
Historic + 2-Gates + Qwest > 0 cfs	4	3	0	1	6	1	33 [5]	9

[5] 0% entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 4. Entrainment Results for Release Point #901

Survey Location /Release Point	% Entrainment from Release Location #901							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic	23	39	5	31	35	8	81	65

Historic + 2-Gates	1	4	1	2	8	1	19	2
Historic + 2-Gates + Qwest > -1,000 cfs	1	4	1	1	4	1	7 [5]	3
Historic + 2-Gates + Qwest > 0 cfs	0	1	0	1	3	0	5 [5]	2

[5] 0% entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 5. Entrainment Results for Release Point #902

Survey Location /Release Point	% Entrainment from Release Location #902							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic	51	60	20	50	56	24	97	92
Historic + 2-Gates	1	2	0	1	6	1	11	4
Historic + 2-Gates + Qwest > -1,000 cfs	1	1	1	0	2	1	4 [5]	3
Historic + 2-Gates + Qwest > 0 cfs	1	0	1	0	2	1	4 [5]	3

[5] 0% entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 6. Entrainment Results for Release Points #915

Survey Location /Release Point	% Entrainment from Release Location #915							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic	77	79	60	65	75	59	100	100
Historic + 2-Gates	2	7	4	5	8	17	68 [6]	32 [6]
Historic + 2-Gates + Qwest > -1,000 cfs	2	4	4	4	4	16	52 [5]	26
Historic + 2-Gates + Qwest > 0 cfs	1	1	4	4	3	13	43 [5]	19

[5] 1% entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.
[6] 0-16 % entrainment observed in Historic + 2-Gates for release point #92 under 1Apr91, 1Mar 01, 2Mar03, 27Mar03, 1Feb05 runs (see Footnote 2). Release point #92 is about 1.5 miles downstream of release point #915 (OR/RR Cut confluence).

Tables 7-12 shows that adding modest Qwest flows to 2-Gate operations sufficiently prevents (< 3%) increased entrainment or reduces entrainment from the Mokelumne and San Joaquin River regions to perform flexible demo operations (red dots on Figure 2):

- Adding Qwest @ San Andreas > -1,000 cfs to 0 cfs to 2-Gates operations prevents increased entrainment or reduces entrainment of particles from the Mokelumne and San Joaquin River regions in two-thirds of the model runs.
- Gates can be left open or operated with additional Qwest flow depending on severity of forecasted condition.

Figure 2. 20 mm Smelt Survey, Particle Release Points and 2-Gate/Qwest Operations

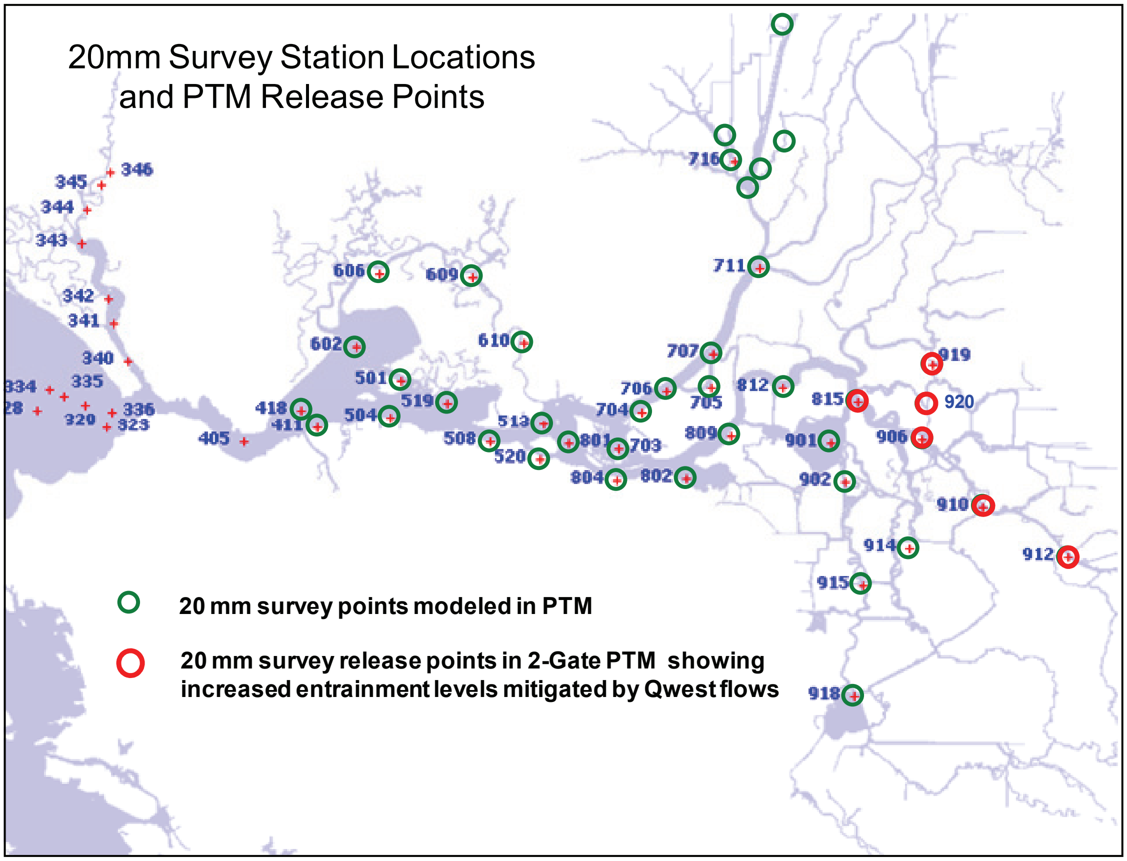

Table 7. % Change in Entrainment from Release Point #919

Survey Location /Release Point	% Change in Entrainment from Release Point #919							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic + 2-Gates	+12	+16	+12	+24	+14	+12	-7	+9
Historic + 2-Gates + Qwest > -1,000 cfs	+9	+1	+7	+4	+4	+12	-21 [5]	+7
Historic + 2-Gates + Qwest > 0 cfs	+8	-10	+7	-8	0	+8	-26 [5]	+4

[5] -74% change in entrainment observed in Historic + 2-Gates + Qwest>-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 8. % Change in Entrainment from Release Point #920

Survey Location /Release Point	% Change in Entrainment from Release Point #920							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic + 2-Gates	+19	+19	+6	+19	+20	+2	+17	+16
Historic + 2-Gates + Qwest > -1,000 cfs	+16	+9	+5	+5	+5	+2	+8 [5]	+14
Historic + 2-Gates + Qwest > 0 cfs	+16	+4	+4	-6	-1	+1	+8 [5]	+12

[5] -19% change in entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 9. % Change in Entrainment from Release Point #815

Survey Location /Release Point	% Change in Entrainment from Release Point #815							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic + 2-Gates	+9	+17	+5	+11	+24	0	+2	+18
Historic + 2-Gates + Qwest > -1,000 cfs	+9	+5	+3	0	+11	0	-16 [5]	+12
Historic + 2-Gates + Qwest > 0 cfs	+5	-9	+2	-10	+8	-1	-23 [5]	+4

[5] -74% change in entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 10. % Change in Entrainment from Release Point #906

Survey Location /Release Point	% Change in Entrainment from Release Point #906							
	Feb-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic + 2-Gates	+6	+4	+9	+17	+10	+7	-10	-2
Historic + 2-Gates + Qwest > -1,000 cfs	+2	-9	+8	0	+1	+4	-21 [5]	-3
Historic + 2-Gates + Qwest > 0 cfs	0	-21	+6	-14	-1	+1	-26 [5]	-6

[5] -86% change in entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 11. % Change in Entrainment from Release Points #910

Survey Location /Release Point	% Change in Entrainment from Release Point #910							
	Mar-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic + 2-Gates	0	+1	+5	+11	-9	+1	-10	-6
Historic + 2-Gates + Qwest > -1,000 cfs	-3	-12	+3	-2	-17	-1	-18 [5]	-8
Historic + 2-Gates + Qwest > 0 cfs	-7	-23	+3	-14	-19	-4	-23 [5]	-10

[5] -82% change in entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.

Table 12. % Change in Entrainment from Release Points #912

Survey Location /Release Point	% Change in Entrainment from Release Location #912							
	Mar-Jun						Dec-Feb	
	9-Jun-99	12-Jun-02	15-May-02	30-May-02	21-May-03	12-May-04	16-Dec-03	30-Dec-04
Historic + 2-Gates	+2	+6	+6	+3	+16	+2	-20	+7
Historic + 2-Gates + Qwest > -1,000 cfs	-1	-3	+3	-10	+6	+2	-3 [5]	+4
Historic + 2-Gates + Qwest > 0 cfs	-2	-12	+1	-18	+1	-2	+3 [5]	+3

[5] -22 % change in entrainment observed in Historic + 2-Gates + Qwest >-1,000 cfs, when exports were curtailed to match San Joaquin River flow during the gate closure.