Handout #5

Draft Water Operations Conservation Measures

Note to Reviewers: *This handout presents a first draft water operations conservation measures section to Chapter 3 "Conservation Strategy," although the conservation measures (called parameters) are only framed and ecological rationale provided here without any specific operational values or ranges given. Analyses continue to be performed to evaluate the range of operational values for each parameter and the additive and synergistic benefits of combining multiple operational parameters as well as various potential physical habitat restoration conservation measures. Table 1 (near-term operations) and Table 2 (long-term operations) are not provided at this time. Tables 1 and 2 will provide the initial operating values and range of operating values for each parameter once these values have been determined in developing the draft water operations scenario in the coming weeks.*

Introduction

Water operations in the Delta are an integrated and interrelated collection of actions that affect flow and water quality outcomes. Criteria (quantitative values) will be identified for each parameter for specific times of year and specific water year types. These criteria are not provided in this document and have not been developed at this time. Tables 1 and 2, when they are prepared, will include the quantitative criteria for each parameter. The following information is provided for each parameter.

Parameter and Adaptive Range. Each parameter section begins with a description of the parameter and specific parameter implementation requirements (*note that specific quantitative requirements are not provided at this time and will be developed in the coming weeks and months*). The adaptive range will be described here as the quantified operating range limits within which the parameter could be adaptively managed during implementation to achieve conservation and planning goals.

Rationale. This section describes the justification for proposing the conservation measure. Rationale statements are primarily directed at identifying the covered species and ecosystem benefits that would be expected with implementing the conservation measure. The identified benefits are based on scientific literature and expert opinion.

Implementation timeframe. This section describes the BDCP implementation period (i.e., near-term or long-term) that is the most appropriate period for implementing the measure. The BDCP near-term implementation period refers to the period from issuance of BDCP permits to completion of the around-Delta conveyance facilities and the BDCP long-term implementation period includes the period from when dual-conveyance operations are initiated over the remainder of the term of the BDCP.

Implementation considerations. This section describes relevant items that may need to be addressed by the BDCP Implementing Entity when planning implementation of the conservation measure.

Resiliency to future change. This section provides a qualitative assessment of the likely ability of the conservation measure to continue to provide the desired level of covered species and ecosystem benefits into the future with anticipated changes in environmental conditions with climate change and sea level rise.

Uncertainties/risks. This section describes important uncertainties associated with ability of the conservation measure to achieve the desired covered species and ecosystem benefits and the ecological risks that may be associated with implementing the proposed conservation measure.

Monitoring and adaptive management considerations. This section describes monitoring and adaptive management-related elements of the conservation measure, including elements of implementation that may be subject to adaptive management and the types of monitoring that may be appropriate for assessing the effectiveness of the conservation measure in achieving desired ecological benefits and for informing the adaptive management process. [***Note to reviewers****: The content of this section will be expanded for each conservation measure to provide more specificity regarding monitoring actions and metrics and adaptive management triggers and actions, as appropriate, through future iterations of these materials*.]

Reversibility. This section qualitatively assesses the likely ability to reverse the environmental outcomes of the conservation measure, if necessary.

The information described above for each of the draft proposed conservation measures will be expanded upon and incorporated into appropriate sections of the BDCP Conservation Strategy chapter.

Operational Control Facilities

Operational control facilities are those structures in the SWP and CVP water management system that physically control the flow of water (Figure 1). These facilities involve physical control structures such as gates, intakes, and pumps that can be set to a range of values of flow operations that affect the Delta hydrodynamics in the immediate vicinity of the structure and often across large portions of the surrounding Delta.

The following is a list of operational control facilities and brief description of their functions:

- North Delta Diversion Facilities – The north Delta diversion facilities would be new multiple intakes along the Sacramento River between Walnut Grove and Freeport. Intakes would be equipped with state-of-the-art positive barrier fish screens to reduce

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entrainment of fish and would connect to an isolated conveyance facility to carry water to the south Delta SWP and CVP export facilities.

- Fremont Weir Operable Gates – New operable gates on the Fremont Weir would allow for the control of the timing, duration, and frequency of inundation of the Yolo Bypass during non-flood stage periods of the Sacramento River.
- Deep Water Ship Channel Bypass Operable Gates – If constructed, these would be new operable gates that would allow for the control of the timing, duration, and frequency of inundation of a new Deep Water Ship Channel Bypass during non-flood

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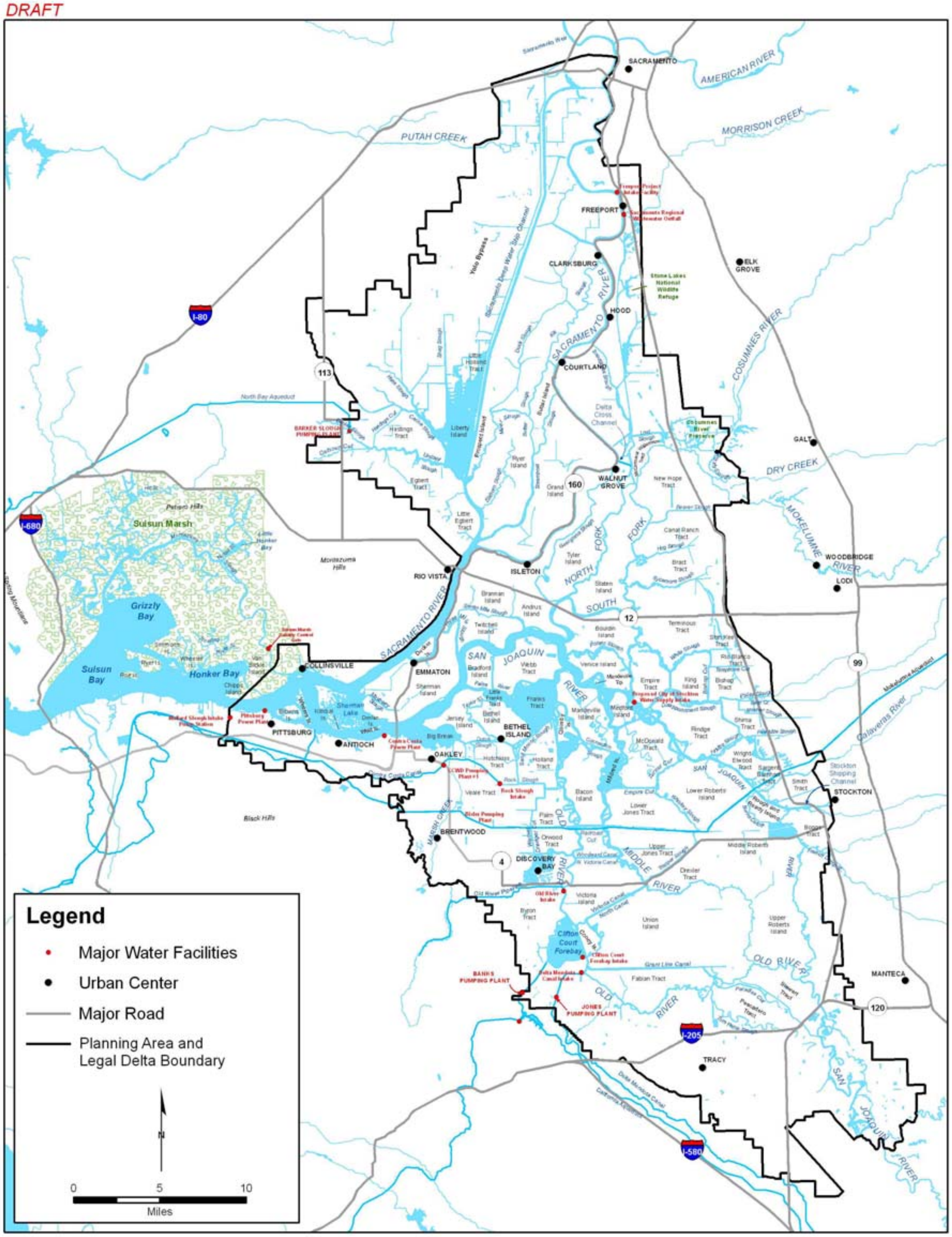

Dr Figure 1. BDCP Planning Area and Suisun Marsh Locator Map stage periods of the Sacramento River.

- Delta Cross Channel Gates – Delta Cross Channel Gates are existing radial gates that control the flow of Sacramento River water through the Delta Cross Channel into the interior Delta.
- Three Mile Slough Gates – These would be new operable gates in Three Mile Slough that would control the flow of Sacramento River water through Three Mile Slough and into the interior Delta.
- Gates on Old River and Connection Slough – These would be new gates installed on the east and west sides of Bacon Island on Old River and Connection Slough to control the flow of water and salinity concentrations in the south Delta..
- Montezuma Slough Salinity Control Gate – Existing gates at the eastern opening of Montezuma Slough that control the flow of fresh and salt water into Montezuma Slough.
- South Delta Diversions – Two existing diversion facilities, the Jones Pumping Plant and the Banks Pumping Plant, divert water from the south Delta to meet water supply demands outside the Delta.

Parameters (Conservation Measures)

This section provides descriptions of the water operations for multiple parameters across the Delta. Each water operations (WAOP) parameter is provided a unique alpha-numeric label (e.g. WAOP1, WAOP2, etc.)

WAOP1: North Delta Facilities Operations and Bypass Flows. This action involves operations of new north Delta diversion facilities on the Sacramento River and conveyance of water through an isolated canal to the south Delta export pumps. The north Delta facility would be prioritized over south Delta diversions to maximize anticipated environmental benefits within the Delta. The quantity and timing of diversions would be affected by specific parameters described in this document.

This action also involves maintaining specified flows in the Sacramento River as it bypasses new north Delta facilities. North Delta facilities bypass flows represent the rate of flow at which the Sacramento River must pass downstream of the new diversion points. Diversion of water from the north Delta facilities would be managed and limited based on compliance with bypass flow requirements. Constraining the amount of water diverted from north Delta facilities will require commensurate increases in diverting water from the existing SWP and CVP south Delta export facilities. This parameter affects WAOP4, 6, 9, 10, 13, and 14.

Adaptive Range. The north Delta facilities operations and bypass flow requirements would apply in the BDCP long-term implementation period following completion of facilities construction. The isolated facility would convey up to 15,000 cfs of water. The operations and bypass flow criteria are described, by water-year type, in Table 2 [*not provided at this time, values to be determined*]. Initially, exports would be split between those conveyed through the isolated facility and those conveyed through the Delta; however, as sea level rise and Delta levee failures reduce the feasibility of pumping directly from the south Delta, annual exports delivered through the isolated facility would increase.

Rationale: For decades, water has been diverted directly from the south Delta through SWP and CVP facilities to meet demands south of the Delta. These diversions have resulted in the development of reverse flows in major Delta channels, as well as entrainment of fish, invertebrates, nutrients, and other organic material. The use of the Delta itself as a conveyance conduit for water exports has been one of a number of stressors to the Delta ecosystem, including toxic discharges, invasion of non-native species, degradation of natural habitat, unsustainable land use practices, changing climatic conditions, and large upstream diversions that, together, are thought to have negatively impacted covered fish species (see Other Stressors and Habitat Restoration Conservation Measures). As a result, water supply in California is less reliable than it has been historically.

This parameter would reduce the impacts of in-Delta pumping on covered fish species, facilitate habitat restoration within the Delta, and improve water supply reliability. It would facilitate implementation of other conservation measures focused on non-flow related stressors by allowing for more environmentally beneficial management of the Delta. The north Delta facility would reduce through-delta conveyance and consequently reduce entrainment of fish, eggs, and organic material at the south Delta facilities. Residence time, and therefore productivity, in the interior Delta is expected to increase while unnatural reverse flows on Old and Middle River associated with fish entrainment would be minimized. North Delta facilities would provide greater opportunity for habitat restoration, including restoration in the western, eastern, and southern delta, and could provide for fluctuating salinity regimes and flow patterns that may emulate natural processes more closely than the current through-Delta system.

The Sacramento River, in addition to its upstream tributaries, is the primary migration corridor and spawning/rearing habitat for Chinook salmon, Central Valley steelhead, and green and white sturgeon within the Central Valley. In addition, both delta smelt and longfin smelt are thought to spawn in the lower Sacramento River (Wang 1986, Bennett 2005). Important fishery issues with respect to seasonal river flows include: (1) adult Chinook salmon, steelhead, and green and white sturgeon attraction flows and upstream migration; (2) juvenile Chinook salmon and steelhead downstream migration; (3) downstream transport of planktonic fish eggs and larvae; (4) downstream transport of food and other organic material; and (5) habitat for both resident and migratory covered fish species within the lower Sacramento River. The importance of river flows to each life stage of the covered fish species varies seasonally depending on each species' life history and habitat requirements. Because of the importance of the Sacramento River as a migration route and habitat for covered fish species, concern has been expressed regarding sufficient flows within the river to support covered fish species.

The diversion of water from the Sacramento River through facilities located between Freeport and Walnut Grove directly affects flows within the river downstream of the points of diversion. Of particular concern are flow rates within Sutter and Steamboat Sloughs (see WAOP4 below). These sloughs are major migration corridors for juvenile Chinook salmon and probably other native species. Survival rate of these species is thought to be higher in these sloughs than in the interior Delta Higher downstream flows and lower reverse flows would likely result in lower exposure to predation and, therefore, greater probability of survival. Non-native predators present throughout the Delta are thought to be a primary cause of in-Delta salmon mortality (see Other Stressors Conservation Measures). If flows in Sutter and Steamboat Sloughs are reduced, residence time and, therefore, exposure to predators of outmigrating species, is expected to increase. Attraction flows for adults can also be reduced if flows are reduced in these channels. Analyses to date, however, indicate that substantial habitat restoration in the Cache Slough area, in combination with bypass flow requirements, would enhance downstream flows in Sutter and Steamboat Sloughs substantially above those present under pre-Wanger conditions without an isolated facility (A. Munevar unpubl. data).

Reduced flows on the Sacramento River downstream of the diversion can affect downstream transport of food, organic material, and multiple life stages of covered fish species. Developing bypass flow criteria for the north Delta diversion facilities involves consideration of the seasonal timing of various life stages of covered fish species within the lower Sacramento River, relationships between river flow, water velocity, transport time, and residence time, and the growth, survival, and distribution of various life stages of the covered species.

North Delta facilities bypass flows also affect the sweeping velocities across the surfaces of intake fish screens, the potential exposure duration of a fish to the screen, local current patterns and hydrodynamics in the vicinity of the screen surface that may affect fish entrainment or impingement, debris loading, effectiveness of fish screen cleaning mechanisms in removing debris from the screen surface, and maintaining a uniform approach velocity within the screen design criterion.

Implementation timeframe: The north Delta facilities bypass flow requirements would become effective during the BDCP long-term implementation period at the time the north Delta diversion facilities become operational.

Implementation considerations: Operation of the north Delta facilities would be subject to appropriate diversion limitations based on bypass flow requirements and constraints on south Delta pumping (WAOP4, 6, 9, 10, 12, and 14). Implementation of the north Delta facilities bypass flow requirement includes consideration of biological processes both downstream of the north Delta diversion facilities and in the south Delta. More demanding bypass flow requirements would result in less water being diverted in the north Delta facility and commensurate increase in south Delta diversions from the existing SWP and/or CVP export facilities. The ecological tradeoffs between pumping in the south Delta and diversion from the north would need to be carefully monitored, with bypass flow requirements adjusted accordingly through an adaptive management plan (see below). In the south, greater through-Delta conveyance is expected to result in greater entrainment of organic material and fish, greater reverse flows in key channels, and potentially less successful in-Delta habitat restoration efforts. In the north, implementation of bypass flow requirements will require consideration of: (1) variation in precipitation and hydrology of the Sacramento River within and among years; (2) seasonal timing of various life stages of covered fish occurring near and downstream of the facilities; and (3) the relationship between river flows and physical and biological processes that affect survival, growth, and abundance of covered species, including downstream transport of food and organic material and distribution of covered species. Diversions into floodplain habitat (WAOP3 and 4) would also affect availability of water to support bypass flows. Implementation of the bypass flow requirement could unintentionally affect operation of upstream reservoirs, with operators holding back releases during periods of high bypass requirements (winter and spring) and maximizing releases during more relaxed bypass requirements during the summer in the mainstem Sacramento River. Implementation of the bypass flow requirement would require a large-scale management effort to coordinate and integrate SWP and CVP water project operations throughout the Central Valley. Flow rates within Sutter and Steamboat Sloughs must also be considered in the implementation of bypass flow criteria.

Minimum bypass flows would also be determined by required sweeping and approach velocities across the surfaces of intake fish screens, the potential exposure duration of a fish to the screen, local current patterns and hydrodynamics in the vicinity to the screen surface that may affect fish entrainment or impingement, debris loading, and the effectiveness of fish screen cleaning mechanisms in removing debris from the screen surface, and maintaining a uniform approach velocity within the screen design criterion.

Resiliency to future changes: North Delta diversion facilities would be physically designed to withstand anticipated levels of sea level rise, as well as foreseeable environmental conditions, such as earthquake and flood events. As sea level rise and Delta levee failures reduce the feasibility of pumping directly from the south Delta, diversions from north Delta facilities are expected to increase with a concomitant decrease in south Delta diversions. Changes in habitat conditions within the Sacramento River upstream and downstream of intakes of the north Delta facilities in the future may alter relationships between Sacramento River flows and the health and survival of covered fish species. In addition, changes in precipitation patterns, both in terms of the quantities of precipitation within a year but also variation in the amount of precipitation as rainfall and snowfall, will also affect the frequency and magnitude of flows in the Sacramento River in the future.

The proposed criteria for bypass flows (Table 2 [*not provided at this time, values to be determined*]) are designed to reflect variation in hydrological conditions within the basin, and specifically within the river at the points of diversion, and therefore would be resilient to future changes in hydrology. Bypass flow requirements can be modified as necessary to adapt to future changes in hydrology, sea level, implementation of other conservation measures, and changes in habitat conditions.

Uncertainties/risks: Although it is anticipated that diverting water from locations north of the Delta will improve overall ecosystem function and substantially decrease entrainment in the south Delta, the population level response of covered species to this parameter is uncertain, largely because numerous other non-flow factors are responsible for their decline, including food limitation, invasive species, discharges of contaminants, and increasing temperature trends. Even if implementation of north Delta facilities completely eliminated negative effects to covered species by exports from the Delta, other stressors may ultimately result in failure of these species to recover. There are uncertainties related to how covered species will respond to various operational aspects of a north Delta facility, which are covered in more detail in the descriptions of other parameters below.

Establishing bypass flow criteria for a North Delta Diversion Facilities located on the Sacramento River has a number of uncertainties. For example, results of coded wire tagged juvenile Chinook salmon survival studies have shown a highly variable and weak correlation between survival and river flows (Hanson 2008). In addition, virtually no information is available on the relationship between Sacramento River flows and survival of other outmigrating species. The quantities of flow needed to attract Chinook salmon, steelhead, green and white sturgeon, and other fish for upstream migration are also largely unknown. There is also uncertainty in the relationship between river flows and downstream travel times of juvenile Chinook salmon and other fish, as well as uncertainty in the relationship between seasonal river flows and survival and growth of larval delta smelt. Potential changes in future hydrology, climate, and sea level rise compound these uncertainties.

Larval delta smelt born in the northern region of the Delta are transported downstream by seasonal flows. There is uncertainty in the relationship between river flows and the residence time and downstream transport rates of planktonic fish eggs, larvae, organic material, phytoplankton, zooplankton, and macroinvertebrates. There is also uncertainty in the relationship between river flows and downstream travel times of juvenile Chinook salmon and other fish, as well as the exposure duration of these juveniles to a positive barrier fish screen. The relationship between seasonal river flows and survival and growth of larval delta smelt is uncertain. Changes in the relationship between river flows and survival, growth, and abundance of covered fish after BDCP habitat restorations have been implemented throughout the Delta are also uncertain. As noted above, changes in Central Valley hydrology in the future, and the effects on reservoir storage and operations, as well as river flows and covered fish species habitat conditions, are also uncertain.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Given the numerous uncertainties described above, it is important to develop appropriate monitoring and adaptive management criteria to evaluate the response of covered fish species to the bypass flow criteria. The impact of modifying bypass criteria on other operational parameters, particularly the level of pumping in the south Delta, would be examined, and the overall impact on covered species and ecosystem health would be evaluated. Future monitoring would include examination of relationships between bypass flows and south Delta pumping levels on survival and abundance of various life stages of covered fish species. Monitoring is also expected to examine the relationship between river flows and the downstream transit times for larval and juvenile fish, nutrients and organic carbon sources, as well as the behavior (e.g., transit rate, residence times, and upstream and downstream tidal movement) of various fish in the immediate vicinity of a positive barrier fish screen. Operational monitoring at one or more points of diversion is expected to include approach and sweeping velocities as a function of both river flows and diversion rates, debris loading and cleaning of the fish screen, sediment deposition and scour within the river in the vicinity of the points of diversion, and changes in fish screen and diversion operations over a range of river stages and flow rates.

Results of both biological and operational monitoring throughout the Delta could be used within the BDCP adaptive management framework to refine and modify river bypass flow rates. For example, additional information on the actual timing of fish migration downstream within the Sacramento River within a given year could result in near-term modification to the river bypass flows to facilitate migration past the points of diversion and fish screens.

Reversibility: Because implementation of operations and bypass flow requirements are operational elements of the BDCP and would not require specific physical facilities, the operations and bypass flow requirements could be easily modified or reversed. The bypass flow requirements, however, are an integral element in overall water project operations and water supply deliveries, as well as environmental protections for species and habitats within the lower Sacramento River and, therefore, institutional reversibility is expected to be difficult.

WAOP2: Fremont Weir Operations. This action involves control of the timing, frequency, and duration of inundation of the Yolo Bypass (see Figure 1) with Sacramento River flows via the Fremont Weir. Operation of a new Fremont Weir gate(s) and associated channels described in Conservation Measure FLOO1.1 would be targeted to increase the frequency and duration of inundation of the Yolo Bypass between [month/day] and [month/day]. (At river elevations below flood stage (Sacramento River stage <33.5 feet [USED] or <33.03 feet [NAVD88]; Sacramento River flow at Fremont Weir <~56,500 cfs), the weir gate(s) would be opened to allow up to __ cfs into the Yolo Bypass as operated according to Figure 2. Once the targeted duration of inundation has been achieved (__ days of inundation in the Bypass with no more than a seven day gap in Bypass flows), the weir gate(s) could be operated to reduce or eliminate flows into the Bypass from the Sacramento River. At flood stage, the weir would overtop as under current conditions.

Inundation of the Yolo Bypass provides additional food and habitat to several covered fish species. This parameter affects WAOP4, 6, and 14. When water inundates the Yolo Bypass, flows are reduced in the Sacramento River between the weir and Rio Vista. Closing the weir gate would provide water to support environmental benefits in Sutter and Steamboat Sloughs, the mainstem Sacramento River between, the Central Delta, and a potential new Deep Water Ship Channel Bypass.

Adaptive Range. Operable gates would be used to manage flows into the Yolo Bypass within the ranges indicated in Tables 1 and 2 [*not provided at this time, values to be determined*] for the near-term and long-term implementation periods, respectively, by water year type. Specific gate operations within the range of flows indicated for a particular water year type would be based on a variety of factors, including the observed biological responses to specific inundation operations in previous years as determined through monitoring (e.g., food production, juvenile salmonid survival, and splittail spawning success).

Rationale: See Conservation Measure FLOO1.1 for the rationale for this parameter.

Implementation timeframe: See Conservation Measure FLOO1.1 for the description of the implementation timeframe for this parameter.

Implementation considerations: See Conservation Measure FLOO1.1 for the description of implementation considerations for this parameter.

Resiliency to future changes: See Conservation Measure FLOO1.1 for the description of the resiliency of this parameter.

Uncertainties/risks: See Conservation Measure FLOO1.1 for the description of the uncertainties/risks associated with this parameter.

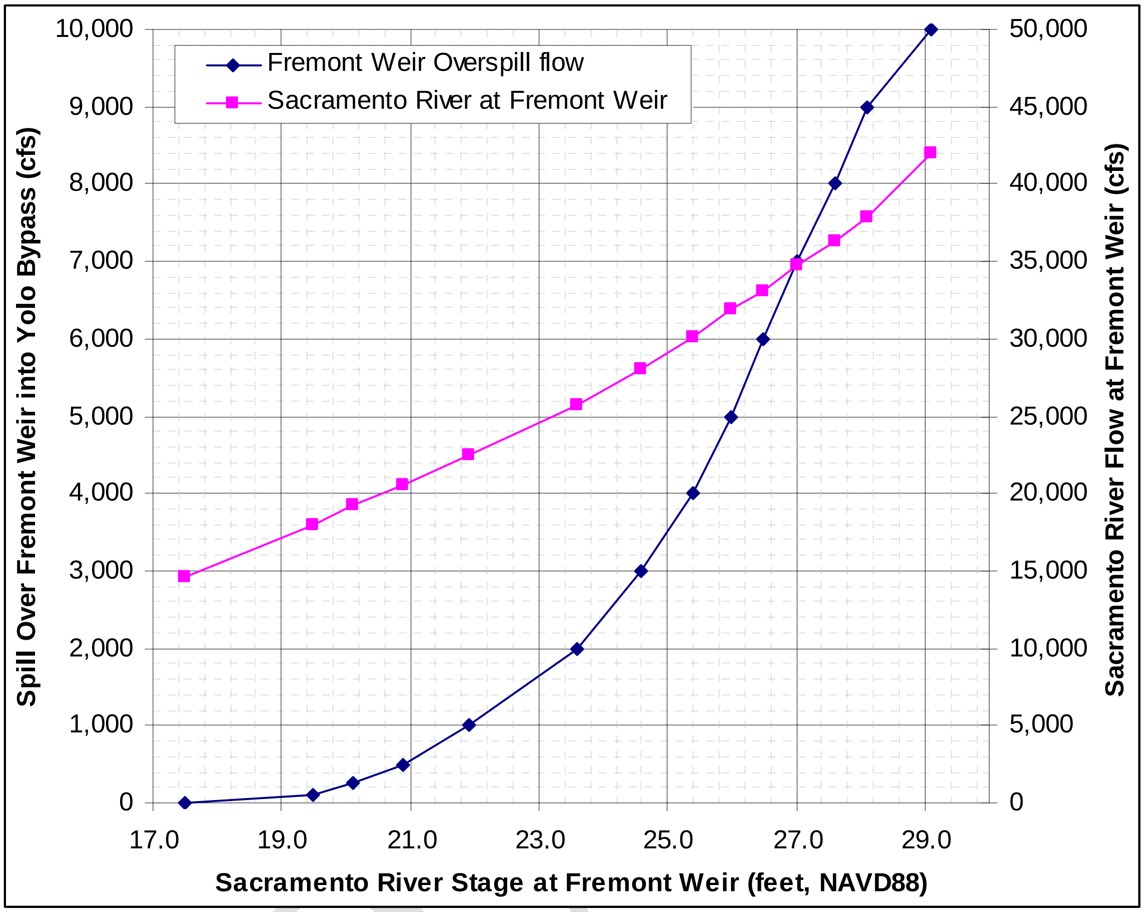

Figure 2. Modeled rating curves for the modified Fremont Weir with estimated weir overspill flows and Sacramento River stage and flows at Fremont Weir assuming proposed gates are fully open. This figure does not represent how gates would actually be operated.

Monitoring and adaptive management considerations: See Conservation Measure FLOO1.1 for the description of the monitoring and adaptive management considerations associated with this parameter.

Reversibility: See Conservation Measure FLOO1.1 for the description of the reversibility of this parameter.

WAOP3: Deep Water Ship Channel Bypass Weir Operations. As described in Conservation Measure FLOO2.1, a Deep Water Ship Channel Bypass may be constructed in the future if it were deemed a necessary improvement to the Central Valley flood control system and, if deemed necessary, the BDCP Implementing Entity would coordinate with flood control agencies to design and operate the new bypass to provide joint flood control and covered fish species benefits. If the new bypass is constructed, this action involves the control of the timing, duration, and frequency of inundation of the new bypass using Sacramento River flows which would affect WAOP4, 6, and 14. A new operable weir gate(s) at the head of the new floodplain bypass (described in Conservation Measure FLOO2.1) would provide for diversion of water from the Sacramento River into the bypass when river stage exceeds 9.0 ft NAVD88 (~30,400 cfs in the Sacramento River at Freeport) between [month/day] and [month/day]. The operable gate(s) would be designed to allow up to __ cfs into the bypass. Once the targeted duration of inundation has been achieved, the gate could be operated to reduce or eliminate flows into the bypass.

Inundation of a Deep Water Ship Channel Bypass would provide additional food and habitat to several covered fish species. When water inundates the Deep Water Ship Channel Bypass, flows are reduced in the Sacramento River between the weir and Prospect Island, reducing flows through Steamboat and Sutter Sloughs and the central Delta.

Adaptive Range. The operable gate(s) would be used to manage flows during the BDCP long-term implementation period within the ranges indicated in Table 2 [*not provided at this time, values to be determined*] by water year type. Specific gate operations within the range of flows indicated for a particular water year type would be based on a variety of factors, including observed biological responses to specific inundation operations in previous years as determined through monitoring (e.g., food production, juvenile salmonid survival, splittail spawning success).

Rationale: See Conservation Measure FLOO2.1 for the rationale for this parameter.

Implementation timeframe: See Conservation Measure FLOO2.1 for the description of the implementation timeframe for this parameter.

Implementation considerations: See Conservation Measure FLOO2.1 for the description of implementation considerations for this parameter.

Resiliency to future changes: See Conservation Measure FLOO2.1 for the description of the resiliency of this parameter.

Uncertainties/risks: See Conservation Measure FLOO2.1 for the description of the uncertainties/risks associated with this parameter.

Monitoring and adaptive management considerations: See Conservation Measure FLOO2.1 for the description of the monitoring and adaptive management considerations associated with this parameter.

Reversibility: See Conservation Measure FLOO2.1 for the description of the reversibility of this parameter.

WAOP4: Sutter and Steamboat Slough Flows. This parameter addresses the flows entering Sutter and Steamboat Sloughs and would be affected by the operations described under WAOP1, 2, and 3 and physical habitat restoration conservation measures in the north Delta. These sloughs are existing channels that convey water from the Sacramento River in the general vicinity of Courtland downstream to approximately Rio Vista (Figure 2) where they re-enter the lower Sacramento River. Both channels currently have a hydraulic capacity greater than 500 cfs. Sutter and Steamboat Sloughs provide an alternative migration route for fish, provide habitat connectivity, riverine habitat for fish and wildlife, and contribute to the production and downstream transport of nutrients to the lower Sacramento River. As part of the long-term implementation of the BDCP, the benefits to covered fish species of the current flow regimes through these sloughs would be maintained or improved. As described in Conservation Measure CHMA1.3, actions may be undertaken to enhance physical habitat conditions for covered fish species within these sloughs and to reorient the upstream confluence between one or both sloughs and the Sacramento River channel to facilitate greater movement of downstream migrating salmon and steelhead into these channels.

Adaptive Range: Near- and long-term outcome criteria for Sutter and Steamboat slough flows are provided in Tables 1 and 2 [*not provided at this time, values to be determined*].

Rationale: Sutter and Steamboat sloughs provide several important functions in support of covered fish species that would be maintained by this parameter. Sutter and Steamboat sloughs provide an alternative migration pathway for juvenile salmon and other fish, juvenile rearing habitat, adult holding and spawning habitat for species such as splittail, and increased nutrient loads that are subsequently transported downstream where they enter the lower Sacramento River and Delta. Steamboat and Sutter sloughs provide a migration route that reduces the risk of exposure to a new North Delta diversion point(s) and fish screen(s) within the reach of the Sacramento River between Courtland and Rio Vista (Figure 1). Both slough channels support substantially more woody riparian vegetation and greater habitat diversity (e.g., water depths, velocities, in-channel habitat, etc.) than is present along the mainstem river between Courtland and Rio Vista. Flows through these two sloughs maintain habitat connectivity for resident and migratory fish, and the transport of fish and nutrients downstream. The sloughs also provide wildlife habitat benefits. The sloughs provide an alternative migration route that circumvents the Delta Cross Channel and Georgiana Slough and, therefore, reduces the likelihood of covered fish species moving into the interior of the Delta, where the susceptibility of covered fish species to predation and entrainment at the south Delta SWP and CVP would be greater than in the mainstem river.

Implementation timeframe: The Sutter and Steamboat Slough flow parameter (WAOP4) would become effective in the BDCP near-term implementation period following completion of modifications to the Fremont Weir that would allow for increasing the frequency and duration of flows that would pass out of the Sacramento River into the Yolo Bypass (see WAOP2). Long-term flow criteria for Sutter and Steamboat sloughs would become effective following initiation of operations of new north Delta diversion facilities.

Implementation considerations: Operational considerations include coordinating diversion of water from the Sacramento River at the north Delta diversion facilities (WAOP1), into the Yolo Bypass (WAOP2), and into a Deepwater Ship Channel Bypass (WAOP3), such that the biological benefits to covered fish species of current Sutter and Steamboat slough flows are maintained or improved over the term of the BDCP. Further, habitat restoration in the north and western Delta is expected to influence tidal amplitude in these sloughs, which would alter their hydrology and the residence time of covered fish species in the sloughs affecting the amount of time they are susceptible to predation by non-native species (A. Munevar unpubl. data).

Resiliency to future changes: Maintenance of the existing Sutter and Steamboat slough channels is expected to be resilient to future changes in hydrology, sea level, and implementation of other elements of the overall BDCP conservation program. The existing slough channels accommodate both base flows and periodic flood flows. Although the frequency, duration, and magnitude of seasonal flows within the Sacramento River and Delta may vary in the future, the basic functional processes and biological benefits associated with maintaining conveyance through Sutter and Steamboat sloughs would continue into the future over the entire range of anticipated changes in future hydrologic conditions. It is anticipated that maintaining the existing conveyance through the sloughs would be resilient and accommodate future changes in environmental conditions.

Uncertainties/risks: Uncertainties exist regarding the effects of maintaining or increasing the passage of fish from the Sacramento River into either Sutter or Steamboat slough. A small number of experimental studies have been conducted that test differences in survival of juvenile Chinook salmon migrating downstream through the sloughs compared to salmon migrating downstream in the mainstem Sacramento River (USFWS unpubl. data). There are uncertainties in the survival and growth of juvenile salmon and other fish that would move from the mainstem river into either Sutter or Steamboat slough. For example, there are uncertainties regarding the vulnerability of juvenile Chinook salmon to predation mortality as a result of passage through the sloughs and the potential for habitat within the sloughs to increase the abundance of non-native predatory fish (e.g., striped bass, large and smallmouth bass). There is currently uncertainty regarding the relationships between water velocities and hydraulic residence times, and resultant changes in habitat conditions within the sloughs.

The relative changes in survival and growth of covered fish moving from the river into the sloughs under these conditions is uncertain. There is uncertainty regarding the relative biological effects that may occur as a result of diverting flows from the river into the sloughs on habitat conditions, migration rates, and the downstream transport of fish eggs and larvae as well as phytoplankton, zooplankton, and nutrients within the mainstem Sacramento River. Reduced flows within the mainstem river have the potential to reduce survival of those organisms that continue to inhabit the mainstem river.

Maintenance of conveyance of fish and flows through both sloughs would be part of the long-term BDCP implementation that would also include a number of associated changes in habitat conditions, water export operations, and hydrodynamic conditions throughout the Delta. There are uncertainties in evaluating the influence of changes in the physical characteristics of the sloughs, in combination with other habitat modifications within the Delta, that could potentially be implemented as near- or long-term conservation projects on the tidal hydrodynamics of the mainstem river and a number of channels within the Delta. Although the limited available data supports the biological benefits of maintaining, and potentially enhancing, passage of various species and lifestages of fish and flows through Sutter and Steamboat sloughs, there is uncertainty regarding the relationship between conveyance from the river into either slough and the benefits for various species.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Future monitoring would be similar and in addition to that currently conducted by the U.S. Geological Survey, which monitors flow, river stage, and water velocity in real time in both Sutter and Steamboat Sloughs. Additional monitoring could be used to evaluate and document the site-specific functional relationships between the conveyance of flows within the sloughs, passage of juvenile salmon and steelhead into and downstream within the sloughs, compositions and abundance of fish inhabiting the sloughs, spawning by species such as splittail, and the growth and survival of covered species within the sloughs compared to the mainstem river. Information developed on these and other aspects of the slough habitat could be used to help adaptively manage the conveyance of flows and habitat. Results of these investigations may show that increased movement of various fish species into the sloughs is beneficial and modifications to the channels could be identified that increase passage. Enhancements of various habitat elements (e.g., overhead cover, etc.) that benefit covered fish (and wildlife) could also be identified through surveys and implemented as both near- and long-term actions. In contrast, results of survival studies and other monitoring may show that fish movement into the sloughs increases the risk of mortality (e.g., increased exposure to predators) and near- or long-term modifications to flows or habitat could be identified and implemented as part of the conservation program to reduce and control predation. Monitoring and adaptive management could also address changes in the relative survival, migration rates and timing, and transport of various fish within the mainstem river as a function of flows in sloughs.

Reversibility: Maintaining the capacity of existing Sutter and Steamboat slough channels is considered to be completely reversible. BDCP operations that affect flow rates through Sutter and Steamboat Sloughs (i.e., operations to inundate north Delta floodplain habitats and to divert water from North Delta Diversion Facilities) could be easily reversed by modifying operations. Institutionally, however, enabling such modifications to operations could be difficult.

WAOP5: Delta Cross Channel Gate Operations. This action involves operating the Delta Cross Channel Gate to improve fish migration, hydrodynamics (including hydraulic residence time), and food and organic material transport while minimizing changes to water quality for agriculture, municipal, and industrial uses in the interior and southern Delta. This parameter would affect WAOP6, 8, 13, and 14.

The Delta Cross Channel serves as a conveyance facility for water to move from the Sacramento River into the interior Delta. The Delta Cross Channel gate is located on the Sacramento River near Walnut Grove (Figure 2). Results of fishery studies have shown that juvenile Chinook salmon, and presumably a number of other fish species, move from the Sacramento River into the interior Delta when the gate is open. Results of survival studies suggest that survival of coded wire tagged and radio tagged juvenile Chinook salmon passing into the Delta through the Delta Cross Channel is lower than survival of those migrating down the mainstem Sacramento River (Brandes and McLean 2001, USFWS unpubl. data, Burau pers. com.). Based on results of these studies, closure of the Delta Cross Channel gates between February and May, is currently required under D-1641 for fish benefits. Closure of the Delta Cross Channel gate, particularly in the late summer and early fall months, is expected to contribute to changes in water quality (increased salinity) in the central and southern regions of the Delta, and may also affect seasonal water quality in other regions of the Delta.

Adaptive Range. The adaptive range for operation of the Delta Cross Channel gate during the BDCP near-term and long-term implementation periods are described in Tables 1 and 2, respectively [*not provided at this time, values to be determined*].

Rationale: Fishery studies conducted within the Bay-Delta estuary suggest increased levels of mortality for juvenile life stages of fish, such as Chinook salmon, within the interior Delta (Baker and Morhardt 2001, Brandes and McLain 2001, USFWS unpubl. data). Several hypotheses have been suggested regarding reduced survival in the interior Delta relative to the mainstem Sacramento River. These factors include, but are not limited to: (1) increased exposure to unscreened water diversions within the Delta channels; (2) exposure to seasonally elevated water temperatures and potentially toxic contaminants; (3) increased residence time and longer migration routes leading to longer exposure to environmental conditions within the Delta and increased vulnerability to predation mortality; (4) delayed migration as a result of altered hydrologic conditions in Delta channels as a result of SWP and CVP export operations; and (5) direct losses as a result of entrainment, predation, or salvage mortality at the south Delta SWP and CVP

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export facilities (Baxter et al. 2008). Although the experimental studies have been conducted only on juvenile Chinook salmon (Brandes and McLain 2001, CALFED 2001, Vogel pers. com., Burau pers. com.), results of these studies are believed to generally reflect effects of migration into the Delta on survival of other fish species as well. Seasonal closure of the Delta Cross Channel gates is designed to prohibit the migration of fish from the Sacramento River into the interior Delta through the Delta Cross Channel, thereby increasing their survival. However, recent studies have failed to show a population level effect of the Delta Cross Channel on Chinook salmon (Manly 2002, 2008). In addition, closure of the Delta Cross Channel gates contributes to greater downstream flows and downstream transport of fish eggs, larvae, juveniles, food, and organic material within the Sacramento River into the Delta.

Implementation timeframe: Implementation of the Delta Cross Channel gate operations would be a near- and long-term operational element of the BDCP conservation program.

Implementation considerations: The existing Delta Cross Channel gates have been designed to allow for periodic closure. The gates are currently closed in compliance with D-1641 and for Sacramento River flood control. Near- and long-term operation of the gates may require additional facility maintenance, repair, and equipment replacement. Longer periods of closure of the gate as part of BDCP conveyance operations would require consideration of effects on Delta water quality conditions for agricultural and municipal and industrial uses.

Resiliency to future changes: Operation of the Delta Cross Channel gate is expected to be resilient to future changes in hydrology, sea level, and implementation of other conservation measures. The gate was designed to operate over a wide range of flows and stages within the Sacramento River and can be opened or closed on demand.

Uncertainties/risks: Recommended seasonal closure of the Delta Cross Channel gate to increase survival of downstream migrating juvenile Chinook salmon and other covered fish species is based on results of a limited number of coded wire tag survival studies. Survival studies conducted over the past several decades are not expected to reflect environmental conditions, habitats, or the potential survival of fish within the interior Delta under future conditions. A major uncertainty is the cause of reduced survival of juvenile Chinook salmon in the interior Delta. A number of habitat restoration projects have been identified that would improve the quality and availability of aquatic habitat within the Delta for juvenile salmon and other fish and may improve survival of these fish in the interior Delta. With north Delta diversion capability, it is expected that there would be significant reductions in south Delta SWP and CVP exports that would reduce the vulnerability of fish to direct losses at south Delta pumping facilities, as well as improve Delta hydrodynamics and aquatic habitat conditions and functions. Closure of the gate in the future would reduce the access and movement of fish from the river into the

Delta where they are expected to benefit from the improved habitat conditions. There is also uncertainty regarding changes to habitat and water quality conditions that would occur in response to gate closure over extended periods of time each year.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Future monitoring is expected to focus, to a large extent, on examining the relationship between Sacramento River flows, gate closure operations, and the survival and abundance of various life stages of covered fish species. Monitoring would also be expected to examine the relationship between river flows and the downstream transit times for larval and juvenile fish, nutrients and organic carbon sources, as well as the behavior (e.g., transit rate, residence times, upstream and downstream tidal movement, etc.) of various fish in the reach of the river downstream of the Delta Cross Channel. Results of biological monitoring could be used within the BDCP adaptive management framework to refine and modify seasonal Delta Cross Channel gate operations.

Reversibility: Because implementation of the Delta Cross Channel gate closure requirement is an operational element of the program, and would not require construction of new facilities, the timing, duration, or triggers for gate closure or opening could be modified or reversed through changes to operations. Delta Cross Channel gate operations are an integral element in overall water project operations and water supply deliveries, as well as environmental protections for species and habitats within the lower Sacramento River and, therefore, institutional reversibility may be difficult.

WAOP6: Rio Vista Flow Requirements. The lower Sacramento River serves as an important part of the aquatic habitat within the Delta. Diversion of water at new North Delta Diversion Facilities, as well as diversion of water from the mainstem river into side channels (e.g., Delta Cross Channel, Georgiana Slough) or seasonally inundated floodplain habitat (e.g., Yolo Bypass), has a direct effect on flow rates in the Sacramento River at Rio Vista. Operations described under WAOP1, 2, 3, and 5 would affect flow at Rio Vista. Identification of a minimum flow requirement at Rio Vista is intended to support fishery and aquatic habitat in the reach of the Sacramento River located between Sacramento and Rio Vista (Figure 2). Flow in the mainstem Sacramento River downstream of Rio Vista is augmented by the flow contribution from Cache Slough, the Yolo Bypass, Sutter and Steamboat sloughs, and other local tributaries. Minimum river flows at Rio Vista, in the fall, are included in current regulations (D-1641) and may be included as elements of both near- and long-term operations under the BDCP conservation program.

Adaptive Range. Near- and long-term flows, by water-year type, at Rio Vista included as part of the conveyance element of the program are provided in Tables 1 and 2 [*not provided at this time, values to be determined*].

Rationale: The Sacramento River, in addition to its upstream tributaries, is the primary migration corridor and spawning/rearing habitat for Chinook salmon, Central Valley steelhead, and sturgeon within the Central Valley. In addition, both delta and longfin smelt likely spawn in the lower river in the general vicinity of Rio Vista. Key fishery issues with respect to seasonal river flows at Rio Vista have primarily focused on adult Chinook salmon and steelhead attraction and upstream migration flows during the fall months. Under the BDCP, consideration regarding Rio Vista flows has also been given to: (1) juvenile Chinook salmon and steelhead downstream migration; (2) downstream transport of planktonic fish eggs and larvae; (3) downstream transport of nutrients and organic material; and (4) habitat for both resident and migratory species within the lower river. The importance of river flows to each of the species and lifestages of covered fish species varies seasonally depending on the life history and habitat requirements of the species. Given the importance of the Sacramento River as a migration route and habitat for covered fish species, concern has been expressed regarding the seasonal flows within the Sacramento River to support covered fish species.

Implementation timeframe: Implementation of the Rio Vista flow requirements would be a near- and long-term operational element of the BDCP conservation program (Tables 1 and 2 [*not provided at this time, values to be determined*]). The long-term Rio Vista flow requirements would apply only after North Delta Diversion Facilities becomes operational.

Implementation considerations: Implementation of the long-term Rio Vista flow requirement includes consideration of the time of the year and occurrence of covered species in the area, hydrologic conditions within the watershed, upstream reservoir releases, water diversions including flows into floodplain habitat such as that discussed for the Yolo Bypass in WAOP2, and tidal flows at the point of diversion. Long-term compliance with the Rio Vista flows also affects coordinated operations of the dual water diversions facilities in which a reduction in diversions at North Delta Diversion Facilities as a result of a Rio Vista flow constraint may result in a commensurate increase in south Delta diversions from the existing south Delta SWP and/or CVP export facilities. Implementation of the Rio Vista flow requirement could affect operations of upstream reservoirs and instream flow releases to meet the flow requirement and provide water supplies at the point of diversion for the isolated conveyance facility.

Resiliency to future changes: Development of the Rio Vista flow criteria in Table 2 (*not provided at this time, values to be determined*) was based, in part, on information regarding past hydrologic conditions within the Central Valley, as well as the expected relationships between Sacramento River flows and the health and survival of covered species based on existing habitat conditions and flow relationships. Changes in habitat conditions within the Sacramento River upstream and downstream of Rio Vista may alter these relationships. In addition, changes in precipitation patterns, both in terms of the quantities of precipitation within a year and variation in the amount of precipitation as rainfall and snowfall, will also affect the frequency and magnitude of flows in the Sacramento River at Rio Vista in the future. The proposed criteria for Rio Vista flows (Table 2 [not provided at this time, values to be determined]) are designed to reflect variation in hydrologic conditions within the basin, specifically under critically dry hydrologic conditions, and therefore would be resilient to future changes in hydrology. Changes in the understanding of how covered fish respond to river flows in the future (e.g., adult Chinook salmon attraction and upstream migration during the fall) could potentially be accommodated through flexibility in the operational criteria as part of the adaptive management component of the BDCP.

Uncertainties/risks: Uncertainties regarding near-term Rio Vista flow criteria include: (1) relationships between Sacramento River flows and survival and/or transport of species including larval delta smelt, steelhead, green sturgeon, and white sturgeon; (2) relationships between river flow and migration and habitat conditions for species including green and white sturgeon; and (3) relationships between river flows and upstream attraction of migrating salmon, steelhead, white sturgeon, green sturgeon, and other fish species.

Establishing a long-term Rio Vista flow criteria for operation of North Delta Diversion Facilities located on the Sacramento River has a number of uncertainties. For example, results of coded wire tagged juvenile Chinook salmon survival studies have shown a highly variable and weak positive, correlation between survival and river flows (Hanson 2008). Virtually no information is available, however, on the relationship between Sacramento River flows and survival of downstream migrating steelhead, or the relationship between river flow and migration and habitat conditions for species such as green and white sturgeon. The relationship between attraction and upstream migration by salmon, steelhead, white sturgeon, green sturgeon, and other fish and river flow at Rio Vista, within the range of flows included in Table 2 (*not provided at this time, values to be determined*), are also largely unknown.

Delta smelt spawned in the northern region of the Delta are transported downstream as larvae in the river by seasonal flows. There is uncertainty in the relationship between river flows and the residence time and downstream transport rates of planktonic fish eggs, larvae, nutrients, phytoplankton, zooplankton, and macroinvertebrates. There is also uncertainty in the relationship between river flows and downstream travel times of juvenile Chinook salmon and other fish. The relationship between seasonal river flows at Rio Vista and survival and growth of larval delta smelt is uncertain.

In addition, the biological response of changes in water diversions from north Delta diversion facilities and the existing south Delta SWP and CVP export facilities in response to Rio Vista flow requirements cannot be predicted with certainty. Changes in the relationship between Sacramento River flows and survival, growth, and abundance of covered fish species after BDCP habitat restoration projects have been implemented throughout the Delta are also uncertain. As noted above, changes in Central Valley hydrology in the future, and the effects on reservoir storage and operations, as well as Sacramento River flows and fishery habitat conditions, are also uncertain.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Future monitoring is expected to focus on examining the relationship between Sacramento River flows and the survival and abundance of various lifestages of covered fish species. Monitoring would also be expected to examine the relationship between river flows and the downstream transit times for larval and juvenile fish, nutrients and organic carbon sources, as well as the behavior (e.g., transit rate, residence times, upstream and downstream tidal movement, etc.) of various fish in the Sacramento River between Sacramento and Rio Vista. Results of biological monitoring could be used within the BDCP adaptive management framework to refine and modify the seasonal river flow criteria at Rio Vista.

Reversibility: Because implementation of the Rio Vista flow requirement is an operational element of the program, and would not require specific physical facilities, the flow requirement could be modified or reversed through changes to SWP and CVP operations. The Rio Vista flow requirements, however, are an integral element in overall water project operations and water supply deliveries, as well as environmental protections for species and habitats within the lower Sacramento River, and therefore institutional reversibility is expected to be difficult.

WAOP7: Three Mile Slough Gate Operations. A new gate at Three-Mile Slough would be operated to reduce the passage of larval and juvenile delta and longfin smelt, Chinook salmon, and other covered fish species from the Sacramento River into the interior Delta. This Action Parameter is expected to influence hydrodynamics of the western and interior Delta, affect WAOP 10, 13, and 14, and potentially work in tandem with WAOP8.

Observations from fishery monitoring have shown that larval and juvenile delta smelt, Chinook salmon, and presumably other covered fish species migrate or pass from the lower Sacramento River into the interior Delta through Three Mile Slough (Figure 1). Although no experimental survival studies have been performed, results of particle tracking model studies suggest that these fish may have increased vulnerability to direct losses at the south Delta SWP and CVP export facilities and exposure to other sources of mortality within the interior Delta under current conditions. Changes in flows through Three Mile Slough are also expected to affect seasonal water quality conditions within the interior Delta (EDAW 2005). To help reduce and manage these potential affects, a structure with operable gates has been identified for potential installation within Three Mile Slough (EDAW 2005). The operable gates could be closed based on the seasonal occurrence of target life stages of covered fish species in the area and/or based on daily tidal conditions. The operable gates, although a relatively large physical structure, could potentially be installed and operated as part of near- and long-term elements of the BDCP.

Adaptive Range. The range of potential near-term and long-term operations of the Three Mile Slough gates are described in Tables 1 and 2 [*not provided at this time, values to be determined*].

Rationale: Larval and juvenile delta and longfin smelt, juvenile Chinook salmon, juvenile steelhead, green and white sturgeon, and other fish species potentially move from the lower Sacramento River into the interior Delta through Three Mile Slough. Results of particle tracking model studies (EDAW 2005) show that movement of these fish into the interior Delta may be in response to tidal currents and hydrodynamic flows between the lower Sacramento and San Joaquin rivers. Results and analysis of past fishery monitoring data have shown evidence of increased mortality for fish within the interior Delta compared to mortality in the lower Sacramento River and Suisun Bay (Baker and Morhardt 2001, Brandes and McLain 2001). Several hypotheses have been suggested regarding the factors within the interior Delta that affect fish survival (Baxter et al. 2008) (see WAOP5 for a description of these factors). Seasonal and/or tidal closure of the operable gates within Three Mile Slough would be designed to prohibit or reduce the active migration and/or passive transport of fish from the Sacramento River into the interior Delta, thereby increasing their survival. Managed gate closures would also be expected to result in increased downstream transport of fish eggs, larvae, juveniles, nutrients, and organic material within the Sacramento River into Suisun Bay. In addition, managed closures of the operable gate are also expected to contribute to seasonal improvements to local water quality (salinity) within the interior Delta (EDAW 2005).

Implementation timeframe: Implementation of the Three Mile Slough operable gate would require design, environmental documentation and permitting, site preparation, and construction of structures that would include one or more operable gates that would extend completely across the slough. It is anticipated that the structure could be constructed during the BDCP near-term implementation period. Given the operational flexibility of the project, the gate would be compatible with both near-term and long-term BDCP conveyance operations.

Implementation considerations: Extensive modeling is currently underway to investigate the changes in hydrodynamics, particle tracking, and water quality that would be expected to occur in response to various alternative gate operational strategies. Gate operations should consider seasonal timing of when various life stages covered fish species are within the vicinity of Three Mile Slough, gate operations (e.g., gate closure on flood tide stage), and the resultant hydrodynamic and water quality changes that occur within the lower Sacramento River and throughout the Delta. Consideration has also been given to the effect of various gate operations, under different hydrologic conditions, on salinity within the

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Delta. A physical structure across Three Mile Slough would have effects on recreational and commercial boating in the area. Various alternative designs for gate and facility design, installation, and operations are also being considered. Near- and long-term operation of the gates would require facility maintenance, repair, and equipment replacement.

Resiliency to future changes: The design, installation, and operations of a Three Mile Slough operable gate structure would include consideration of resiliency to future changes in hydrology, sea level, and export operations as part of long-term operations. The structure and gate would be designed to operate over a wide range of flows and stages within the slough. Consequently, operation of the gate is expected to be resilient to future changes in hydrology, sea level, and implementation of other conservation measures.

Uncertainties/risks: Although changes in Delta hydrodynamics, water quality, and expected changes in the movement patterns and distribution of fish have been modeled, there remain a number of uncertainties regarding the actual effects of operation of the gates in the future. For example, there is uncertainty in the magnitude of change in survival for species such as larval and juvenile delta smelt and juvenile Chinook salmon that may result from gate operations. Although results of modeling can be used to predict that expected future hydrodynamic conditions and the distribution of fish would be biologically beneficial, there is a relatively high degree of uncertainty in quantitative predictions of the change in survival that would occur under different hydrodynamic conditions in the future. There is also uncertainty in the changes in survival for covered fish species that would occur as a result of the gate closures in the future in relation to the large number of other changes that will occur in the Delta in the future.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Monitoring is expected to focus on examining the relationship between Three Mile Slough gate operations and the survival and abundance of the various life stages of the covered fish species. Monitoring would also be expected to examine the relationship between river flows and the downstream transit times for larvae and juvenile fish, nutrients and organic carbon sources, as well as the behavior (e.g., transit rate, residence times, upstream and downstream tidal movement, etc.) of covered fish species in the lower Sacramento River downstream of Three Mile Slough. Changes in the geographic distribution of life stages, such as larval delta smelt and juvenile Chinook salmon, within the interior Delta channels in response to gate operations may also be investigated. Results of biological monitoring could be used within the BDCP adaptive management framework to refine and modify seasonal to tidal gate operations.

Reversibility: Gate operations would be highly reversible. Operation of the Three Mile Slough gates could be changed on demand. The design, installation, and operations of the gates could be modified or reversed in the future if warranted. Removal of the gate structure from the slough, although possible, would be difficult.

WAOP8: Two-Gates Operation – Old River and Connection Slough. Operable gates would be installed on Old River and Connection Slough on the west and east sides of Bacon Island and operated to reduce entrainment of fish, invertebrates, nutrients, and organic material into Old and Middle Rivers, which is an area of high entrainment risk by SWP and CVP facilities. The gates would be installed such that they could begin operation during BDCP near-term implementation. The gates would also maintain water quality in the south Delta by reducing salt water intrusion from downstream bays. The gates would be closed when covered fish species are in the vicinity of the western Delta and during times of low water quality in the south Delta, such as during low flow periods. Operations under this parameter would affect WAOP10, 13, and 14 and could potentially work in tandem with WAOP7 (Three Mile Slough Gate operations) to reduce entrainment into south Delta pumps.

Adaptive Range. As part of the near-term operations under the BDCP conservation program new gates at Old River and Connection Slough would be operated as described in Table 1 [*not provided at this time*, *values to be determined*]. It is anticipated that these gates will not be needed for long-term operation and would be removed once dual conveyance becomes operational.

Rationale: The diversion of water from the south Delta SWP and CVP export facilities results in local and regional changes in hydrodynamics, particularly in south Delta channels such as Old and Middle Rivers, and the direct entrainment of a variety of covered fish and other aquatic species. The influence of exports on south Delta hydrodynamics includes changing the magnitude (velocity and volume of flows) and the direction of tidal flows (creating negative or reversed net flows). Planktonic organisms, such as larvae, phytoplankton, and zooplankton, that move passively with water currents can be transported from areas within the Delta to the export facilities, as has been shown using particle tracking models. Many of the fish that migrate through the Delta, including juvenile and adult Chinook salmon, steelhead, delta smelt, longfin smelt, and sturgeon, use current patterns as migration and navigational cues. Changes in the direction of current patterns in response to exports have the potential to adversely affect the migration and movement of these and other Delta species, which can lead to false attraction, longer migration routes, delays in migration, and increased transport towards export facilities.

One approach to reducing fishery losses resulting from export operations has been through the use of various gates and barriers designed to guide fish away from exports and/or exclude fish from entering channels in which they would be more vulnerable to entrainment. Examples of the use of gates and barriers for fishery management within the Delta include the seasonal closure of the Delta Cross Channel (see WAOP5), seasonal closure of the Head of Old River Barrier, and gate operations proposed for Three Mile Slough (see WAOP7). These control structures have included both permanent structures with operable gates (Delta Cross Channel) and temporary structures with little or no operational flexibility (Head of Old River Barrier). Opportunities also exist to design and construct gated structures that offer operational flexibility that would be semi-permanent (e.g., could be removed in the future). These control structures can be designed and operated in a number of modes including having the gates open or closed for seasonal periods (e.g., months), gates operated in response to hydrologic and export conditions (e.g., days or weeks), or gates operated in response to tidal conditions (e.g., hours). The goal of these gated structures is to reduce and avoid local and regional changes in hydrodynamic conditions and pathways that contribute to increased entrainment of covered fish at the SWP and CVP export facilities.

Based on results hydrodynamic and particle tracking simulation models, this parameter would consist of two controllable gates on Old River and Connection Slough (referred to as "two gate" operations) as a near-term element of the BDCP conservation strategy.

Implementation timeframe: Design, construction, and initial operations of the two gates would be accomplished as a near-term action. It is anticipated that, once the north Delta diversion facility (WAOP1) is operational, resulting reductions in south Delta export operations would preclude further need for these control gates. Therefore, these gates would not be an element of the long-term BDCP conservation strategy.

Implementation considerations: Construction and operation of the two gates requires consideration of the specific location of each gate and supporting structure, design of the structures, specific plans for gate operations (e.g., tidal, response to various flow conditions, etc.), additional simulation modeling of results of gate operations, impacts to recreational boating and other beneficial uses of the area, changes in salinity and water quality, and integration of gate operations with operations of the SWP and CVP export facilities. Installation of the two gates would require environmental documentation (CEQA and/or NEPA), permitting (e.g., Clean Water Act Section 404 permit), and ESA compliance (e.g., incidental take authorization under Section 7).

Resiliency to future changes: Controllable gates and supporting structures would be designed to accommodate a range of environmental conditions associated with variations in Delta hydrology, tidal conditions, and increases in sea level. The gates would be intended for use as a near-term element of the conservation strategy and, therefore, would not be subject to long-term changes in climate or other conditions within the Delta. Flexible gate operations would allow the facilities to respond to changes in environmental conditions. The gates and supporting structures would be designed to be removable. Based on these considerations, the gates are expected to be resilient to future changes in environmental conditions within the Delta.

Uncertainties/risks: Existing design and operational plans for the two gates have been based, in large part, on results of hydrodynamic and particle tracking simulation model (PTM) predictions. The basis for simulation models is continuing to evolve and improve as new information and understanding of the Delta hydrodynamics and the response of various covered fish becomes available. Uncertainties exist in the response of various lifestages of the covered species to changes in Delta hydrodynamics that would occur in the future with gate operations. Uncertainties also exist in the interrelationships between gate operations and export operations under differing hydrologic conditions. Future changes in regulations and constraints on export operations (e.g., new biological opinion requirements), and how they would be affected or interact with two gate operations, are also uncertain. Uncertainty also exists in that additional species could be identified for protection that have differing responses to two gate operations, or conflicts among protections for covered species could be identified that would require future modifications to two gate operations.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* The primary focus of monitoring would be on changes in the salvage and incidental take of covered fish at the SWP and CVP export fish salvage facilities. In additional to salvage monitoring, fishery monitoring could also be conducted across the Delta (similar to existing fishery monitoring programs) that would be used to assess changes in the geographic distribution and movement patterns of covered species in response to two gate operations, south Delta exports, and Delta hydrology. Fishery monitoring would include larval and juvenile lifestages of covered species (e.g., larval and early juvenile delta and longfin smelt). Radio and acoustic tagging could be used to monitor the behavioral response and migration of juvenile and adult lifestages for species such as Chinook salmon, steelhead, splittail, and sturgeon and how movement through the Delta channels varies in response to two gate operations. Measurements of hydrodynamic conditions (water velocity, direction of flow, tidal effects, etc.) within selected Delta channels, in combination with monitoring of salinity and other water quality parameters would also be used to assess and evaluate the effectiveness of two gate operations within the south Delta. Because the two gates would allow flexible operations information collected through these monitoring programs could be used to refine gate operations and/or establish various physical or biological triggers for changes in gate operations. Adaptive operational changes could include leaving one or both gates open or closed for longer periods, modifying gate operations based on changes in water surface elevation or tidal conditions, changes in gate operations in response to high or low flows within the channels, or the occurrence of covered fish in the SWP and/or CVP fish salvage monitoring.

Reversibility: The two gate facilities are expected to be highly reversible. The two gate facilities would be designed to have flexible operations and could be removed in the future as conditions change regarding south Delta export operations as part of overall Delta diversion operations.

WAOP9: Delta Outflow. Delta outflows provide for downstream transport of fish and other aquatic organisms as well as nutrients and food supplies into the lower reaches of the Delta and Suisun Bay. Delta outflows also control, in balance with upstream salinity intrusion from the bay, the location of the low salinity region of the estuary (Kimmerer 2004). For example, Delta outflow is the regulating factor in the determining the X_2 location discussed in WAOP10 (because Delta outflow and X_2 location are highly correlated, abundance relationships with X_2 location discussed above are comparable to those with Delta outflow). Operations under WAOP1 and 12 could affect Delta outflow.

Adaptive Range: Criteria for Delta outflow have been established for both the BDCP near-term and long-term implementation periods (Tables 1 and 2 [*not provided at this time, values to be determined*]).

Rationale: Fishery monitoring studies conducted by DFG (Baxter et al. 1999) suggest that abundances of juvenile lifestages of many fish and macroinvertebrates are correlated with the location of the low salinity zone during the late winter and spring (e.g., February through June; Kimmerer 2004). For some species, such as longfin smelt, the juvenile abundance indices increased as the location of X_2 moved further downstream (west) within Suisun Bay (Kimmerer 2004). For a number of species there was little or no correlation between X_2 location and indices of abundance. Results of recent fishery surveys have shown that the previous correlations between X_2 location and fish abundance indices have changed (Kimmerer 2004). The changes observed in these relationships have been hypothesized to be the result of the introduction and rapid colonization of Suisun Bay by the filter feeding Asian overbite clam (*Corbula*) and a subsequent reduction in phytoplankton and zooplankton as food supplies for juvenile fish within Suisun Bay (Kimmerer 2004). It is thought that another change in this relationship has occurred since 2001 in conjunction with the pelagic organism decline, although the cause of this change is currently unknown (Baxter et al. 2008). Resident and migratory fish inhabit the Suisun Bay open water area, with the greatest abundance during the late winter and spring. The low salinity zone of the estuary is known to support spawning, juvenile rearing, and adult habitat, and serve as a migratory corridor for both adult and juvenile passage between freshwater and marine habitats (Kimmerer 2004). The shallow tidal waters of Suisun Bay have been shown to be a highly productive region of the estuary (Kimmerer 2004). The relatively shallow waters, residence times, and nutrient cycling within the open water habitat are all thought to contribute to high production of phytoplankton and zooplankton that form the base of the aquatic food chain (Kimmerer 2004). Factors that may to contribute to the relationship between Delta outflow (as well as X_2 location) and juvenile fish abundance include increased productivity and availability of high quality habitat within Suisun Bay, downstream transport of fish, food, and organic matter, reduced temperature and/or ammonia concentrations with lower X_2, inundation of backwater and floodplains with high flows, and the distribution of the earlier lifestages of fish into habitats that are located further downstream with decreased vulnerability to direct and indirect effects of south Delta SWP and CVP export operations.

Implementation timeframe: Implementation of Delta outflow requirements would occur as part of both near- and long-term elements of the BDCP conservation program.

Implementation considerations: The location of the low salinity habitat within the estuary is determined by the balance between freshwater outflow from rivers and saltwater inflow from San Francisco Bay. Freshwater outflow includes flows from upstream tributaries and releases from reservoir storage minus in-Delta diversions and exports. Implementation considerations for both near- and long-term Delta outflow criteria include effects of increasing freshwater releases on water supply availability and exports, effects of reservoir releases on fishery habitat within the reservoirs, and effects of freshwater releases on reservoir storage and upstream coldwater pool within the reservoirs that supports salmon and steelhead spawning and juvenile rearing habitat within the tributaries. For example, increased releases have the potential to deplete coldwater pool storage and adversely impact spawning and rearing for several of the covered fish species including winter-run and spring-run Chinook salmon and steelhead. Other implementation considerations include the correlations between Delta outflow (and X_2 location**)** and abundance indices, the slope of the relationship (e.g., how much change in abundance could be expected for a given change in Delta outflow), and the effects of non-native species such as *Corbula* on the relationships. Although the relationship between X_2 and abundance of several fish species has served as the basis for D-1641 X_2 requirements, recent analyses have identified stronger correlations between abundance and contaminant concentrations (e.g., ammonia) and water temperature (D. Fullerton unpubl. data). This issue should be further investigated to evaluate the relative contribution of contaminants and temperature to population of covered species and the relationship to the D-1641 X_2 criteria. Results could affect implementation of this parameter.

Criteria for this parameter in the BDCP long-term implementation period also needs to consider the level of covered species benefits that would be provided by BDCP restoration and enhancement actions that would increase the availability and quality of open water habitats, changes in hydrodynamic conditions and potential for entrainment risk associated with a reduction in south Delta SWP and CVP exports, changes in hydrology and sea level rise associated with future climate change, and potential effects of planned or catastrophic Delta island levee failures.

Resiliency to future changes: Low salinity habitat during the late winter and spring is expected to remain an important factor affecting the survival, growth, and abundance of estuarine fish, and as a migratory corridor for anadromous fish, in the future. Changes in sea level and/or hydrology may have an effect on the distribution of saltwater intrusion in the future, and the hydraulic relationship between the magnitude of Delta outflow and X_2 location. The functional relationship between open water habitat conditions and population dynamics of many of the estuarine fish and macroinvertebrates, however, is expected to remain the same. The relationships between Delta outflow (X_2 location) and juvenile abundance for covered fish species and invertebrate species may change in the future, as has been observed in recent years, in response to competition and/or predation by introduced non-native aquatic species. Large-scale changes in the species composition of the aquatic community, such as that which occurred with the expansion of the *Corbula* population, may have dramatic effects on the population dynamics and response to habitat conditions and Delta outflow in the future.

Uncertainties/risks: A large source of uncertainty in the response of covered fish to open water habitat conditions is the potential future effects of competition and/or predation by introduced non-native fish and invertebrate species. Changes in the aquatic community in the future have the potential to substantially increase the level of uncertainty regarding the response of each species to Delta outflow conditions. Based on changes in the relationship between abundance and open water habitat that has been observed in recent years, there is a substantial risk that increases in Delta outflow (e.g., locating X_2 further to the west) may not produce the predicted or desired improvements in habitat and the population response of covered species or their habitat (e.g., food resources). The relationship between Delta outflow and abundance indices for covered fish species has focused primarily on the late winter and spring; there is uncertainty associated with this relationship, and even greater uncertainty associated with the importance of Delta outflow to survival and abundance of covered fish during the remainder of the year. There is also substantial uncertainty in the relationship between Delta outflow and fish abundance in the BDCP long-term implementation period after changes have been implemented to enhance Delta aquatic habitat, reduce SWP and CVP exports from the south Delta, and improve hydrologic conditions within Delta channels. There is uncertainty of a cause and effect relationship between outflow (or X_2) and abundance of some covered fish species because it is a correlation. In fact, recent analyses suggest that relationships between abundances of some fish species and water temperature and ammonia are stronger than those with outflow/X_2 (D. Fullerton unpubl. data).

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Long-term fishery monitoring has been conducted by DFG to assess changes in indices of abundance for a variety of fish species (e.g., 20 mm townet, Spring

Kodiak trawl, Fall midwater trawl, and Bay study surveys). Monitoring trends and changes in the response of various species to changes in open water habitat conditions is expected to continue. Results of fishery monitoring will also provide information on changes in species composition and relative abundance over time. Monitoring of flows, salinity gradients, open water habitat conditions, and characteristics of the aquatic community are expected to continue. Based on results and analysis of monitoring data, adaptive modifications to management of Delta outflow can occur through such changes as modifications to the criteria, by seasonal or water-year type (hydrology), or by addressing other stressors and factors that may be affecting the survival or abundance of a covered fish species.

Reversibility: Because implementation of the Delta outflow requirement is an operational element of BDCP that does not require specific physical facilities to achieve, the timing, duration, or triggers for Delta outflow could be modified or reversed through changes to operations. Operations based on maintaining specific Delta outflows are an integral element in overall water project operations and water supply deliveries, as well as environmental protections for covered fish species and habitats within the estuary, and therefore institutional reversibility is expected to be challenging.

WAOP10: Suisun Bay and Western Delta Salinity Conditions. Suisun Bay and the western Delta represent important low salinity habitat areas within the estuary. The abundance of life stages of a number of fish species, including some covered fish species, has been positively correlated with the location of the low salinity zone (generally measured as X_2) within the estuary (Baxter et al. 1999, Kimmerer 2004). Suisun Bay is a transition zone between the freshwater riverine habitats of the Sacramento and San Joaquin rivers and the marine habitats within San Francisco Bay and coastal waters (Kimmerer 2004). Open water habitat within Suisun Bay and lower reaches of the Sacramento and San Joaquin rivers serve as spawning, larval and juvenile rearing, adult holding, and foraging habitat for resident and anadromous fish and a wide variety of other aquatic and wildlife species, and as a migration corridor for anadromous species such as salmon, steelhead, and sturgeon. Based on the information regarding the relationship between fish abundance and X_2 location, the State Water Quality Control Board's D-1641 includes requirements for maintaining the X_2 location during the late winter and spring within Suisun Bay. Operations under WAOP1, 5, 7, 11, and 12, as well as many habitat restoration conservation measures, could affect the position of the low salinity zone in the estuary.

Adaptive Range. Criteria for the location of the low salinity habitat zone (X_2) are included as both near-term and long-term elements of the BDCP conservation plan (Tables 1 and 2 [*not provided at this time, values to be determined*]).

Rationale: Fishery monitoring studies conducted by DFG (Baxter et al. 1999) suggest that abundances of juvenile lifestages of many fish and macroinvertebrates are correlated with the location of the low salinity zone during the late winter and spring (e.g., February through June; Kimmerer 2004). For some species, such as longfin smelt, the juvenile abundance indices increased as the location of X_2 moved further downstream (west) within Suisun Bay (Kimmerer 2004). For a number of species there was little or no correlation between X_2 location and indices of abundance. Results of recent fishery surveys have shown that the previous correlations between X_2 location and fish abundance indices have changed (Kimmerer 2004). The changes observed in these relationships have been hypothesized to be the result of the introduction and rapid colonization of Suisun Bay by the filter feeding Asian overbite clam (*Corbula*) and a subsequent reduction in phytoplankton and zooplankton as food supplies for juvenile fish within Suisun Bay (Kimmerer 2004). It is thought that another change has occurred since 2001 in conjunction with the pelagic organism decline (Baxter et al. 2008). Resident and migratory fish inhabit the Suisun Bay open water area, with the greatest abundance during the late winter and spring. The low salinity zone of the estuary is known to support spawning, juvenile rearing, adult habitat, and serve as a migratory corridor for both adult and juvenile passage between freshwater and marine habitats. The shallow tidal waters of Suisun Bay have been shown to be a highly productive region of the estuary (Kimmerer 2004). The relatively shallow waters, residence times, and nutrient cycling within the open water habitat are all thought to contribute to high production of phytoplankton and zooplankton that form the base of the aquatic food chain (Kimmerer 2004). Factors that may contribute to the relationship between X_2 location and juvenile fish abundance include increased productivity and availability of high quality habitat within Suisun Bay, downstream transport of fish, food, and organic matter, reduced temperature and/or ammonia concentrations with lower X_2, residence time, inundation of backwater and floodplains with high flows, and the distribution of the earlier lifestages of fish into habitats that are located further downstream with decreased vulnerability to direct and indirect effects of south Delta SWP and CVP export operations.

Implementation timeframe: Implementation of open water X_2 location requirements would be part of both near- and long-term elements of the BDCP conservation program.

Implementation considerations: The location of the low salinity habitat within the estuary is determined by the balance between freshwater inflow from rivers and saltwater inflow from San Francisco Bay. Freshwater outflows to meet the X_2 requirement include both flows from upstream tributaries and releases from reservoir storage. Implementation considerations for both near- and long-term open water habitat criteria include effects of increasing freshwater releases on water supply availability and exports, effects of reservoir releases on fishery habitat within the reservoirs, and effects of freshwater releases on reservoir storage and upstream coldwater pool within the reservoirs that supports salmon and steelhead spawning and juvenile rearing habitat within the tributaries. For example, increased releases have the potential to deplete coldwater pool storage and adversely impact spawning and rearing for several of the covered fish species including winter-run and spring-run Chinook salmon and steelhead. Other implementation considerations include the correlations between X_2 location and abundance indices for covered fish species, the slope of the relationship (e.g., how much change in abundance could be expected for a given change in X2 location), and the effects of non-native species such as *Corbula* on the relationships. Criteria for this parameter in the BDCP long-term implementation period also needs to consider the level of covered species benefits that would be provided by BDCP restoration and enhancement actions that would increase the availability and quality of open water habitats, changes in hydrodynamic conditions and potential for entrainment risk associated with a reduction in south Delta SWP and CVP exports, changes in hydrology and sea level rise associated with future climate change, potential effects of planned or catastrophic Delta island levee failures.

Resiliency to future changes: Low salinity habitat during the late winter and spring is expected to remain an important factor affecting the survival, growth, and abundance of estuarine fish, and as a migratory corridor for anadromous fish, in the future. Future changes in sea level and/or hydrology may affect the distribution of saltwater intrusion and the hydraulic relationship between the magnitude of Delta outflow and X_2 location. The functional relationship between open water habitat conditions and population dynamics of many of the estuarine fish and macroinvertebrates, however, is expected to remain the same. The relationships between X_2 location and juvenile abundance for covered fish species and invertebrate species may change in the future, as has been observed in recent years, in response to competition and/or predation by introduced non-native aquatic species. Large-scale changes in the species composition of the aquatic community, such as that which occurred with the expansion of the *Corbula* population, may have dramatic effects on the population dynamics and response to habitat conditions, such as the X_2 open water habitat, in the future.

Uncertainties/risks: A large source of uncertainty in the response of covered fish to open water habitat conditions is the potential future effects of competition and/or predation by introduced non-native fish and invertebrate species. Changes in the aquatic community in the future have the potential to substantially increase the level of uncertainty regarding the response of each species to open water habitat conditions. Based on changes in the relationship between abundance and open water habitat that has been observed in recent years, there is a substantial risk that increases in open water habitat (e.g., locating X_2 further to the west) may not produce the predicted or desired improvements in habitat and the population response of covered species or their habitat (e.g., food resources). The relationship between X_2 location and abundance indices for covered fish species has focused primarily on the late winter and spring; however the importance of the location of X_2 to survival and abundance of covered fish species during the remainder of the year is uncertain. There is also substantial uncertainty in the relationship between X_2 location and fish abundance in the BDCP long-term implementation period after changes have been implemented to enhance Delta

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aquatic habitat, reduce SWP and CVP exports from the south Delta, and improve hydrologic conditions within Delta channels.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Long-term fishery monitoring has been conducted by DFG to assess changes in indices of abundance for a variety of fish species (e.g., 20 mm townet, Spring Kodiak trawl, Fall midwater trawl, and Bay study surveys). Monitoring trends and changes in the response of various species to changes in open water habitat conditions is expected to continue. Results of fishery monitoring will also provide information on changes in species composition and relative abundance over time. Monitoring of flows, salinity gradients, open water habitat conditions, and characteristics of the aquatic community are expected to continue. Based on results and analysis of monitoring data, adaptive modifications to management of open water habitat can occur through such changes as modifications to the X_2 criteria, by seasonal or water-year type (hydrology) or by addressing other stressors and factors that may be affecting the survival or abundance of a covered fish species.

Reversibility: Because implementation of the open water habitat requirement is an operational element of BDCP that does not require specific physical facilities to achieve, the timing, duration, or triggers for X_2 location could be modified or reversed through changes to SWP and CVP operations. Operations based on maintaining specific X_2 locations are an integral element in overall water project operations and water supply deliveries, as well as environmental protections for covered fish species and habitats within the estuary, and therefore institutional reversibility is expected to be difficult.

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WAOP11: Montezuma Slough Salinity Control Gate. Under this action, the BDCP Implementing Entity would coordinate with the Suisun Marsh Charter Group over the term of the BDCP to seek amendments to the Suisun Marsh Habitat Management, Preservation, and Restoration Plan (in development) that would provide for relaxing or ceasing operation of the Montezuma Slough Salinity Control Gate. This action would allow more water to flow past Chipps Island and would improve access of covered fish species to existing and future restored intertidal marsh habitats. This parameter would involve either changing gate operations or removing the gate and would affect WAOP10 and 14. Suisun Marsh is currently managed largely as to provide seasonal freshwater wetland habitat, primarily to support waterfowl habitat and recreation. The Montezuma Salinity Control Gate was originally installed in Montezuma Slough and operated as a tidal pump to reduce salinity within the marsh. The salinity control structure has been shown to alter local hydrodynamics and water quality conditions and impede the migration and passage of various fish species.

Adaptive Range. The range of near-term and long-term operations of the Montezuma Salinity Control Gate is described in Tables 1 and 2 [*not provided at this time, values to be determined*].

Rationale: The Montezuma Slough Salinity Control Structure has been identified as an impediment to migration and passage of species such as Chinook salmon, steelhead, and green sturgeon through Montezuma Slough (Fujimura et al. 2000). In addition, existing operations of the control structure alter local current patterns and tidal hydrodynamics within Montezuma Slough, in large regions of Suisun Marsh, and in the main river channel between the control gate and Suisun Bay (Department of Water Resources 1999). For example, operation of the control structure during the late fall in dry years can cause a significant upstream shift in X_2, potentially increasing the risk of entrainment at the SWP/CVP export facilities of smelt and other species that are situated near X_2 (Fullerton 2008). These changes in environmental conditions are thought to have resulted in adverse impacts on covered species and other aquatic resources within the area. It has been hypothesized that large-scale changes in salinity within the slough and marsh channels are a factor contributing to changes in the aquatic habitats and species assemblages within the area. Furthermore, diking of large regions of Suisun Marsh that are currently managed primarily as seasonal freshwater wetland has removed tidal brackish water that historically supported delta smelt, Chinook salmon, steelhead, sturgeon, and Sacramento splittail habitats.

Implementation timeframe: This action may be implemented either in the near-term or long-term BDCP long-term implementation periods, depending on when necessary amendments to the Suisun Marsh Habitat Management, Preservation, and Restoration Plan (in development) are adopted.

Implementation considerations: Compliance with the State Water Quality Control Board salinity standards for Suisun Marsh must be addressed and

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modification of the standards to allow more variable salinity within the marsh would be necessary. If the salinity control gate is removed, consideration would be given to the logistics of removing the existing structure and temporary localized effects, such as increased suspended sediments and disturbance that would occur during removal of the structure. Consideration would also be given to changes that would occur with the conversion of existing managed seasonal wetlands to restore brackish intertidal marsh (see Conservation Measure BIMA1.1).

Resiliency to future changes: Removal or reoperation of the existing salinity control structure would result in greater salinity variation within Suisun Marsh channels and Montezuma Slough under current tidal conditions as well as greater variation in the future in response to sea level raise and changes in hydrology. One of the objectives of removing or reoperating the control structure would be to return unfettered hydrodynamic conditions and processes to the area that could respond to future conditions. These changes would be intended to be compatible with and accommodate future changes.

Uncertainties/risks: Although the effects of changes in tidal hydrodynamics and salinity to fish passage, variable salinity, and tidal hydrodynamics are expected to be positive for covered fish species and the aquatic habitats within the area, specific effects on species or communities inhabiting the area cannot be quantified with confidence.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Monitoring has been conducted by UC Davis to document salinity and hydrodynamic conditions within Suisun Marsh and associated channels over a number of years. It is expected that additional monitoring would be performed after removal or reoperation of the control structure to document and verify the anticipated response in physical conditions. Extensive fishery monitoring has been conducted within the marsh channels by UC Davis to document the species composition, geographic distribution, and changes in abundance of the fishery community. It is expected that this monitoring program would continue to document changes that occur after removal or reoperation of the structure. Vegetation surveys have been conducted by DFG (unpubl. data) within the marsh that establish existing conditions that can then be compared to monitoring data to assess changes in vegetation species composition, distribution, and areal extent after removal of the salinity control structure. In the event that the control structure remains in place and the gates are opened, results of monitoring could be used in the future to adaptively manage the control gates (resume gate operations) in the event that unexpected undesirable consequences are detected. If the control structure is removed, adaptive management of salinity regimes would require modifications of Delta outflow to manage salinity within the marsh.

Reversibility: Reversibility of the action would be high in the event that the control structure remains in place with the gates open and the system remains functional. Reversibility would be low because of high cost in the event that the control structure is removed from Montezuma Slough.

WAOP12: South Delta Diversions. This parameter is intended to reduce the impacts of south Delta diversions on covered fish species and the Delta environment and would affect WAOP9, 10, and 14. Diversions from the south Delta SWP and CVP facilities would be reduced considerably with operation of new North Delta Diversion Facilities. In the BDCP long-term implementation period, water would be diverted from the south Delta to augment North Delta diversions and may be diverted in appropriate circumstances to improve circulation and maintain water quality conditions in the interior and southern Delta.

Export operation of the SWP Banks Pumping Plant and CVP Jones Pumping Plant contributes to local changes in water current patterns, water quality, and direct entrainment and losses of fish, macroinvertebrates, nutrients, phytoplankton, and zooplankton from the Delta environment (Department of Water Resources 2006). Changes in local current patterns (e.g., Old and Middle river reverse flows) have been identified as a factor adversely affecting aquatic habitat, altering fish distribution and migration patterns, and increasing the risk of entrainment losses (Department of Water Resources 2006, Baxter et al. 2008). Current SWP and CVP export operations are regulated by D-1641, conditions of the USFWS and NMFS biological opinions, and federal court order.

Adaptive Range. As part of the near-term operations under the BDCP conservation program SWP and CVP exports would be operated as described in Table 1 [*not provided at this time, values to be determined*]. With operation of North Delta Diversion Facilities, the existing south Delta SWP and CVP export facilities would be operated as part of a dual conveyance facility, however exports from the south Delta would be substantially reduced (the North Delta Diversion Facilities would be equipped with state-of-the-art positive barrier fish screens and would be the primary point of long-term diversion). The dual export system would be operated to meet water supplies. Long-term operational criteria for the south Delta export facility are summarized in Table 2 [*not provided at this time, values to be determined*].

Rationale: Export operations of the SWP and CVP diversion facilities in the South Delta have been identified as primary factors in altering hydrodynamic conditions within Delta channels and associated fishery habitat, altering the distribution and passage of resident and migratory fish, and contributing to the direct loss of a variety of fish (including covered species) and other aquatic organisms (including food resources) as a result of entrainment into the export facility (Department of Water Resources 2006, Baxter et al. 2008). The export facility is equipped with a series of louver arrays that are intended to guide juvenile and larger fish from the water into on-site holding tanks before water is exported (Fujimura et al. 2008). The fish collected in the holding tanks are periodically placed into tanker trucks and transported to return locations on the lower Sacramento and San Joaquin rivers on Sherman Island. The extent of species- and size-specific mortality that results from the collection, handling, transport, and release of salvaged fish is currently being investigated (Fujimura et al. 2008). Small fish (estimated to be less than 20 mm in length) are not salvaged by the louvers and are lost from the Delta. In addition, studies have demonstrated that juvenile fish, such as Chinook salmon and steelhead, are vulnerable to predation mortality within Clifton Court Forebay and at other locations within the export facilitate (Gingras 1997, Clark et al. 2008). Near-term regulation of the seasonal rate of exports are intended to reduce the direct and indirect effects of south Delta exports on covered fish species and other aquatic organisms. As part of the long-term BDCP program, south Delta exports, the associated effects on covered fish, as well as other aquatic species and their food resources, and hydrodynamic conditions within the Delta channels affecting fish migration and habitat would be substantially reduced through preferential operation of North Delta Diversion Facilities on the Sacramento River.

Implementation timeframe: Near-term operations of SWP and CVP export diversions from the south Delta, only. Long-term operations of dual conveyance facilities.

Implementation considerations: Considerations in the management of south Delta exports include near-term regulations and requirements in D-1641, the USFWS and NMFS biological opinions for OCAP, and operating criteria implemented in response to federal court orders. Compliance with these requirements has resulted in reduced water supply deliveries to the SWP contractors and service area. Various alternative operations in combination with new physical facilities such as gated barriers are currently being investigated in an effort to manage ongoing export operations while reducing the direct and indirect effects of export operations on covered fish and their habitat. Hydrologic and water quality simulation models are also being used to examine the predicted effects of various alternative export operations on hydrologic conditions within the Delta and the potential effects of these changes on near- and long-term exports and associated changes in direct and indirect impacts on fish and aquatic habitats. Many of these near-term analyses are being conducted as part of the OCAP ESA Section 7 consultation process that may define near-term operations of the south Delta export facilities. Analyses are also underway to assess the inter-relationship between BDCP conservation measures such as increased aquatic habitat at various locations throughout the Delta and water export operations.

Resiliency to future changes: Results of preliminary simulation modeling have shown that the existing SWP and CVP export operations are vulnerable to future changes within the Delta (Department of Water Resources and Department of Fish and Game 2008). The existing export operations are vulnerable to environmental changes that may result from increased salinity intrusion into the

Delta as a result of sea level rise, future changes in climate and precipitation patterns, and levee failures that occur within the Delta. Primary objectives of developing the BDCP are to develop facilities and operations that reduce adverse effects on covered fish and their habitat and to increase the reliability and resiliency of water project operations; dual intake locations and operations in the north and south Delta would provide flexibility for operations in the face of changes to Delta hydrodynamics.

Uncertainties/risks: There is currently a high degree of uncertainty regarding the operating criteria for water export from the south Delta. A number of open water fish species and other aquatic organisms have recently undergone a substantial decline in abundance (Sommer et al. 2007), referred to as the Pelagic Organism Decline (POD). In addition, Chinook salmon stocks have declined, based on recent adult returns to the Central Valley rivers, to very low levels (Pacific Marine Fisheries Council unpubl data) that are thought to be the result, in part, of poor ocean rearing conditions in recent years. Recent critically dry water years and the prospect of additional dry years, and the associated stresses on both fishery habitat and water supplies, further contribute to near-term and long-term risks. Uncertainties also remain regarding the significance of export operations as the primary factor affecting covered fish species and aquatic habitat within the Delta. A large number of other species stressors have also been identified as part of the BDCP process, POD investigations, and other processes that affect covered fish species directly or indirectly within the Delta (e.g., other stressors conservation measures). The significance of competition and predation mortality by non-native introduced species, for example, has been identified as a major factor affecting the aquatic ecosystem and covered fish species (e.g., Moyle et al. 2004, Bennett 2005, Nobriga et al. 2005). There is uncertainty in the magnitude of potential benefits to various covered fish species that may result from a change in south Delta export operations given the diversity of other factors that also affect these populations.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Long-term monitoring of south Delta SWP and CVP export operations and fish salvage has occurred and is expected to continue into the future. Monitoring of export operations is required for compliance with D-1641, as well as the biological opinions. In addition, extensive fishery monitoring occurs throughout the Delta to document changes in the abundance, species composition, and geographic distribution of fish that provide information on changes in the status and trends in species (e.g., DFG's 20 mm townet, Bay study, Summer townet, and fall midwater trawl surveys). Results of these site-specific and regional fishery monitoring programs provide information that can be used to assess changes in the covered species and to examine the relationship between export operations and characteristics of the aquatic community within and among years. Information on the fishery resources is also being used, in combination with hydrologic and water quality simulation modeling, to develop refined methods of analysis to evaluate the information being developed from monitoring on changes to the aquatic community. Monitoring programs have also been developed and are being refined to provide near real-time information on the geographic distribution of various species and to assess the potential risk of adverse effects with sufficient time to implement adaptive management decisions as part of water project operations (e.g., Interagency Ecological Program's Delta Smelt Risk Assessment Matrix, Data Assessment Team, and Water Operations Management Team). It is anticipated that these monitoring programs, predictive tools, and adaptive management decisions for water project operations will continue to be refined and implemented by BDCP and responsible agencies in a joint effort to improve export operations and efficiency/reliability as well as the improve the level of near-term fishery protections.

Reversibility: Changes to operations at south Delta export facilities can be made through regulatory and institutional processes.

WAOP13: Old and Middle River Flows. This parameter is intended to improve the direction and rate of flows in Old and Middle Rivers. These rivers are subject to reduced or reverse flows as a result of low Delta inflow, flood tides, and high water export rates at SWP and CVP facilities. These flow conditions can result in increased risk of entrainment of fish, invertebrates, and food. This parameter would be affected by operations associated with WAOP1, 5, 7, 8, and 12.

Adaptive Range. Criteria for Old and Middle rivers flows have been established for both the BDCP near-term and long-term implementation periods (Tables 1 and 2 [*not provided at this time, values to be determined*]).

Rationale: Operation of the SWP and CVP export facilites has resulted in changes in hydrodynamics of south Delta channels including reversal in the direction of tidal flows within the Old and Middle river channels. The rate of SWP and CVP exports, in combination with factors such as Delta inflow and tidal effects, are important factors in determining changes to local and regional hydrodynamics in response to export operations. Although the response of various lifestages of covered species to flows within Old and Middle rivers is dynamic and variable within and among species, results of analyses performed on pre-spawning adult delta smelt indicate a relationship between the magnitude (average monthly) of reverse flows within Old and Middle rivers and the occurrence of smelt in SWP and CVP fish salvage during the winter months (J. Johns unpubl. data, P. Smith unpubl. data). Results of PTM simulations predict that there is a greater risk that planktonic early lifestages of covered fish species (e.g., larval and early stages of delta smelt) would be vulnerable to entrainment at the SWP and CVP export facilities when reverse flows within Old and Middle rivers increase. Furthermore, a number of the covered fish, including the juvenile and adult lifestages of Chinook salon, steelhead, delta smelt, longfin smelt, strugeon, and splittail are expected to use hydrodynamic cues (e.g., channel flow direction and magnitude) to help guide movement through the Delta. Reverse flows in Delta channels contribute to false attraction to migration cues, longer migration routes that may expose fish to sources of mortality such as predation, exposure to seasonally elevated water temperatures and other stressors, and increased vulnerability to entraiment at the SWP and CVP south Delta export facilities.

Reverse flows within the Old and Middle river channels also affect local and regional habitat conditions for covered fish and other aquatic species. Changes in channel velocity and flow patterns affect hydraulic residence time in the area and the production of phytoplankton and zooplankton that are important in the diet of covered fish. Channel velocities and scour and deposition patterns affect habitat for benthic organisms and other macoinvertebrates. Changes in tidal hydrodynamics, especially channel velocity, have been identified as factors affecting habitat suitability for covered fish and other aquatic species in the area.

Various approaches have been used to regulate and manage south Delta export rates for the protection of covered fish and other aquatic resources. Direct regulation of the maximum rate of exports is currently managed under SWRCB water right order D-1641 based on the seasonally adjusted allowable export:inflow ratio. Recent federal district court orders have stipulated that SWP and CVP export rates be managed during the late winter and spring months to reduce export-related impacts on delta smelt. Under the court order, exports are regulated based on a combination of delta smelt salvage at the export facilites and restrictions on export rates based on the magnitude of reverse flows within Old and Middle rivers. Relationships between the magnitude of reverse flows in Old and Middle rivers and corresponding changes in salvage of various covered fish, such as juvenile Chinook salmon, steelhead, splittail, longfin smelt and sturgeon, are highly variable. Analyses and evaluations are ongoing to further assess the potential biological benefits of managing SWP and CVP south Delta exports based on direct diversion rates and/or changes in the magnitude of reverse flows in Old and Middle rivers.

Implementation timeframe: Export management and the effects of south Delta exports on flow reversal within Old and Middle rivers is primarily a near-term management issue. Implementation of a dual diversion facility as part of the long-term BDCP program is expected to result in substantial reductions in export rates from the south Delta, and corresponding long-term reductions in the frequency and magnitude of reverse flows in Old and Middle rivers.

Implementation considerations: SWP and CVP export operations are currently being managed in compliance with federal court order to seasonally adjust export rates based on the geographic distribution of delta smelt, the risk of entrainment at the salvage facilities, and actual occurence of coverd fish in the fish salvage operations. These operations require no additional physical facilities. Near-term restrictions on south Delta export operations result directly in a reduction in water supply deliveries to SWP and CVP contractors and service areas.

Resiliency to future changes: Operational changes to SWP and CVP exports are flexible and could be modified in the future to respond to changes in climate, Delta hydrology, or sea level. Given the ability to manage south Delta exports based on real-time conditions, this action is expected to be resilient to future environmental conditions.

Uncertainties/risks: Uncertainties and risks associated with managing SWP and CVP south Delta exports based on Old and Middle river reverse flows include the magnitude of reduction in water supply deliveries resulting from additional export restrictions and the uncertainty in the resulting benefits to covered fish. There is high uncertainty regarding the relationship between seasonal timing, magnitude, and duration of reverse flows and adverse effects on covered fish. These biological uncertainties include regarding the relationship between reverse flow and the risk of entrainment at the SWP and CVP export facilities, as well as high degree uncertainty regarding the effects of direct and indirect effects of reverse flows and fish salvage on overall population abundance of covered fish species. Risks and uncertainties also exist in the biological benefits of direct regulation of SWP and CVP export rates or the indirect regulation of exports using a surrogate measure such as Old and Middle river reverse flows.

Monitoring and adaptive management considerations: ***[Note to reviewers:*** *this section is a general summary; more detail will be provided in future iterations.]* The primary focus of monitoring would be on changes in the salvage and incidental take of covered fish at the SWP and CVP export fish salvage facilities. In additional to salvage monitoring, fishery monitoring could also be conducted throughout the Delta (similar to existing fishery monitoring programs) that would be used to assess changes in the geographic distribution and movement patterns of covered species in response to changes in the magnitude of Old and Middle river reverse flows, south Delta exports, and Delta hydrology. Fishery monitoring would include the larval and juvenile lifestages of covered species (e.g., larval and early juvenile delta and longfin smelt). Radio and acoustic tagging could be used to monitor the behavioral response and migration of juvenile and adult lifestages for species such as Chinook salmon, steelhead, splittail, and sturgeon and how movement through the Delta channels varies in response to reverse flow conditions. Measurements of hydrodynamic conditions (water velocity, direction of flow, tidal effects, etc.) within Old and Middle rivers on other selected Delta channels, in combination with monitoring of salinity and other water quality parameters, would also be used to assess and evaluate the effect of reductions in reverse flows on habitat conditions for covered fish within the south Delta. Information collected through these monitoring programs could be used to refine export operations and/or establish various physical or biological triggers for changes in exports and associated reverse flows. Adaptive operational changes could include modifications in export rates and reverse flows based on changes in water surface elevation or tidal conditions, changes in reverse flows in response to high or low flows within the channels, or the occurrence of covered fish in the SWP and/or CVP fish salvage monitoring.

Reversibility: Management decisions regarding reductions in Old and Middle river reverse flows can be reversed. Reverse flows are controlled through operational changes in SWP and CVP export rates.

WAOP14: Delta Salinity Standards. This parameter would modify salinity standards to benefit covered fish species. The State Water Resources Control Board's D-1641 established salinity standards in the Delta for agricultural, municipal, industrial, and environmental purposes. Agricultural standards establish maximum salinity concentrations in the western, interior, and southern Delta during the growing season to ensure fresh water is available for diversion in these parts of the Delta. Municipal and industrial standards establish maximum salinity concentrations at major municipal diversion intakes. Environmental salinity standards establish maximum salinity concentrations in Suisun Marsh for aquatic plants that support waterfowl and in the San Joaquin River for fish during specific seasons.

Salinity standards could be modified to benefit covered fish species by mimicking conditions that would likely occur under natural unimpaired flows. Delta salinity could be lower during winter and spring associated with higher inflows of freshwater into the Delta and higher during summer and fall associated with reduced inflows of freshwater into the Delta. In Suisun Marsh, salinity standards could be relaxed in association with brackish marsh restoration (see Conservation Measure BIMA1.1) and removal or reoperation of the Montezuma Salinity Control Gate (see WAOP11). Operations under WAOP 1, 2, 3, 5, 7, 11, and 12 could affect this parameter.

Adaptive Range. Near- and long-term criteria, by water-year type, included as part of the operations element of the BDCP are summarized in Tables 1 and 2 [*not provided at this time, values to be determined*].

Rationale: Salinity in the Delta is primarily a function of freshwater flowing in from the tributary rivers and saltwater intrusion from San Francisco Bay. Areas located downstream such as Suisun Bay and further west are characterized by increasing salinity gradients. The northern and eastern Delta is characterized by primarily freshwater aquatic habitats. The lower San Joaquin River and southern Delta are characterized by low salinity waters, primarily resulting from saline agricultural drainage returns with elevated salt concentrations discharging into the San Joaquin River (Department of Water Resources et al. 2006).

Native species inhabiting the Delta and Suisun Bay evolved to a set of salinity conditions in the estuary (Lund et al. 2007). The geographic distribution of species within the estuary varied in response to changes in salinity distribution and the salinity tolerance and preference of each species. As a result of construction of upstream impoundments and modification of land use within the Delta, salinity regimes have become more regulated and the seasonal timing and variability in salinity experienced within Suisun Bay and the western Delta has been altered (Contra Costa Water District 2007). Natural timing and variability in environmental conditions, including salinity, have been hypothesized to increase the diversity, complexity, and resiliency of estuarine community of species inhabiting the Delta (Lund et al. 2007). Altered timing and variability in salinity, as a result of regulation and management, is believed to have reduced the robustness of the ecosystem and the ability to resist the effects of future environmental perturbations (Lund et al. 2007). Modifying salinity standards with operation of North Delta Diversion Facilities and BDCP restoration of physical habitats in the Delta and Suisun Marsh could establish seasonal patterns in salinity more similar to historical patterns to the benefit of covered fish species.

Implementation timeframe: This parameter would be a potential long-term element of the BDCP conservation program.

Implementation considerations: Implementation considerations would include an assessment of the need for developing alternative water supplies and associated infrastructure for deliveries of water with appropriate water quality to support agricultural, municipal, and industrial uses and seasonal wetland management for waterfowl. Implementation would also need to assess the potential effects of changing salinities on covered species. Consideration would also need to be given to the potential beneficial and adverse effects of changes in spatial and temporal patterns in salinity on covered fish species and other fish and wildlife inhabiting the estuary. Changes in the D-1641 salinity requirements would require modification to the existing water right decision and the water quality control plan.

Resiliency to future changes: Future changes in sea level and/or hydrology may affect the distribution of saltwater intrusion in the future, thus altering salinity patterns in the Delta and Suisun Marsh. However, changes would likely be in the direction of proposed changes in salinity regimes (higher flows/lower salinity in winter and spring and lower flows/higher salinity in summer and fall). Upstream impoundments and water management could at least partially allay future changes that do not benefit covered fish species.

Uncertainties/risks: Predictions of the response of various fish and other aquatic organisms to changes in the salinity regime, is uncertain. The habitat conditions and species present in the estuary have been highly modified by both physical and biological (e.g., introductions of non-native species) over the past century. The dynamics of the estuarine ecosystem are poorly understood and highly dynamic. Predictions of the response of individual species or the community response to large-scale environmental changes to the salinity regime and other factors cannot be quantified with confidence. Large-scale changes in the salinity regime within the estuary have the potential to result in large-scale biological benefits (increased species diversity and resilience) or to large-scale degradation (jeopardy of extinction). The response of the aquatic community to changes in the salinity regime is expected to take a number of years.

Monitoring and adaptive management considerations: *[**Note to reviewers:** this section is a general summary; more detail will be provided in future iterations.]* Currently, both *in situ* monitoring of salinity within various locations of the Delta in response to changes in tidal conditions and hydrology is underway that complements the use and refinement of hydrologic and water quality simulation models. It is expected that both monitoring and simulation modeling will occur in the future to assess changes in salinities that occur in response to various actions and events. Monitoring associated with a more variable salinity regime is expected to include additional fishery surveys, as needed, to assess changes in the geographic distribution, growth, survival, health, and abundance of various lifestages of each of the covered fish species and other components of the estuarine aquatic ecosystem (e.g., abundance and composition of phytoplankton, zooplankton, and macroinvertebrates; abundance and distribution of invasive non-native plants and covered fish species' predators/competitors). Changes in aquatic vegetation and habitat conditions within various regions of the estuary in response to salinity variation and the performance of habitat enhancement projects would be monitored. Monitoring of physical changes to environmental conditions at a variety of locations dispersed throughout the estuary within and among years would also be expected. Within the BDCP framework of adaptive management, the management response to adverse impacts resulting from a variable salinity regime would be based, in large part, on adjusting management of Delta inflows and Delta outflows.

Reversibility: Implementation of an altered salinity regime within the Delta has the potential to result in large, adverse, and potentially unexpected environmental consequences. Reversing large-scale environmental changes within estuarine aquatic ecosystem would be difficult, and in the event that these changes lead to species extinction, they could not be reversed. Although feasible, large-scale changes in salinity distribution and concentrations, and the resulting changes in land use and other beneficial uses, would be difficult, and may take a number of years, to reverse.

References

Bake PF, JE Morhardt. 2001. Survival of Chinook salmon smolts in the Sacramento-San Joaquin Delta and Pacific Ocean. Contributions to the Biology of the Central Valley Salmonids.

Baxter R, K Hieb, S DeLeon, K Fleming, JJ Orsi. 1999. Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. Sacramento

(CA): Interagency Ecological Program for the San Francisco Bay-Delta Estuary. Technical Report 63.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. January 15, 2008. Available at: http://www.fws.gov/sacramento/es/documents/POD_report_2007.pdf.

Benigno GM, TR Sommer. 2008. Just add water: sources of chironomid drift in a large river floodplain. Hydrobiologia. 600(1): 297-305.

Bennett WA. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science [online serial]. Vol. 3, Issue 2 (September 2005), Article 1.

Brandes PL, JS McLain. 2001. Juvenile chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Brown RL, editor. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179(2). Sacramento (CA): California Department of Fish and Game. pp 39-136.

CALFED. 2001. Scrutinizing the Delta Cross-Channel. News from the CALFED Bay-Delta Science Program.

Clark KW, MD Bowen, KP Zehfuss, RB Mayfield. 2008. Pre-Screen Loss of Steelhead within Clifton Court Forebay. Abstract for the 2008 CalFed Science Conference.

Contra Costa Water District. 2007. Trends in hydrology and salinity in Suisun Bay and the Western Delta. Version 1.2. June 2007. Available at: http://www.ccwater.com/salinity/HistoricalSalinity.pdf.

Department of Water Resources. 1995. Delta Atlas. Available at: http://baydeltaoffice.water.ca.gov/DeltaAtlas/index.cfm

Department of Water Resources. 1999. Biological Assessment: Suisun Marsh Preservation Agreement as Modified by Amendment Three.

Department of Water Resources. 2008. North/Central Delta Salmon Out-migration Study. Accessed on 10/16/2008. http://baydeltaoffice.water.ca.gov/ndelta/salmon/index.cfm

Department of Water Resources, U.S. Department of the Interior, Bureau of Reclamation. 2006. South Delta Improvements Program Final Environmental Impact Statement/Environmental Impact Report.

Department of Water Resources and Department of Fish and Game. 2008. Risks and options to reduce risks to fishery and water supply uses of the Sacramento/San Joaquin Delta. A report pursuant to requirements of Assembly Bill 1200, Laird. Available at: http://www.water.ca.gov/floodmgmt/dsmo/sab/drmsp/docs/AB1200_report.pdf.

EDAW. 2005. Flooded Islands: Pre-Feasibility Study Report. Prepared for: California Department of Water Resources.

Fullerton D. 2007. The interaction among turbidity, salinity and smelt during fall and winter: a work in progress. CALFED Bay-Delta Brown Bag Seminar Presentation at CALFED Headquarters. November 27, 2007.

Fujimura RW, G Edwards, D Killam, TM Frink, L Millett. 2000. Evaluation of adult salmon migration passage at the Suisun Marsh Salinity Control Gates in Montezuma Slough, California. In: JH Eiler et al. (ed.). Biotelemetry 15: Proceedings of the 15th International Symposium on Biotelemetry, Juneau, Alaska USA, May 9-14, 1999. pp. 68-75

Fujimura RW, J Morinaka, G Aasen, V Afentoulis. 2008. CHTR Program Overview: Six Years Later. Abstract for the 2008 CalFed Science Conference.

Gingras M. 1997. Mark/Recapture Experiments at Clifton Court Forebay to Estimate Pre-Screening Loss to Entrained Juvenile Fishes: 1976-1993. Interagency Ecological Program Technical Report 55 (November 1997).

Hanson CH. 2008. Declaration of Charles H. Hanson, PhD in support of defendant-intervenor State Water Contractors' status report. United States District Court, Eastern District of California, Fresno Division. September 4, 2008.

Harrell WC, TR Sommer. 2003. Patterns of adult fish use on California's Yolo Bypass floodplain. In P.M. Faber, ed. California riparian systems: Processes and floodplain management, ecology, and restoration. 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, California. Pages 88-93.

Jassby AD, JE Cloern. 2000. Organic matter sources and rehabilitation of the Sacramento-San Joaquin Delta (California, USA). Aquatic Conservation: Marine and Freshwater Ecosystems. 10(1): 323-352.

Kimmerer W. 2004. Open Water Processes of the San Francisco Estuary: From Physical Forcing to Biological Responses. *In.* San Francisco Estuary & Watershed Science.

Kimmerer WJ. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. *In.* San Francisco Estuary & Watershed Science.

Lund J, Hanak, W Fleenor, R Howitt, J Mount, P Moyle. 2007. Envisioning Futures for the Sacramento-San Joaquin Delta. *In.* Public Policy Institute of California (PPIC). February 2007, 324 pp. ISBN 978-1-58213-126-9.

Manly BFJ. 2002. Analysis of Cross Channel Effects. Western EcoSystems Technology Inc. Report Dated April 21, 2002.

Manly BFJ. 2008. Review of the report an evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies by K.B. Newman. Western EcoSystems Technology Inc. Report Dated July 16, 2008.

Moyle PB, RD Baxter, T Sommer, TC Foin, SA Matern. 2004. Biology and population dynamics of the Sacramento splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: a review. San Francisco Estuary and Watershed Science [online serial]. Volume 2, Issue 2 (May 2004), Article 4.

NMFS (National Marine Fisheries Service).1997. Fish Screening Criteria for Anadromous Salmonids. Southwest Region

Nobriga M, T Veldhuizen, Z Hymanson. 2000. Delta Smelt Concerns Result in Changes in SWP and CVP operations. Interagency Ecological Program for the Sacramento-San Joaquin Estuary, Newsletter. Volume 12, Number 3:33-34.

Nobriga ML, F Feyrer, RD Baxter, M. Chotkowski 2005. Fish community ecology in an Altered River delta: Spatial patterns in species composition, life history strategies, and biomass. Estuaries and Coasts. 28(5): 1559-2723.

Schemel LE, SW Hagar, D Childers. 1996. The supply and carbon content of suspended sediment from the Sacramento River to San Francisco Bay. In J.T. Hollibaugh, ed. San Francisco Bay: The Ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA. Pages 237-260

Sommer T, B Harrell, M Nobriga, R Brown, P Moyle, W Kimmerer, L Schemel. 2001a. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6-16.

Sommer T, ML Nobriga, B Harrell, W Batham, WJ Kimmerer. 2001b. Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Sommer TR, WC Harrell, ML Nobriga, R Kurth. 2003. Floodplain as habitat for native fish: Lessons from California's Yolo Bypass. In PM Faber, ed. California riparian systems: Processes and floodplain management, ecology, and restoration. 2001

Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, California. Pages 81-87.

Sommer TR, WC Harrell, R Kurth, F Feyrer, SC Zeug, G O'Leary. 2004. Ecological patterns of early life stages of fishes in a river-floodplain of the San Francisco Estuary. In F Feyrer, LR Brown, RL Brown, JJ Orsi, eds. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland. Pages 111-123.

Sommer T, C Armor, R Baxter, R Breuer, L Brown, M Chotkowski, S Culberson, F Feyrer, M Gingras, B Herbold, W Kimmerer, A Mueller-Solger, M Nobriga, K Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32:270-277

Suisun Marsh Salinity Control Gate Steering Group Technical Team (SMSCGTT). 2001. Findings of the Suisun Marsh Salinity Control Gate Steering Group Technical Team.

Wang JCS. 1986. Fishes of the Sacramento-San Joaquin estuary and adjacent waters, California: a guide to the early life histories. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Tech. Rep. 9. Stockton, CA.